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Amitabh Chandra
Harvard University

Jonathan Skinner
Dartmouth College

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TECHNOLOGY GROWTH AND EXPENDITURE GROWTH IN HEALTH CARE*

Amitabh Chandra
Harvard University and NBER
amitabh_chandra@ksg.harvard.edu

Jonathan Skinner
Dartmouth College and NBER
jon.skinner@dartmouth.edu

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Abstract

In the United States, health care technology has contributed to rising survival rates, yet health care spending relative to GDP has also grown more rapidly than in any other country. We develop a model of patient demand and supplier behavior to explain these parallel trends in technology growth and cost growth. We show that health care productivity depends on the heterogeneity of treatment effects across patients, the shape of the health production function, and the cost structure of procedures such as MRIs with high fixed costs and low marginal costs. The model implies a typology of medical technology productivity: (I) highly cost-effective “home run” innovations with little chance of overuse, such as anti-retroviral therapy for HIV, (II) treatments highly effective for some but not for all (e.g. stents), and (III) “gray area” treatments with uncertain clinical value such as ICU days among chronically ill patients. Not surprisingly, countries adopting Category I and effective Category II treatments gain the greatest health improvements, while countries adopting ineffective Category II and Category III treatments experience the most rapid cost growth. Ultimately, economic and political resistance in the U.S. to ever-rising tax rates will slow cost growth, with uncertain effects on technology growth.

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1. Introduction

The science section of a U.S. newspaper routinely features articles on new surgical and pharmaceutical treatments for cancer, obesity, aging, and cardiovascular diseases, with rosy predictions of expanded longevity and improved health functioning (Wade, 2009). The business section, on the other hand, features gloomy reports of galloping health insurance premiums (Claxton et al., 2010), declining insurance coverage, and unsustainable Medicare and Medicaid growth leading to higher taxes (Leonhardt, 2009) and downgraded U.S. debt (Stein, 2006). Not surprisingly, there is some ambiguity as to whether these two trends, in outcomes and in expenditures, are a cause for celebration or concern.

Economists and other observers often point to technology growth as the source of both trends. Newhouse (1992) considered a wide variety of factors that could reasonably have caused the rapid growth in health care expenditures, such as an aging population or the expansion of health insurance, and concluded that only technology growth could explain the vast majority of expenditure growth. Similarly, Cutler (2004) has argued that technological advances have generated both the far-reaching advances in longevity and the rapid growth in costs.¹ Unfortunately, simply attaching the label of “technological growth” as the major cause of increases in health care expenditures doesn’t get us much closer to understanding either the pathology of the disease – if it is a disease – or a meaningful way to address the problem – if it is a problem. Thus the principal focus of the paper is to better understand technological growth in health care and its impact on cost-growth and productivity improvements.

As a first step, we develop a demand-side model of health care, and like Hall and Jones (2007), show that rising income levels can optimally generate rapid growth in health care costs in a model with well functioning private insurance markets. But we also show that a rising role of government financing in health care can attenuate optimal growth as marginal tax rates rise (Baicker and Skinner, 2011). We then complete the supply-side with a parsimonious model of physician behavior, anchored by the assumption that physicians want to do everything in their power to cure their patient, given financial, ethical, and resource constraints.

The model is then used to distinguish among three general categories of treatments, ranked in

¹ Cutler (2004) writes, “Money matters in health care as it does in few other industries. Where we have spent a lot, we have received a lot in return.”

order of their contribution to health care productivity, defined as the improvement in health outcomes per dollar increase in costs. (These three categories closely parallel the Wennberg, Fisher, and Skinner (2002) categorizations of effective, preference sensitive, and supply-sensitive care.) We find that the greatest health contribution occurs for low cost but highly effective treatments: antibiotics for bacterial infection, a cast for a simple fracture, or aspirin and beta-blockers for heart attack patients. Highly productive innovations may be expensive – for example, anti-retroviral drugs for the treatment of people with HIV/AIDS. But the key to the high average productivity of these expensive drugs is a strongly negative *second* derivative of the survival (or production) function, so that benefits quickly turn negative for non-HIV-infected patients. Thus, few patients are treated in a cost-ineffective way, whether because of serious adverse effects (as in the case of anti-retrovirals) or because the treatments are so inexpensive (in the case of aspirin for heart attacks).

A second broad category of medical technologies includes treatments and procedures whose benefits are substantial for at least some patients, but where the second derivative of the survival function is small in magnitude, meaning there is a large population of potential patients for whom health benefits converge towards zero as costs accumulate. Angioplasties with stents are a good example. In this procedure, a catheter is used to free blockages in the heart, and the stent, a wire mesh, is inserted to maintain blood flow. For heart attack patients treated within the first 12 hours following the heart attack, the benefits of stents are substantial. But there are many more patients where the value of angioplasty is less clear, for example among those with stable angina, or among those with little taste for the inherent risk of surgery. Because there are more people in the latter category than in the former and the U.S. health care system compensates generously for all procedures, the marginal health benefits of this innovation are driven to zero and average productivity is diminished substantially.

The third treatment category of technological innovations encompasses those treatments for which benefits are small or there is little scientific evidence of their value. This wide category includes treatments for which randomized trials indicate no benefit (vertebroplasty, in which cement is injected to stabilize vertebrae), as well as procedures whose effectiveness has not been evaluated (intensity-modulated radiation therapy for prostate cancer). There are also many decisions made in the management of chronic illness that correspond to this category. Few randomized trials have been conducted to evaluate when pneumonia patients should be admitted

to the hospital, how frequently patients with chronic disease need to see a physician, or whether specialists or primary care physicians can best coordinate and provide high-quality care. Not surprisingly, much of the improved health is generated by our first category of treatments, while much of the cost growth is generated by the third.

To return to our original question, we suggest that it's not technology *per se* that causes growth in health care expenditures – it's the patients with full insurance coverage who demand the latest prosthetic hip. It's the urologist who installs the latest 64-slice CT scanner in his office. Thus U.S. health care spending as a percentage of GDP has risen rapidly compared to other countries because the reimbursement system encourages the widespread diffusion of both old and new technology. This is particularly true of the U.S. Medicare program that offers generous incentives for more intensive care. In some cases, this means that the U.S. can be the first to enjoy the benefits of as-yet unproven technology. The downside is the widespread use of treatments with unproven value, and the scarcity of cost-saving innovations (Nelson et al., 2009).

What are the implications for the future? In a classic 1991 article, Weisbrod suggested that the then-new Medicare prospective payment system would provide incentives to develop cost-saving technologies. His prediction may have been premature, but there is increasing evidence of the potential for cost-saving technologies (with equivalent or better outcomes) in the management and organization of health care to yield substantial productivity gains. But these types of innovations are unlikely to diffuse widely through the U.S. health care system until there are much stronger incentives to do so. Whether U.S. health care reform can change these incentives remains to be seen. But ultimately, the growth in health care spending will be limited by the shrinking ability of private insurance markets and tax revenues to finance ever-rising health care bills.

2. Empirical Patterns of Health Care Costs and Outcomes

It is well understood that the United States is an outlier with respect to health care spending, whether on a per-capita dollar basis, or with respect to the share of GDP devoted to health care, which in 2009 was 17.6 percent. But is the U.S. also an outlier with respect to *growth* in health care spending?

This question is considered in more detail using a comprehensive sample of 21 developed countries (Table 1) and a smaller sample of 6 countries (Figure 1).² Countries are ranked according to their initial 1980 share of GDP devoted to health care, and further categorized into low, medium, and high shares of health care spending relative to GDP. In 1980, the U.S. was the highest among this sample (9.0 percent of GDP), but not much higher than in Sweden and Denmark (8.9 percent), West Germany (8.4 percent), or Ireland (8.2 percent). The U.S. is not an outlier with respect to real per-capita growth rates in health care spending: its annual growth rate from 1980 to 2008 (4.0 percent) is lower than in Spain, Portugal, Norway, and Ireland, and barely higher than in the U.K. (3.8 percent).³ Nor is it an outlier with respect to annual real GDP growth: its 1.8 percent annual rate was roughly average among the sample of 21 countries.

But the U.S. *is* an outlier with respect to growth in the share of GDP devoted to health care: a growth of 7 percentage points (from 9 to 16 percent of GDP) between 1980 and 2008, well above the average of the other OECD countries (2.7 percentage points) and the next-highest country, Portugal (4.6 percentage points). As Figure 1 also shows, the U.S. particularly stands out among the countries with initially high 1980 health spending: Average growth in the share of GDP devoted to health care in Sweden, Denmark, and Germany (excluding the U.S.) is less than one percentage point. Price differences may explain a portion of inter-country spending differences at a point in time (Anderson, et al., 2003), but we do not think that U.S. price growth explains the more rapid increase in the U.S. share of health spending.

It is useful to at least check that U.S. survival rates didn't grow faster than the countries with the slower-growing health care sectors. Garber and Skinner (2008) found that, over time, U.S. life expectancy growth has lagged behind a sample of 5 benchmark European countries. And while Preston and Ho (2009) have suggested that different trends in health behavior can explain these lagging U.S. mortality rates, Muennig and Glied (2010) finds U.S. survival trends lagging even after adjusting for smoking behavior and obesity trends.

² All data from OECD (2010). These countries were chosen if data existed for 1980-2008 (a few countries were missing 2008 data so we used 2007 or 2006 data instead. Korea and Turkey were excluded because their initial share of GDP devoted to health care (3.9 and 2.4 percent respectively) were so low. We are comparing unified Germany in 2008 with West Germany in 1980, but constructing two series (1980-90 for West Germany and 1992-2008 for unified Germany) and adding their growth, implies a smaller percentage point increase in health care spending; just 0.8 rather than 2.5 percentage points.

³ White (2007) however has argued that even U.S. growth rates were excessive relative to other OECD countries.

Variation in Medicare growth rates can also be seen within the United States. Figure 2 reports the growth of per-capita Medicare spending for specific Hospital Referral Regions. During 1992-2006, inflation-adjusted per-capita Medicare spending rose at an average annual rate of 3.5 percent. But this rapid growth still masked variations in levels of spending and in growth rates across regions; San Francisco grew slower than the US at 2.4 percent, while Miami, already starting from a high level of spending, experienced above-average 5.0 percent annual growth. McAllen, Texas, the subject of an influential *New Yorker* article (Gawande, 2009) experienced the most rapid recent growth – 8.3 percent annually – of all regions. Confronted with these differences in growth rates and growth rates across regions (Chernew, et al., 2009), it is natural to ask: Why did health care spending in some regions or countries grow faster than others? And how did these differing growth rates affect health outcomes? Our paper offers a framework to analyze both questions.

3. A Simple Model of Health Care and Growth

The traditional introduction to the economics of health care begins with the question of why is health care so different from other goods. A reasonable place to begin is what appears to be a fundamental human concern with the pain and suffering of others, which in turn has been reflected in a collectivist view of health care. As health care became more expensive, insurance markets appeared to insure patients against growing financial risk, ensure that providers got paid, and in the case of publicly-provided insurance, to garner political dividends arising from the creation of a broad-based entitlement program (Fuchs, 1998). Widespread insurance markets lead naturally to the twin problems of moral hazard and adverse selection (Cutler and Zeckhauser, 2004). Moral hazard occurs because a third-party, the insurance company, is paying most of the cost of the transaction between the first party (the physician or health provider) and the second party (the patient). This can lead to individuals not taking sufficient precaution against illness, or more commonly, it can cause patients and providers to consume and provide “too much” health care (Newhouse, 1993).

Adverse selection can occur on both sides of the market. Insurance companies structure contracts in a way to attract low-risk enrollees away from other firms, for example by offering managed care options that are most appealing to healthy enrollees. Adverse selection can also

occur on the consumer side of the market, for example when people with higher expectations of poor health buy long-term care insurance (Finkelstein and McGarry, 2006).

A third issue that arises in health care is the principal-agent problem; that because of asymmetric information, the physician is making decisions on behalf of the patient, leading to decisions that accommodate physician interests. This is the basis for a long-standing debate over the existence of “supplier-induced demand,” a literature extending back several decades that seeks to find evidence of physicians acting in their interest – to shift out demand for their services – even when it may harm, at least financially, the patient (McGuire, 2000).

While each of these three issues is clearly important for health care policy, they are not equally important in explaining the twin growth rates in technological progress and health care costs. We are less concerned with the adverse-selection problem, since rapid growth in spending occurs even in settings where adverse selection issues are less important, such as Medicare (covering nearly every elderly American) and other countries with national health insurance. Rather, we argue that the combination of moral hazard and the principal agent problem has provided fertile ground for the particularly rapid growth in health care costs.

In our analysis we are not thinking as much of the traditional (static) moral hazard problem, since typical estimates of price elasticity cannot explain more than a tiny fraction of the overall growth in health care costs (Newhouse, 1992; Manning et al., 1987). The more important role of insurance is in financing the dramatic growth in health care expenditures through innovation and the rapid diffusion of technology (Finkelstein, 2007). This view has its antecedents in Weisbrod’s (1991) classic article arguing that the structure of insurance coverage was an integral part of rapid cost growth. The intuition is straightforward: if you pay for it, they will build it. This paper seeks to retain the spirit of Weisbrod’s insights as we next develop a simple model of demand (consumer) and supply (provider) decisions to characterize the process of growth in technology and expenditures.

3.1 The Demand for Health Care

We develop intuition from the demand-side models in Hall and Jones (2007) and Murphy and Topel (2006) by collapsing the structure to a 2-period model of consumption and leisure, where a consumer’s utility is based on consumption and leisure in the first period, and post-

retirement consumption in the second period.⁴ The probability of surviving to the second period, $s(x)$, is in turn influenced by medical spending x :

$$(1) \quad V = U(C_1, \ell_1) + \frac{s(x)\tilde{U}(C_2)}{1 + \delta}$$

where C_i is consumption in period i , ℓ_1 is leisure in period 1 (and retiree leisure is subsumed in the second-period utility function \tilde{U}), δ is the discount rate, x measures health care inputs, and the survival function is concave, so that $s'(x) \geq 0$, $s'' < 0$.⁵ More generally, s may be viewed as a “quality of life” indicator that reflects both survival and functioning since it augments second-period consumption and leisure. Measuring quality of life, and not simply survival, is important in assessing the productivity of new innovations. Hip replacements, knee replacements, and back surgery for spinal stenosis are all procedures that improve the quality and not the quantity of life.

Utility is maximized subject to the budget constraint:

$$(2) \quad w_1(1 - \ell_1) - P = C_1 + px + C_2/(1 + r)$$

where w_1 is the wage rate, p the consumer price of health care, P the premium paid for insurance when p differs from q , the social cost of health care, and r is the interest rate.⁶ The maximization problem yields the optimality condition for the individual (holding P constant)

$$(3) \quad p \frac{\partial U}{\partial C_1} = \frac{s'(x)\tilde{U}(C_2)}{(1 + \delta)}$$

This captures the idea that optimal spending on health should be at the point where p dollars given up for period one consumption should yield equal incremental benefits from an improved chance of surviving to period two. Rearranging (3) yields

⁴ In a more complicated n -period model, technological innovation in health care provides benefits throughout the life cycle (Baicker and Skinner, 2011).

⁵ When the $s(x)$ function is non-concave, the presence of health insurance can also have a first-order impact on utility (Nyman, 1999). This occurs in the case where insurance allows low income individuals to receive, say, a \$100,000 bone marrow transplant for which there is no reasonable alternative that is slightly less effective but lower cost.

⁶ For more complex models involving investments in health capital, see Grossman (1972).

$$(4) \quad \Psi \equiv \frac{\tilde{U}(C_2)}{(1 + \delta) \frac{\partial U}{\partial C_1}} = \frac{p}{s'(x)}$$

We define Ψ to be individual demand for an extra quality-adjusted year of survival, which in turn depends on the ratio of total second-period utility divided by the marginal utility of period-one consumption. In other words, because health is viewed as extending the period of time that one enjoys in this world, the benefit relates to total utility of retirement leisure and consumption (Murphy and Topel, 2006). Thus the value of remaining life years could therefore remain substantial even after the individual has retired and is supported by Social Security and pension income.⁷

Assume that the price of health care p is equal to its social cost q , and we can normalize health care inputs x such that the social cost $q = 1$. Then the right-hand side of Equation (4) is simply the cost-effectiveness ratio, or how much it costs at the margin to gain one quality-adjusted life year, which is optimally set equal to marginal demand, Ψ .

A key implication of this model is that a rise in income and consumption will imply a more-than-proportional decline in the marginal utility of non-medical consumption. For example, if we assume a constant relative risk aversion γ of 2 for utility, then doubling income would reduce the marginal utility of consumption to $2^{-2} = .25$ times its previous level. Combined with the small increase in second-period utility, willingness to pay for health care will rise more than four times, thus stimulating demand for additional health care – or moving society along the $s(x)$ curve to a point where the optimal cost-effectiveness ratio is considerably larger than it is now. Intuitively, the marginal utility of a third car or flat screen TV in a future affluent world should be much lower than an increased opportunity to enjoy that extra utility in the future (Hall and Jones, 2007). Thus Hall and Jones suggest that we might (optimally) devote as much as one-third of future GDP to health care.

A limitation of this utility-based approach arises because we cannot measure directly year-specific utility. The typical approach to writing utility in these models is to include a constant

⁷ For the social planner, there is an additional term, which captures whether an individual is making a net contribution to society in the sense of their income being greater than consumption (Murphy and Topel, 2006; Hall and Jones, 2007).

term, so that $\tilde{U} = b + \frac{C_2^{1-\gamma}}{1-\gamma}$ where γ is, as above, the Arrow-Pratt constant relative risk aversion.

The reason why we need an intercept term b is because otherwise, when $\gamma > 1$, utility is less than zero ($C^{1-\gamma}/(1-\gamma) < 0$), implying that early death would improve lifetime utility. Thus b is a free variable, and in practice it is calibrated to match existing evidence on how much to value a human life. Murphy and Topel (2006) suggest that a life-year may be worth as much as \$350,000 depending on age based on an EPA midpoint of \$6.2 million for a human life. But there is considerable debate about the “value” of a life, with confidence intervals from earlier studies ranging from one to ten million dollars (Dockins, et al., 2004; also see Aldy and Viscusi, 2008). Ashenfelter and Greenstone’s (2004) estimate of 1.9 million dollars (in 2006 dollars) is at the lower end of the estimates, but yields a value per life-year of about \$100,000 for middle-aged people, consistent with the Garber and Phelps (1997) rule-of-thumb that a life-year should be valued at roughly double average annual income.

One might also object to the model’s assumption that the expected value of second-period utility is $s(x)\tilde{U}(C_2)$ rather than a more general functional form $\bar{U}(s(x), C_2)$ allowing for diminishing returns to greater longevity. While the former specification matches the time-series evidence in the U.S., it does less well in matching cross-sectional data. When $\gamma = 2$, for example, an individual with \$200,000 in income should be willing to pay 100 times as much at the margin for health care as an otherwise identical person with \$20,000 in income. Even allowing for the presence of health insurance (which would blunt such income differences), we do not observe such a pronounced difference in health care expenditures (McClellan and Skinner, 2006).

One could reconcile this paradox in a model where fundamental choices about health care technology are made collectively. Society chooses a single basic level of technology for everyone, either because of ethical and equity concerns, because the care is provided under a uniform insurance program (e.g., Medicare), or because it makes little sense to maintain hospitals and emergency rooms catering solely to high-income patients. In this case, the optimal level of care is determined by treating health care as if it were a public good, where optimal health care is determined by equating the sum of marginal rates of substitution between health care and other goods across the entire population equal to aggregate costs. This approach, which implies a single aggregate “value of life,” would exhibit rising health care costs over time but

much less variation across income groups at a point in time.

Another concern with the above framework is the assumption that health care (or health care insurance) is purchased in a representative agent model. In practice, health care financing involves both the government sector and considerable amounts of redistribution, from young to old and from healthy to sick. Consider the extreme case of a health care system financed entirely by a payroll tax with no copayments:

$$(2') \quad (1 - \ell_1)w(1 - \tau) = C_1 + \frac{C_2}{1 + r}$$

where τ is the marginal tax rate. Ignoring other government expenditures, the budget constraint for the government (in per capita terms) is $qx = (1 - \ell_1)w\tau$. The first-order condition in Equation (4) is rewritten:

$$(5) \quad \Psi \equiv \frac{\tilde{U}(C_2)}{(1 + \delta) \frac{\partial U}{\partial C_1}} = \frac{p\Omega}{s'(x)}$$

where $\Omega = [(1 - \ell_1)] / [(1 - \ell_1) - \tau d\ell_1 / d\tau]$. Note that Ω is greater than one whenever taxation induces efficiency costs. Furthermore, as the marginal tax rate rises, Ω will rise more than proportionally, leading to a much-diminished demand for additional health care.⁸ Thus over time, financing constraints could act as an additional brake on health care demand (Baicker and Skinner, 2011).

Despite these caveats, the implications of the model are twofold: that relative demand for health care may be expected to increase over time, and that “optimal” growth depends on how health care is financed. We next turn to the supply side of the health care market.

3.2 A Static Model of Provider Behavior

We develop a model of physician and provider behavior based in a standard economic framework, but one which tries to capture what physicians say and do. The model is grounded in

⁸ As Kaplow (2008) has argued, the diminished demand for health care arises not so much from the distortion of the tax *per se*, which in theory can be undone by appropriate transfers, but because of the increased requirement to redistribute resources across individuals.

a single assumption about behavior:

Health care providers seek to maximize the perceived health of their patient, but may deviate from this goal because of financial incentives, resource capacity, ethical judgment, and patient demand.

That is, the vast majority of physicians and health care providers do their best to improve as many lives as they can.⁹ While there are always occasional rogue physicians who game the system at the expense of patients,¹⁰ most physicians believe that what they are doing is best for their patient, and when unconstrained, say they've done everything possible.¹¹ While there is remarkable heterogeneity in physician beliefs, as we document below, let us for the moment assume that there is a single known survival or "production" function () for patient i at time t , and that physicians seek to maximize the value of health () by driving the marginal value of spending to zero.

In practice, there are both explicit and implicit (or hidden) constraints on health care. In the U.S. explicit restrictions are rare, and they are generally restricted to gatekeeper models of health maintenance organizations (HMOs), which may require a second opinion or a sign-off for common medical procedures. Implicit restrictions are more common; the limitations of

⁹ This model is simpler in many respects than the model in Pauly (1980), where physicians provide two kinds of services (diagnostic and therapeutic), and they may adjust both prices and quality of care (e.g., accuracy of diagnosis) depending on market demand and the extent of competition in the market.

¹⁰ For example, two cardiac surgeons in Redding, CA, motivated by artificially high payment rates, pulled healthy patients off the golf course for emergency cardiac surgery (Enkoji, 2002).

¹¹ This is illustrated in the following quotation from an ICU physician (Goertz, 2004):

Here is an example I have used when teaching medical students and residents: You are taking care of a patient in the ICU. You have done every test and procedure you know to do and have done everything that all the consultants have recommended. I now tell you that you must spend another \$5,000 (originally I used \$1,000) to improve the patient's quality of care. What would you do with the money?

By this point the student or resident is in a bit of a quandary because they are not quite sure how to use the additional money. If there were a continuing positive linear relationship, it should be reasonably easy to suggest more things that result in improved patient care. Generally the suggestions are more, or repeated, tests and procedures. I respond to the common answers with a statement that if you do more tests or procedures, you could in fact make the patient worse. How? If you do more tests, all tests have false positives and negatives. How will you use results that contradict earlier tests? With again more tests, and the subsequent potential for much more confusion. If you repeat or do another procedure, how do you interpret the results? Also, procedures generally have potential side effects or complications, so again you have a very high risk of NOT improving quality or outcome with more money.

physicians who only have 24 hours in the day, a lack of diagnostic or surgical facilities (or catheterization labs not staffed at night), and queues for the MRI or intensive care unit (ICU) beds. Physicians often do not chafe against these implicit restrictions or are even aware of them, simply adjusting their “best practice” to the resources they are accustomed to using.

Physicians also care about the income they make. Let income for physician j be defined as

$$(6) \quad Y_{jt} = m_{jt}W_t + \pi_{jt}x_{jt} - R_{jt}$$

where income comprises two parts: the salary component, equal to W_{jt} (payment per patient) times the number of patients m_{jt} ; and the business component; the number of total procedures per physician summed over their $I(j)$ patients, $x_{jt} = \sum_{i=I(j)} x_{ijt}$ times marginal profitability π_{jt} minus fixed costs R_{jt} . Note that the price paid by the patient, p , could be quite different from the profitability of the procedure, π .¹²

We posit that income Y enters positively in the utility function, but allow as well for a target or reference income Z_{jt} (see Rizzo and Zeckhauser, 2003), so the income-based component of utility is $\Omega = \Omega(Y_{jt} - Z_{jt})$.¹³ Thus the health care provider is assumed to maximize the sum $\Psi_{jt}(x_{jt}) + \Omega$.

One factor that could affect growth differentially is the fraction of physician income derived from salary versus business sources. For example, many health care providers in the U.S. own or lease expensive machinery such as MRIs, 64-slice computerized tomography, and robotic surgical machinery. These tend to exhibit high fixed costs R and (at least in the U.S.) high marginal profit (π) per unit of use, up to their capacity limit; thus both income and substitution effects would encourage expanded use. Thus, the structure of how new technologies are reimbursed affects the speed and extent of their diffusion across countries.

Capacity constraints are more likely in countries such as the U.K. or other countries with centralized financing. In this case, the central health agency has a global budget used to provide inputs to individual hospitals and clinics, for example a certain number of artificial knee or hip

¹² While we maintain a single composite x for inputs, in practice different types of inputs exhibit much different levels of profitability, for example cardiac procedures are typically very well compensated (Hayes et al., 2007), while others are loss leaders.

¹³ Target income behavior would be generated by specifying that Ω' is large and positive for $Y_{jt} - Z_{jt} < 0$, and zero otherwise.

joints devices (Aaron and Schwartz, 2005). Similarly, some regions may not be allocated as many magnetic resonance imaging (MRI) machines, or cardiac catheterization units. Typically, physicians adjust implicitly to these constraints, although waiting lists for surgery are often the subject of public demonstrations and political controversy. Alternatively, the constraint could reflect ethical norms against spending too much of the nation's resources. Whether implicit or explicit, physicians and hospitals in these cases are operating subject to constraints, which can be expressed as $x_{jt} \leq X_{jt}$.

An implication of the supplier-induced demand model is that physicians will knowingly harm their patients if they are paid enough to do so. This model, however, assumes that every physician *believes* their actions will benefit the patient. We therefore include an additional constraint that the patients treated by physician j must be better off than the utility level in the absence of the treatment, \bar{v}_j .¹⁴ This is admittedly a simplistic way to consider the demand side, but it is consistent with empirical evidence (Jacobson, et al., 2010).

At a point in time, the Lagrangian for a given physician is written:

$$(7) \quad \mathfrak{L} = \Psi_t s_t(x_{jt}) + \Omega(m_{jt} W_t + \pi_{jt} x_{jt} - R_{jt}) - \mu_{jt}(x_{jt} - \bar{X}_{jt}) - \Phi_{jt}(\bar{V}_{jt} - V_{jt})$$

The first-order condition for (7) is:

$$(8) \quad \Psi_t s_t'(x_{jt}) + \omega_{jt} \pi_{jt} = \mu_{jt} - \Phi_{jt} v_{jt}$$

where ω_{jt} is the derivative of Ω , and v_{jt} the total derivative of V with respect to x (including any decline in non-medical consumption as a consequence of purchasing x), evaluated for the j th physician at time t . That is, physicians spend up to the point where the combination of the social marginal value of health or functioning, and the financial reward or penalty, weighted by the importance of such rewards (ω), is limited by a capacity (or knowledge) constraint μ and a demand-side constraint that insures the individual is better off with the treatment than without. It is convenient to define a variable λ that summarizes the overall impact of financial incentives, capacity constraints, and demand:

$$\lambda \equiv -\omega_{jt} \pi_{jt} + \mu_{jt} - \Phi_{jt} v_{jt}$$

¹⁴ Note that the constraint that patients are better off does not preclude putting the patient at some risk – for example, plastic surgery carries risks, but the patient prefers the treatment. For the sake of simplicity, we assume a representative patient rather than multiple patients each with a binding constraint.

How then is supply and demand equated? Note that demand in Equation (4) can be rewritten as $\Psi_{tS_t}'(x) = p_t$ (or the price facing the consumer) while the physician sets $\Psi_{tS_t}'(x) = \lambda_t$. Different scenarios are illustrated in Figure 3, where the model assumes that physicians are able to allocate treatments to those who would benefit most. In the framework of labor economics, this is the assumption that physicians use a Roy Model to rank patients on the basis of their benefit from a benefit and then work down that distribution, so the marginal patient is the one with the lowest incremental benefit. This assumption is supported by empirical work for heart attacks (Chandra and Staiger, 2007) and for Cesarean sections (Baicker, Buckles and Chandra, 2006).

First consider a hypothetical country arbitrarily labeled “UK” where supply constraints are sufficiently high to exceed both out-of-pocket costs for most treatments, so that ($p < \lambda$), but are also high enough so that λ exceeds the social cost q . In this case, there is too little spending on health care. (One might expect private markets to spring up in this case, where wealthy patients demand additional services even at q .) Next, consider the case where individuals face the full price of their health care q , perhaps because they lack insurance or are paying from a health savings account.¹⁵ Even when the physician makes money by doing more than the optimal, she will still provide at most the optimal quantity of health care x^* because of the binding constraint that doing more than x^* will make the patient worse off. The key assumption here is that the physician acts as an agent of the patient. This assumption will not hold if patients ascribe greater benefits to procedures than is justified by clinical evidence or physician beliefs (Rotherberg, et al., 2010), or if the physician does not always account for patient preferences (Pritchard et al., 1998).

Finally, we consider the more common case in the U.S. where low out-of-pocket expenses faced by consumers coupled with profitable compensation for procedures results in $\lambda < q$ and hence the conventional over-use of health care, as shown in Figure 3. (The constraint that physicians act as the agent of their patients ensures that $p \leq \lambda < q$ as well.) At the extreme, when there are *no* restrictions interfering with physicians’ motives to do as much as possible, utilization is x' where $s'(x) = 0$, as shown in Figure 3.¹⁶

¹⁵ The health savings account involves spending after-tax dollars, but these accounts also help to offset pre-existing tax distortions (such as the tax on labor supply), thus potentially moving the consumer’s choice closer to x^* .

¹⁶ To keep the figure simple, we have assumed constant social costs, but that is not necessary to make our point: marginal social costs can increase in the level of x (that is, $q'(x) > 0$).

More complicated is where net profitability π is positive, there are no capacity constraints, and physicians are able to convince patients that the treatments will benefit them, implying that $s'(x)$ may turn negative. Examples where physicians expose patients to serious mortality risk in return for financial gain are rare, but there is a larger potential margin for procedures where there is little evidence for improved survival but side effects are significant. Examples include the decrement in sexual functioning following treatments for prostate cancer among older men, or chemotherapy administered to people with incurable cancers. The complex interaction between provider and patient is revisited in Section 4.2 below.

Finally, how might malpractice laws affect this equilibrium? While much of the concern about malpractice laws have been directed towards “defensive medicine” that would tend to increase utilization, this model suggests more modest effects such as those found in Mello et al. (2010). Malpractice premiums increase fixed costs R , increasing work effort through the income effect, while the risk of malpractice should encourage more diagnostic tests. But malpractice liability rules also reduce utilization through the substitution effect: the incremental procedure exposes the physicians to more malpractice risk and thus raises her implicit marginal cost per procedure (Currie and MacLeod, 2008; Baicker, Fisher, and Chandra, 2007).

3.3 A Dynamic Model of Provider Behavior

To this point, the analysis has been in a static framework. We next turn to one that attempts to model the dynamics of change (see also McGuire, 2009). Our approach is to take the derivative of the first-order equation (8),¹⁷ rearrange and simplify. Letting $\Delta x_{jt} = x_{jt+1} - x_{jt}$ and similarly for other variables, we write:

$$(9) \quad \Delta x_{jt} = \frac{\Delta \Psi_t s_t'(x_{jt}) + \Psi_t \Delta s_t'(x_{jt}) + \omega_{jt} \Delta \pi_{jt} + \Delta \omega_{jt} \pi_{jt} - \Delta \mu_{jt} + \Delta \Phi v_{jt} + \Phi v_{jt}'}{-\Psi_t s''(x_{jt})}$$

Thus, the growth in health care real inputs is expressed as the sum of several components. Looking first at the numerator of (9), as income trends upward, one might expect a

¹⁷ Taking the total differential of the first-order condition yields the following expression:

$$\begin{aligned} & \Delta \Psi_t s_t'(x_{jt}) + \Psi_t \Delta s_t'(x_{jt}) + \Psi_t s''(x_{jt}) \Delta x_{jt} \\ & = -\omega_{jt} \Delta \pi_{jt} - \Delta \omega_{jt} \pi_{jt} + \mu_{jt} \Delta \bar{X}_{jt} + \Delta \mu_{jt} - \Phi \frac{d^2 V_{jt}}{dx_{jt}^2} - \Delta \Phi \frac{dV_{jt}}{dx_{jt}} \end{aligned}$$

corresponding increase in the value of a human life $\Delta\Psi_t$, as noted in the demand-side model above, and hence a more than proportional increase in the demand for health care innovations. On the other hand, premiums for health insurance P_t (from the budget constraint in Equation 2) would likely rise to maintain actuarial balance in the private insurance market; this in turn could dig into disposable income, cutting back on demand. The second term on the RHS of (9) captures a shift in the survival curve – technological innovations that increase survival holding constant inputs; these imply movement along the survival production function to reestablish equilibrium conditions. For example, through either learning-by-doing or knowledge spillovers, the ability of providers to use a technology may improve over time. If so, more of that technology *should* be delivered to patients.

The primary control over U.S. health care expenditure growth is through the setting of prices, for example, through reimbursement rates for physician or inpatient services by Medicare and Medicaid (Newhouse, 2002), or through the negotiation of discounts by large managed care organizations and insurance firms. Thus the third term reflects the substitution effects arising from changes in the profitability of health care services – lower profitability reduces use of inputs. But as the literature on physician behavior has emphasized, cutting reimbursement rates can have offsetting effects when physician or provider practices experienced reduced income, leading to the fourth term, at least for procedures or services that continue to be profitable.

The fifth term reflects changes in the shadow price of capacity or knowledge constraints. Capacity constraints are typically more explicit in countries such as the UK and Canada, where quantity restrictions based on central decisions of the government are the primary determinants of changes in both outcomes and costs. But they may also be present in the U.S. in the short term through shortages in resources such as ICU hospital beds, specialists, or MRIs. Changes in these resources are subject to a whole host of incentives, but changes take time, so gradual capacity adjustment could translate into short-term quantity constraints.

The final terms in (9) reflect the potential that individual patients are no longer better-off as a consequence of the additional health care services, and thus we assume that procedure growth would be curtailed or halted. This would occur, for example, when the price facing consumers p , is rising, income is falling, or if the marginal value of the procedure is fading.

A critical parameter that affects the magnitude and speed of the growth in x is in the

denominator of Equation (9), the second derivative of the production function s'' . When there are well-defined groups of people who benefit from the treatment, and where outside of that group the treatment causes harm – such as anti-retroviral therapy for people with HIV/AIDS – the magnitude of s'' is large, meaning that any changes in prices, income, or other factors has a very small impact on its expansion. By contrast, when there are a large number of people who could potentially benefit if only a small amount, then $-s''$ is very small, which magnifies dramatically the potential changes over time in utilization.

4. A Typology of the Productivity of Medical Technologies

The above analysis describes the static and dynamic nature of technology use for a given physician. But the aggregate productivity of health care spending depends critically on which technologies are used and which patients get them. That is, consider Equation (9) but now extended to a variety of k different technological innovations or treatments. Aggregate productivity for a given increase in spending will depend on the relative diffusion of each of these specific technological innovations and their respective value in improving outcomes. Summing the change in expenditures over all treatments yields

$$\Delta(q_t, x_t) \cong q_t \Delta x_t + x_t \Delta q_t = \sum_k q_{kt} \Delta x_{kt} + x_{kt} \Delta q_{kt},$$

where q_t is the year-specific aggregate price index and we have already summed over all j health care providers. Ignoring the “revaluation” of existing lifespan because of change in the marginal value of life Ψ_t , the change in the economy-wide value of the quality-adjusted survival due to health care treatments (x) is approximated by:

$$(10) \quad \Psi_t \Delta s_t \cong \sum_k \Psi_t \{ \Lambda s_{kt}(x_{kt}) x_{kt} + [s'_{kt}(x_{kt}) - q_{kt}] \Delta x_{kt} \}$$

where $\Lambda s_{kt}(x_{kt})$ is the shift in the k th input production function, evaluated at x_{kt} .¹⁸ Combining (9) and (10), the net improvement in health outcomes relative to expenditures is:

$$(11) \quad \Psi_t \Delta s_t - \Delta(q_t, x_t) \cong \sum_k \Psi_t \Lambda s_{kt}(x_{kt}) x_{kt} - \Delta q_{kt} x_{kt} + [\Psi_t s'_{kt}(x_{kt-1}) - q_{kt}] \Delta x_{kt}$$

¹⁸ That is, Λs_{kt} is the shift in the production function from t to $t+1$, holding factor inputs constant, or technological progress in the absence of technical or productive inefficiency (See Jacobs, Smith, and Street, 2006; also see Figure 1 of Färe et al., 2004). This equation ignores potential productivity spillovers, for example as was found in Chandra and Staiger (2007), or other interactive effects.

Thus, Equation (11) can be used to parse productivity gains as the sum of three components. The first term measures in part traditional technological innovation in health care as noted above; this may also include the development of complementary technologies that make existing technologies more productive. But it will also reflect any secular change in relative technical inefficiency, for example if in the aggregate, hospitals or provider groups move closer to the production possibility frontier (Färe et al., 1994). The second term represents changes in the real price q of inputs x . Some view the level of q as the primary reason why health care costs so much in the United States (Anderson, et al., 2003).¹⁹ More relevant here is whether q is growing more rapidly in the U.S. than elsewhere. While Gaynor and Vogt (2003) have shown that market consolidation can lead to cost increases, the magnitude of such effects are modest relative to aggregate trends. Conversely, technological innovations producing the same inputs x but at *lower* cost q could lead to productivity gains (Weisbrod, 1991), a point to which we return in Section 6.4.

The third term reflects the net productivity benefit of the k th treatment (the term in brackets, or the difference between the value of extra health less its costs) times the speed at which the k^{th} treatment diffuses (Δx_{kt} , as in Equation 9). While this latter term affects our overall measure of productivity, it arises because of *allocative* inefficiency, in that the marginal rates of substitution for each input are not equal to their marginal rates of transformation (Garber and Skinner, 2008).²⁰

At this point, we can begin to see how the nature of preexisting distortions in health care might affect the aggregate productivity of health care expenditures. First, consider a conventional competitive non-health sector of the economy where the marginal value of production always equals social cost. In this case, the third term in (11) would drop out. But in health care, there is both enormous heterogeneity in the cost-effectiveness of specific treatments, and heterogeneity in the speed at which inputs diffuse across treatment categories. Regions or countries will experience attenuated productivity growth (conditional on total spending) when

¹⁹ Even at a point in time, the case of price differences is difficult to establish. Two nations may have the same number of hospitalization days or physician visits per capita. Because the intensity of these visits may be very different in terms of what was done and prescribed, these unmeasured differences in utilization will manifest themselves as price differences.

²⁰ This formulation sidesteps both the controversy surrounding how one accounts for future costs when a current innovation increases future survival probabilities, or future costs (e.g., Lee, 2008).

the fastest growing treatments are also those with poor net value. This could occur both because the new technology has poor cost-effectiveness ($\Psi_{t s_{kt}} - q_{kt} < 0$) or because the health care system fails to sort patients and deliver care to those who would benefit the most.

In considering medical technology, we therefore group technologies into three categories based on their *average* cost-effectiveness: (I) Highly effective care including “home run” treatments with cost effectiveness ratios of as little as \$50 per life-year (e.g. Cutler, 2004) and for whom the social productivity of expanding use is strongly positive (Ψ_{s_k} is much larger than q_k); (II) Treatments where there are clear positive gains for a subset of people receiving treatment, but with considerable heterogeneity in the marginal effectiveness across the population; and (III) technology with poor cost-effectiveness for the overwhelming majority of patients or where we simply don’t know the value because of a lack of clinical studies.

4.1 Category I: “Home Run” Technologies

The first category of medical technologies includes those that are cost-effective and useful for nearly everyone in the relevant population. Perhaps the most famous example of such an intervention is Joseph Lister’s recommendation that surgeons wash their hands, use gloves, and swab wounds with carbonic acid (Lister, 1867).²¹ Improved health behaviors, arising for example from the publication of the 1964 Surgeon General’s Report on smoking, also fit into this category of innovation (Cutler and Kadiyala, 2003).

Cutler, Deaton, Lleras-Murray (2006) argue that new drugs, primarily antibiotics such as sulphonamide drugs, played an important role in reducing US mortality between the 1930s and 1960. In particular, the development of these drugs allowed for progress against a range of bacterial killers including pneumonia, tuberculosis, dysentery and venereal disease. Similarly, the development of low-cost antibiotic “sulfa” drugs led to remarkable improvements in outcomes following outbreaks of bacterial meningitis. After the 1950s, there were incremental gains in meningitis mortality, but a large portion of the new developments, such as the third-generation cephalosporins, were designed to treat infections that had developed resistance to the first- and second-generation antibiotics.

²¹ Lister acknowledged that his research was influenced by the Austrian physician, Ignaz Semmelweis. Semmelweis demonstrated that maternal mortality from puerperal fever (an infection of the genital tract after giving birth) could be reduced from 12.2 percent to 2.4 percent by making physicians wash their hands with chlorinated lime between autopsy and obstetrical rotations.

Another example of highly cost-effective interventions comes from the introduction of surfactants to treat neonatal acute respiratory distress for newborns. In the last quarter of 1989 the Food and Drug Administration (FDA) approved the use of two new formulations of this class of drugs. Schwartz et al. (1994) estimate that this drug reduced the odds of in-hospital mortality by 30 percent, and attribute to it 80 percent of mortality decline between 1989 and 1990. In addition to being a miracle drug for thousands of low birth-weight babies, surfactants also proved to be protective of cost, which declined by 10 percent for survivors, and 30 percent for decedents.

Often highly productive treatments diffuse slowly. In some cases, policies that relax capacity or financial constraints, for example expanding coverage to highly productive neonatal care, can generate large productivity shifts (Currie and Gruber, 1997). In other cases, overall productivity gains are enhanced when overtreatment is limited. For example, consider the technologies characterized by initial large benefits for a segment of the population, but where $-s''$ is large in magnitude, as illustrated in Figure 4. Even when the marginal productivity is pushed to $s'(s) = 0$, as shown at x^* , the average productivity of this innovation since its introduction – that is, the area under the curve in Figure 4 (gross benefits) less the shaded rectangle (costs) is still substantial.

In other words, Category I treatments aren't always low-cost. The best example is anti-retroviral drugs for the treatment of HIV patients to prevent the development of full-blown AIDS, a treatment which, despite its high costs of both development and treatment, exhibits favorable cost-effectiveness ratios under \$25,000 per life year (Duggan and Evans, 2005; Lichtenberg, 2006). One study has found that the marginal dollar value to patients in terms of future life expectancy is roughly 20 times the costs of development (Philipson and Jena, 2006). Given the serious side-effects of the drug, however, no physician would ever prescribe it to anyone without HIV/AIDS.²²

Another example of a Category I success story is the treatment of testicular cancer. Before 1970, diagnosis was followed by near-certain early death. Since that time, new developments in the treatment of testicular cancer have exhibited dramatic success, with remarkable cost-effectiveness or even cost-saving (Shibley et al., 1990). However, few men would agree to

²² The curve is not discontinuous however; treatment may start too early before CD4 counts fall off.

undergo an orchiectomy (don't ask) without a confirmed diagnosis, limiting the growth in expenditures on testicular cancer. And unfortunately, the AIDS and testicular cancer success stories are the exception rather than the norm, limiting their use as paradigms for health care productivity.

4.2 Category II: Potentially Cost-Effective Technologies with Heterogeneous Benefits

A more interesting set of medical technologies are those which are cost-effective in some patients but have declining marginal benefits in others (so that $-s''$ is small). Despite clear benefits to some patients, such technologies can still exhibit modest or even poor *average* cost-effectiveness across all patients.²³ A leading example is angioplasty, more commonly known as PCI (percutaneous coronary intervention), an invasive procedure in which a cardiologist inserts a thin wire into the coronary arteries, and inflates a balloon at the tip of the wire to restore blood flow because of an arterial occlusion. Typically a wire mesh cylinder, known as a stent, is also inserted in the artery to prevent blockage from occurring again. The price depends on who pays for it, but generally runs above \$15,000. These have been shown to dramatically improve survival following a heart attack only if performed within the first 12 or 24 hours following its onset, and it is highly cost-effective for this use (Hartwell et al., 2005; Hochman et al., 2006). For stable coronary disease, roughly one-third of all PCI procedures, clinical trials have found no survival benefit and modest improved functioning relative to optimal medical therapy (Boden et al., 2007; Weintraub et al., 2008). Its value, as measured by survival, is also higher for relatively younger patients, and is highly cost effective for this group, but it is of lesser value in older populations.²⁴ Other examples include the continued diffusion of existing technologies such as Cesarean-sections, or new technologies, such as stent technology to repair malfunctioning aortic valves (Leon et al., 2010).

We therefore draw this innovation as having quite different characteristics from Category I advances. Figure 5 shows a hypothetical graph of Category II benefits and costs using PCI as an example. While there are some who clearly benefit (i.e., primary PCI just after a heart attack),

²³ While heterogeneity in treatment effects is typically the norm, Category II treatments also include homogeneous treatments with uniform yet similarly uninspiring cost-effectiveness ratios of (say) \$200,000 per life year.

²⁴ Chandra and Staiger (2007) note that the causal effect of intensive treatments for heart attacks improves one year survival by 18.5 percent in patients less than the age of 80, but increases one year survival by only 3.5 percent in those over the age of 80 (the latter result was not statistically different from zero).

there are many more people who gain small or near-zero benefits; on net as represented in Figure 5, the average productivity of this innovation could in theory be zero or even negative.

Schwartz (1987) offers a related view of technological diffusion and cost growth. He notes that new technologies involve fewer risks, for example the use of laparoscopy rather than open surgery to remove inflamed gallbladders, and therefore they increase costs not because each procedure is more expensive, but because so many more patients may now experience relative gains. As a consequence, per patient costs fall but total costs increase as the new procedure diffuses (Cutler and Huckman, 2003).

It is well known that across physicians, there are differences in the perception of benefits for specific procedures; furthermore they appear to predict overall spending across regions (Sirovich et al., 2009). For example, stent (PCI) rates in Elyria, Ohio were three times the national U.S. average, and nearly six times the Canadian average (Abelson, 2006; Lucas et al., 2006; Alter et al., 2006). The higher rates arose both from the strongly-held beliefs by Elyria cardiologists that a wider swath of elderly people could benefit from a stent, and that more stents (per person) should be inserted (Abelson, 2006). These beliefs would be reinforced by lower complication rates among incremental patients with minimal arterial blockage.

This phenomenon can be illustrated as well in Figure 6, which shows how higher perceived (or actual) productivity, as shown by the dotted line, affects utilization. When health care systems are constrained or $-s$ is large, differences in perceptions have little impact on utilization; Figure 6 shows optimal utilization, where the marginal productivity is equal to q , at M and M' ; these differ by only a small amount. However, when there are few if any constraints, and $-s$ is small, very large utilization variations arise, as shown by the differences between X' and Z . As can be seen by the much larger cost “box” in Figure 6, these small differences in beliefs by providers can have very large effects on overall health care productivity.

Similarly, imaging technologies offer enormous incremental value for a subset of patients, but their efficacy in marginal patients is hard to establish. Iglehart (2006) notes that physicians are now using computed tomography (CT), MRIs, and even positron-emission tomography (PET) for an ever-expanding list of diseases, leading to double-digit growth rates during some years (see Baker et al., 2003). Despite this rapid growth, some suggest low marginal effectiveness (MedPAC, 2003; Miller, 2005). In other words, there are specific uses of imaging

with unequivocal value, but at the margin the value approaches zero or even becomes harmful given the risk of false positives, incidental findings unrelated to the original inquiry (“incidentalomas”) or risks of radioactive exposure.²⁵

A final issue with Category II relates to differences in preferences across patients regarding the benefits and side-effects entailing loss of quality-of-life. This idea can also be captured by Figure 6; think of the dotted line as representing someone who is willing to risk the potential adverse outcomes associated with PCI (such as complications from surgery resulting in death) in return for functioning gains. Alternatively, the individual may have a lower discount rate, and therefore value the benefits of increased survival at a higher rate. Thus when δ is small, modest differences in *demand* can also lead to large differences in utilization.

An example where preferences should matter is the treatment of prostate cancer for men. There is good evidence that, once clinically apparent, there are benefits of treatment through surgery or radiation therapy for men under age 65 (Bill-Axelsson et al., 2008). More controversial is the prostate-specific antigen (PSA) test, which is predictive of prostate cancer years before it becomes clinically apparent but cannot distinguish between benign and virulent prostate cancers. While a large U.S. randomized trial showed no mortality benefit from PSA screening, a recent Scandinavian study found PSA screening led to a large reduction in prostate cancer deaths, albeit with identical overall mortality rates.²⁶ Unfortunately, the side effects associated with the treatments include the potential loss of sexual functioning and incontinence, as well as exposure to radiation. Thus choices surrounding prostate cancer for men – like breast cancer screening for women under age 50 -- should depend not on “cookie cutter” guidelines, but on how patients trade off longevity with quality of life. For these procedures, the key to productivity growth is ensuring that only well-informed people who want the procedure actually get it (Meltzer et al., 2005).

4.3 Category III: Technologies with Modest or Uncertain Effectiveness

²⁵ One study suggested 1.5 to 2 percent of all cancers in the U.S. were caused by CT radiation exposure (Brenner and Hill, 2007).

²⁶ Schroder et al. (2009) and Huggoson, et al. (2010); also see Andriole et al., 2009. Preston and Ho (2009) show a marked drop in U.S. prostate cancer deaths beginning in the early 1990s. The mystery is why mortality rates dropped so rapidly at that time; PSA testing, which first diffused in the late 1980s, yields no survival benefits for at least a decade (Huggoson et al., 2010).

If Category I treatments are highly cost-effective, and Category II less so, this final category captures treatments where the average value of the procedure leads to poor (or non-existent) cost-effectiveness, or where there is considerable uncertainty about its benefits. The classic example is a trial published in the *New England Journal of Medicine* on arthroscopic surgery for osteoarthritis of the knee, in which surgeons enter the knee and clean out particles from the joint (Moseley et al., 2002). Over 650,000 such surgeries had been performed each year at a cost exceeding \$5,000 per surgery. In the study, those in the control group received “placebo surgery”— skin incisions and simulated surgery. The trial found no gain from arthroscopic surgery relative to sham surgery.

For ethical and logistical considerations, it is difficult to conduct double-blinded trials to establish the efficacy of every medical and surgical therapy. For many surgeries that target quality of life instead of well-defined clinical endpoints such as death or an acute hospitalization, measuring outcomes is more difficult and may be subject to patient biases, particularly where “sham” treatments would be unethical. More generally, there is often considerable uncertainty about the benefits of a procedure for a specific patient – even if randomized trials show little average benefit, physicians may believe that because of heterogeneity in the population and the physician’s considerable skill and experience, *their* patients will benefit (Kolata, 2009). While this may be true in some cases, aggregate productivity depends on the average benefit, so continued use of such procedures with zero net benefit – given their positive cost – is guaranteed to reduce productivity.

Other Category III intensity measures include the frequency of office visits, ICU days for the chronically ill, and referrals to specialists (see Barnato et al., 2007). Strictly speaking, these treatments do clearly benefit some patients – for example, Doyle (2010) suggested higher ICU days contributed to lower mortality for Florida tourists (but not Florida residents) admitted to emergency rooms. On the other hand, patients treated aggressively in the hospital for advanced lung cancer experienced worse quality of life and *shorter* life expectancy relative to palliative care (Temel et al., 2010). More commonly, treatments are included in Category III because so much of their utilization is of unknown value.

One of the real challenges in evaluating new technology is that innovations whose benefits are not well understood could be viewed initially as Category III and thus not approved for use

(Schreyögg, Bäumlner, and Busse, 2009). It could take years for randomized (or observational) studies to establish them as Category II or even Category I treatments. For example, the use of stents for recent heart attacks was once considered “off-label”, until randomized trials demonstrated effectiveness. In contrast, arthroscopic surgery for knee osteoarthritis was a Category II technology before the Moseley et al. (2002) study moved it to Category III.

Recognizing the wide differences in cost-effectiveness ratios for specific Category I, II, and III treatments, ranging from just a few hundred dollars to millions per life-year, also helps to make sense of otherwise puzzling empirical patterns (Weinstein and Skinner, 2010). Most studies of health care spending and outcomes find modest or even negative associations between spending and longer-term outcomes (Fisher et al., 2003a,b; Baicker and Chandra, 2004; Skinner et al., 2006; Silber et al., 2010; Barnato et al., 2010). One way to think of these patterns as reflecting flat-of-the-curve (or nearly-flat) health care. A different interpretation is that these weak associations reflect the near-independence of hospital-level investments in Category I treatments (that save lives) and Category III treatments (that cost money). For example, hospitals quickest to adopt Category I treatments for heart attack patients such as aspirin and β blockers spent slightly less overall (Skinner and Staiger, 2009). However, within each hospital, spending more (conditional on their adoption of Category I treatments) still yielded better outcomes, but at a rapidly diminishing rate.

5. Aggregate Growth in Expenditures and Health Outcomes

Armed with typology of treatments it is natural to ask: How much of these gains in survival, and how much in costs, during the past several decades have been driven by growth and diffusion of Category I, II, and III treatments? After all, during the past several decades, the average productivity of health care spending appears to be substantial. Murphy and Topel (2006) find that the value of improved health through longevity has risen by 95 trillion dollars between 1970 and 2000, roughly three times medical spending during this period.

Ford et al. (2007) addressed this question by considering factors that explained the decline in cardiovascular mortality between 1980-2000, a decline of more than 300,000 deaths annually and the majority of survival gains during this period. Their results are summarized in Table 2.

Sixty-one percent of the reduction in deaths was the consequence of risk factors such as smoking, drinking, and lower cholesterol and hypertension prevalence without medical intervention. Diabetes and obesity, on the other hand, were responsible for a 17% increase in mortality during the same period. Thus nearly half of the overall gain in survival comes from behavioral factors rather than health care *per se*.²⁷ Another 20 percent of the decline in mortality was the consequence of Category I treatments: cost-effective aspirin, beta blockers, and anti-hypertensives. Thirteen percent of the gains in survival occurred through higher cost pharmaceuticals: ACE inhibitors, anti-cholesterol statins and thrombolytics; these might be classified as Category I+ because their net benefit is substantial and marginal cost of production is modest, even if overuse poses risks (Wilson, 2010). The Category II high-tech surgical interventions such as angioplasty, stents, and bypass surgery in turn accounted for an additional 7 percent of the gain (Ford et al., 2007). Of course, many of these treatments at the outset of the study period, 1980, would have been considered unproven and hence Category III, and only gradually were switched to Category I or II. Similarly, there may be other treatments that are currently Category III but which could account for at least some of the residual 10 percent of the overall gains in mortality that aren't otherwise explained by existing Category I and II treatments.

Doing this same breakdown for costs is trickier. The Category I (and even I+) treatments were not likely to account for more than a small fraction of the enormous rise in U.S. health care costs. For non-cardiac treatments, expenditures per HIV/AIDS patients are high, but the fraction of the population on anti-retrovirals is still small. The role of Category II treatments in cost growth, such as stents and back surgery, is much larger (e.g., Groeneveld, et al., 2010), but the largest contribution to overall cost growth is likely to be Category III spending. In part, this can be inferred from the stagnation in productivity growth over time. Even when averaged across all three categories of treatments, the average cost of saving an additional life-year has risen three-fold since the 1970s, to as much as \$246,000 per life-year (Cutler et al., 2006; Garber and Skinner, 2008).

²⁷ Thus Murphy and Topel (2006) attribute too much of the overall improvement in life expectancy to health care expenditures given that behavioral factors accounted for about half of the survival improvement. But their conclusion that biomedical research exhibits extraordinarily high social returns still holds if medical research includes the landmark epidemiological studies (such as those linking tobacco to lung cancer) that provided the basis for behavioral changes.

There is also evidence that less effective Category II and III treatments in the U.S. have diffused more widely than in other countries, potentially explaining the much higher growth in health care spending relative to GDP. We consider four examples below. First, cardiovascular procedures in the U.S. (587 per 100,000) lead those in Germany (357), and are far ahead of Denmark (207) and Switzerland (115) (Peterson and Burton, 2007). The greater availability of primary PCI for heart-attack patients saves lives in the U.S., but its corresponding greater use for patients with little benefit (e.g., Tu, et al., 1997), attenuates overall productivity gains.

Second, the US is a leader in the diffusion of expensive new Category III technologies with unproven benefits. One example is “robotic” surgery tools, which require an up-front investment of \$1 million to \$2.5 million per unit. The leading manufacturer of such devices sold 1400 units in the United States during 2009, compared to just 400 in the rest of the world, with an annual price-tag for U.S. health care of up to \$2.5 billion (Barbash and Glied, 2010). Similarly, proton-beam therapy for prostate cancer require facilities costing up to \$100 million and has experienced rapid growth in the U.S., but without a consensus on its benefits relative to conventional radiation therapy (Terasawa et al., 2009).

A third example comes from the use of intensive care unit (ICU) hospital beds. In the U.K., the use of ICU beds is similar to that in the U.S. for conditions such as cardiac surgery that clearly indicate post-surgical ICU care. However, among elderly people over 85, 1.3% die in an ICU in the U.K., compared to 11.0% in the United States (Wunsch et al., 2009). This by itself does not tell us whether the U.K. is using too few ICU days, or the U.S. too many. But the rapid U.S. growth in ICU use since the 1990s, coupled with the likely cost-ineffectiveness of those incremental ICU days (Barnato et al., 2010), are consistent with poor productivity in U.S. health care spending.²⁸

Finally, the U.S. often experiences rapid diffusion of expensive pharmaceutical treatments with uncertain benefits. Ezetimibe, a costly ingredient in the cholesterol-reducing drug Vytorin, was not recommended as a first-line treatment, nor has it subsequently been shown to be relatively effective at reducing cardiovascular disease. In 2006 Ezetimibe accounted for 15 percent of U.S. cholesterol-lowering drug sales, compared to just 3 percent in Canada

²⁸ Average ICU days per Medicare enrollee in the last six months of life increased from 1.2 days in 1994 to 3.5 days in 2005 (www.dartmouthatlas.org). It seems unlikely that ICU days for the over-65 population in the U.K. could have grown so rapidly, given the very low level of use in 2001.

(Jackevicius, et al., 2008). Another example comes from the FDA approval of Avastin for recurrent glioblastoma (brain tumors) in the U.S. based on the results of an uncontrolled trial. Citing the *same* results, the European Medicines Agency reached the opposite decision.²⁹

Differences in spending growth between the U.S. and other countries cannot be explained simply by slower innovation in Europe: drug-eluting stents were approved for use in Italy a year before FDA approval in the U.S. (Schreyögg, Bäumlér, and Busse, 2009). And acknowledging that the U.S. is more likely to adopt Category II and III technologies doesn't explain why it happens. One potential explanation stems from Weisbrod's (1991) 'induced innovation' hypothesis. The willingness of the U.S. insurance programs to reimburse for new innovations leads to dramatic growth in these categories of care. It is less clear whether innovation occurs differentially because of market-size, insurance expansions, or factor prices (see Acemoglu and Linn, 2004; Acemoglu, Cutler, Finkelstein, and Linn, 2006; Acemoglu and Finkelstein, 2008). But we should still expect a far more rapid rate of innovation when there is an implicit promise that those innovations will be reimbursed, regardless of whether the innovation yields good value for the extra cost.³⁰

Another key explanation of differences in health care spending relative to GDP growth is the ability to finance health care spending, as shown originally by Getzen (1992). Recall from Table 1 that all of the other high-spending countries in 1980 (except for the U.S.) experienced, on average, less than a one-percentage point increase in the share of GDP devoted to health care. Many of these high-spending countries began the 1980s with an already heavy tax burden (with roughly half of GDP devoted to taxation in Sweden and Denmark), limiting their ability to raise taxes further to support health care cost growth (Baicker and Skinner, 2011). By contrast, the U.S. began the 1980s with an aggregate tax effort of about 30 percent, and funded much of the increase in health care costs through the less salient mechanism of rising insurance premiums reflected in sluggish take-home wage growth.

²⁹ See the debate between American and European researchers in Wick, Weller, van den Bent and Stupp (2010) and Friedman et al. (2010).

³⁰ And in the longer-term, the newly developed product could become cost-effective once off-patent. One could also argue that successful innovations developed in the U.S. benefits everyone in the world. But US norms for ineffective Category II or III treatments could also diffuse to other countries, saddling them with excess costs.

6. Future Prospects for Controlling Health Care Costs

We return to our initial question regarding the twin trends in technology and cost growth in health care: How can countries ensure that a rising share of GDP devoted to health care is a good thing, and not a cause for concern? We categorize potential reforms by considering each component from the model in Equation 9: capacity constraints (μ), demand-side changes (p, ψ), more cost-effectiveness analysis to understand the shape of $s(x)$, and improving incentives faced by physicians and other health care providers (π, ω). We consider approaches to improving health outcomes and reducing both the *level* and *growth rate* of inefficient spending.³¹

6.1 Capacity Constraints

In the U.S., Medicare regulatory boards evaluating new technology are concerned solely with whether drugs or procedures provide positive benefits, but rarely reference costs. Elsewhere, regulatory boards such as England's National Institute for Health and Clinical Excellence (NICE), use explicit cost factors in setting standards for the use of Category II or Category III treatments. In theory, these capacity constraints (μ) should ensure that any growth in costs should be limited to cost-effective treatments. Typically these rulings are limited to specific and discrete choices, for example whether specific drugs can be used for a specific disease. In practice, Category II treatments with heterogeneous benefits are more difficult to classify under “cover/not cover” decision rules.

Medicare accounts for 20 percent of total spending, but what about the larger fraction of health care spending (32 percent) in private insurance markets? Here the legal system – not so much malpractice *per se*, but the inability of private insurance companies to deny coverage for procedures with unproven (Category II or III) benefits – may be at fault for failing to control cost growth (Ferguson, Dubinsky and Kirsch, 1993). These pressures are strengthened by the fact that Medicare does not reimburse with regard to economic value, making it very difficult for private insurers, especially a single private insurer, to use value in guiding their own coverage decisions.

As well, U.S. corporate laws make it very difficult for insurers and hospitals individually to

³¹ We assume here that rising costs are not a symptom of “Baumol’s cost disease”: sectors of the economy that rely heavily on human interactions fail to share in overall productivity gains. Health care seems particularly well posed to enjoy large productivity gains, for example from the diffusion of information technology.

reduce the use of Category II and III technologies, even when physicians are employed by the hospital. These provisions prohibit any interference by insurers or hospitals with the medical judgment of physicians, on the grounds that only physicians hold medical licenses. State laws also require insurers to pay for any medically necessary service as determined by a physician. Together, these incentives undercut the ability of an insurer to act as a residual claimant, so they ‘reduce’ spending by negotiating prices with providers, rather than scaling back utilization.

Historically, the U.S. has not relied on quantity restrictions in health care planning, except for sometimes ineffective certificate of need programs (Conover and Sloan, 1998). In theory, regional restrictions to discourage duplication and overbuilding of surgical units, MRIs, and hospital or ICU beds could control unrestricted growth in Category II or III procedures. But this approach to market-level quantity restrictions would require a tectonic shift in the U.S. regulatory and policy environment.

6.2 Demand-side incentives

Economists are naturally drawn to the idea of raising the price (p) faced by consumers to ensure that patients truly value the treatments they receive. Consequently, there is widespread support for limiting the income-tax exclusion for employer-sponsored health insurance, thereby raising the out-of-pocket costs of health insurance (Gruber, 2009). Health savings accounts (HSA), tax-preferred savings designed to be accumulated over time for health care bills, are another approach to reducing moral hazard. These are typically coupled with a catastrophic insurance cap on health care spending that may depend in turn on household income. Once above the cap, however, moral hazard still intrudes; even with a \$5,000 deductible, the patient has no cost incentive to choose procedure A costing \$10,000 over procedure B costing \$20,000. For this reason, one recent proponent of demand-side incentives suggested a catastrophic cap of \$50,000 – thus effectively dismantling the risk-sharing component of health insurance for low and middle-income households (Goldhill, 2009).

In the conventional approach to improving cost-sharing, the copayment is either uniform across different types of treatment (ranging from highly effective to ineffective), or is set depending on the elasticity of demand for the service. For well-informed patients who are cognizant of marginal costs and benefits, this is sufficient (Pauly and Blavin, 2008). But patients may not always make appropriate decisions about the use of services when faced with higher

copayments and coinsurance.³² A different approach is to use “value-based” insurance plans that have higher prices for Category III and some Category II payments, but lower prices for Category I treatments. Prices (or more generally, the size of patient-cost sharing) could be based on the results of clinical trials. While this approach has been applied to lowering prices of Category I treatments with some success (e.g. Chernew et al., 2008), insurance plans that assess significant copayments for Category II or III treatments are rare, perhaps because of the difficulty in determining the medical necessity of specific hospital or ICU admission, or the idiosyncratic benefit that a patient may attach to these services.

How will a demand-side approach affect the adoption or diffusion of new technology? If the expansion of health insurance coverage under Medicare in 1966 led to rapid technological diffusion (Finkelstein, 2007), then why shouldn't cost-sharing reverse the tide? There is at least anecdotal evidence that high-income patients would just say no to cost-ineffective treatments if asked to pay out-of-pocket, suggesting that cost-sharing would discourage the most expensive new and marginally effective technologies.³³ But even with demand-side incentives for a larger fraction of the population, government agencies must decide whether (or how much) Medicaid and Medicare will cover for new treatments, or how to adopt coverage and cost-effectiveness rules as Ψ , the implicit value of additional health benefits, evolves over time.

6.3 Comparative-Effectiveness Analysis

To the extent that inefficiency is partially caused by providers not knowing the shape of $s(x)$, more trials or well-designed observational studies could improve the productivity of health care spending (Chandra, Jena, and Skinner, 2011). But many Category II and III interventions require estimating treatment effects across a wide variety of phenotypes and genotypes, requiring much larger study sample sizes and lengthier study periods than typically available. Complicating decisions further, the benefits of an intervention vary not only by type of patient but also by type of provider who delivers the treatment (Wennberg et al., 1998; Chandra and Staiger, 2007). None of these concerns lessen the value of what can be learnt from trials and observational

³² Although most evidence suggests that health is not adversely affected by greater patient cost-sharing on average; see Newhouse (1993) and Chandra, Gruber, and McKnight (2010).

³³ One former corporate finance officer whose insurance covered the \$93,000 prostate cancer drug Provenge was explicit about his willingness-to-pay: “I would not spend that money, because the benefit doesn't seem worth it.” (Marchione, 2010). Others have pointed out the difficulty of judging “true” demand for health care, particularly among those near the end of life (Becker, Murphy, and Philipson, 2007).

studies, but it does suggest that a serious attempt to embrace comparative effectiveness research would require many trials and a large budget – albeit a budget justified by the considerable world-wide benefits of improved physician and patient decision-making.

6.4 Changing health care provider incentives

Growth rates may vary because of the evolution of ω , or the marginal importance of financial factors for health care providers. Certainly the rapid real growth rate in spending observed in McAllen TX, 8.3 percent during 1992-2006, in contrast to El Paso TX which grew at just 3.4 percent, is consistent with the evidence of a growth in McAllen’s “entrepreneurial” activities during the period of analysis.³⁴ Another cause for ω to evolve is the time-varying intensity of market competition affecting both income and prices. For example, Rau (2010) has documented a very rapid growth in diagnostic and surgical facilities in Provo, Utah during the 2000s as multiple health care providers sought to expand market share.

More generally, a change in payment incentives away from traditional fee-for-service care could also affect growth in both outcomes and costs. For example, if the incentive model were expanded to include more profitable reimbursements π for improved health outcomes, one could observe both better outcomes and lower costs. However, current incentives provide little scope for this type of innovation (Cutler, 2010). In one case, a back pain clinic began to steer patients to low-cost rehabilitation, rather than sending them to the hospital immediately for diagnostic tests and back-surgery. Despite improved outcomes and lower costs, the hospital was forced to petition the insurance company to reimburse it for some of the lost profits on MRIs not performed (Fuhrmans, 2007).

The current system in the U.S. is not particularly supportive of competition among insurance carriers or providers. Medicare is explicitly prohibited from selectively contracting with more efficient physicians. In contrast, hospitalizations are reimbursed by bundled payments measured as DRGs (diagnosis-related groups), thus limiting the incentives to over-provide hospital care. In the Medicare program, there has been very little per capita real growth since 1992 in these types of DRG-related categories, more likely to encompass Category II treatments. By contrast,

³⁴ As Gawande (2009, p. 38) characterized the change in ω : “The surgeon came to McAllen in the mid-nineties, and since then, he said, ‘the way to practice medicine has changed completely. Before, it was about how to do a good job. Now it is about “How much will you benefit?””

growth in home-health care, outpatient visits, office visits and diagnostic testing—all Category III areas of care where reimbursements are based on volume and the “right rate” is not known – have exhibited very rapid growth (Chandra et al., 2010). And at least for home health care, the additional spending appeared to have no impact on health outcomes (McKnight, 2006).

Rewarding cost-savings would be a natural place to increase the productivity of health care spending. This dilemma also confronted Weisbrod (1991), who optimistically described the prospective payment system (PPS) then recently introduced by Medicare:

With a hospital’s revenue being exogenous for a given patient once admitted, and an HMO’s revenue being exogenous for a member for the given year, the organization’s financial health depends on its ability to control costs of treatment. Thus, under a prospective payment finance mechanism, the health care delivery system sends a vastly different signal to R & D sector, with priorities the reverse of those under retrospective payment. The new signal is as follows: *Develop new technologies that reduce costs, provided that quality does not suffer “too much.”* (p. 537, italics in original text.)

Weisbrod was perhaps too sanguine about PPS; in retrospect it has not fundamentally changed the incentives to innovate, as it created DRGs for new procedures (McClellan, 1996), created incentives to “unbundle” post-acute care, and exempted certain capital costs from the expenditure cap, thereby failing to discourage capital spending (Newhouse, 2002; Acemoglu and Finkelstein, 2006). Currently, less than 0.5% of new innovations would qualify as Weisbrod’s cost-saving technologies (Nelson et al., 2009).

But the fundamental message in Weisbrod is still correct – only when health care is reimbursed on the basis of its fundamental value will innovations be directed at highly cost-effective treatments. The greatest saving could arise not so much from new cost-saving devices, but instead from reducing the organizational fragmentation inherent in U.S. health care (Cebul et al., 2008). The more than two-fold differences in risk- and price-adjusted costs across top-ranked U.S. academic medical centers treating heart attack patients (Fisher et al., 2004) are not due to “what” is provided, since nearly all academic medical centers have access to the latest technology. Instead, differences are related to “how” it is provided or the *organization* of the health care treatment – the frequency of follow-up visits, referrals to subspecialists, hospital days, and the intensity of diagnostic testing and imaging procedures.

To confront problems of fragmented care, some have embraced the idea of an integrated

delivery system. Because such systems retain the savings from better prevention, lower readmission rates, and greater compliance with medications, they have better incentives to avoid therapies of dubious benefit. The 2010 U.S. health care reforms focused on “accountable care organizations” (ACOs); examples include the traditional integrated systems such as Intermountain in Utah or the Geisenger Clinic in Pennsylvania, but can also encompass traditional hospital-physician networks (Fisher et al., 2009). Such a construct could come closer to the ideal expressed by Weisbrod by providing incentives for cost-saving innovations. However, we do not know how well ACOs could sidestep cost-ineffective technologies, particularly if the latest shiny innovation enhanced market share (Chernew, et al., 2010).

7. Conclusion

There are no easy solutions to the problem of rising costs in health care, as has become evident in the political debate over the 2010 U.S. health care reform bill. Douglas Holtz-Eakin, then-director of the Congressional Budget Office (CBO) put it best: “Social-Security is Grenada. Medicare is Vietnam.” (Wolf, 2005) Still, our lengthy survey of the economics and medical literature suggests several observations.

First, attributing cost growth and improvements in outcomes to “technology growth” is too simplistic and tells us little about where the cost growth is occurring, whether such growth should be tamed, and if so, how it should be done. Some countries and some regions in the U.S. have managed to avoid the very rapid growth in expenditures that is now threatening the financial health of many federal and state budgets around the world. The key point is that U.S. growth in health care costs is neither inevitable nor necessarily beneficial for overall productivity gains. Instead, cost growth is the aggregated outcome of a large number of fragmented decisions regarding the use and spread of both old and new health technologies.

Second, there is wide heterogeneity in the productivity of medical treatments, ranging from very high (aspirin for heart attacks and surfactants for premature births) to low (stents for stable angina), or simply zero (arthroscopy for osteoarthritis of the knee). This fact motivated our distinguishing among three different types of treatments, arrayed by their contributions to productivity gains. The Category I set of effective treatments appears to be the largest contributor to survival and functioning gains, while the Category III set of low-productivity

group or with uncertain benefits, is most strongly associated with health care cost growth. It is perhaps tautological, but still worth noting that countries or systems of care that encourage the first group of innovations but discourage the third group are most likely to exhibit high aggregate productivity growth and a slower overall growth rate relative to GDP.

Finally, the most difficult questions relate to health care policy going forward, where there does not appear to be a single magic bullet to “solve” the health care problem. The U.S. and most other countries are struggling with rising costs and a diminished ability to raise taxes or health insurance premiums. As well, the U.S. leads the world with the extent of waste in their health care system (McKinsey Global Institute, 2008). The extent of waste in the U.S. could, ironically, prove to be a boon if a fundamental restructuring of health care unleashed some of this lost productivity; gradually eradicating 30 percent of waste would depress cost growth rates by 1.3 percentage points over the next two decades. The alternative to not making such changes is far more worrisome: Rising political and economic resistance against tax and insurance premium hikes could serve as a particularly inefficient brake on both health care costs and health care innovation.

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Table 1: Health Care Share of GDP for OECD Countries, 1980 and 2008

Country	Healthcare Share of GDP			Annual Growth Rate (1980-2008)	
	1980	2008	Increase	Healthcare Spending	GDP Per Capita
<i>Countries with Low 1980 Health Spending (as a % of GDP)</i>					
Spain	5.3	9.0	3.7	4.5%	2.5%
Portugal	5.3	9.9*	4.6	4.4%	2.4%
UK	5.6	8.7	3.1	3.8%	2.2%
Greece	5.9	9.7	3.8	3.1%	1.5%
New Zealand	5.9	9.8	3.9	3.0%	1.1%
Australia	6.1	8.5	2.4	2.9%	1.8%
Belgium	6.3	10.2	3.9	3.3%	1.4%
Finland	6.3	8.4	2.1	3.0%	1.9%
Iceland	6.3	9.1	2.8	2.4%	1.0%
Japan	6.5	8.1	1.6	2.5%	1.8%
<i>Countries with Medium 1980 Health Spending (as a % of GDP)</i>					
Canada	7.0	10.4	3.4	2.9%	1.5%
France	7.0	11.2	4.2	3.1%	1.4%
Norway	7.0	8.5	1.5	4.3%	3.5%
Switzerland	7.3	10.7	3.4	2.4%	1.0%
Austria	7.4	10.5	3.1	2.8%	1.6%
Netherlands	7.4	9.9	2.5	3.1%	2.1%
<i>Countries with High 1980 Health Spending (as a % of GDP)</i>					
Ireland	8.2	8.7	0.5	4.2%	3.8%
Germany	8.4	10.5	2.1	1.8%	1.6%
Denmark	8.9	9.7	0.8	1.9%	1.7%
Sweden	8.9	9.4	0.5	1.6%	1.4%
United States	9.0	16.0	7.0	4.0%	1.8%

Source: OECD, 2010. Data for either 2007 or 2008, except for * (2006). The 1980 German data refers to West Germany only. Adding the growth in health care spending relative to GDP for 1980-1990 and for 1992-2008, yields an increase of only 0.8 percentage points.

Table 2: Accounting for Improved Cardiovascular Health 1980-2000

<i>Medical Cost</i>	<i>Intervention</i>	<i>Number of Deaths Avoided/Postponed</i>
Very low	Good Behavior (Drop in smoking, blood pressure, cholesterol, inactivity)	209,000 (61%)
Very low	Bad Behavior (Rise in obesity, diabetes)	- 59,370 (- 17%)
Low (pennies)	Aspirin, beta blockers, anti- hypertensives	70,762 (20%)
Moderate (dollars)	Statins , ACE inhibitors, thrombolytics	44,870 (13%)
Expensive (thousands of dollar)	Angioplasty / stents / bypass	25,630 (7%)

Source: Ford et al. (2007) and authors' calculations

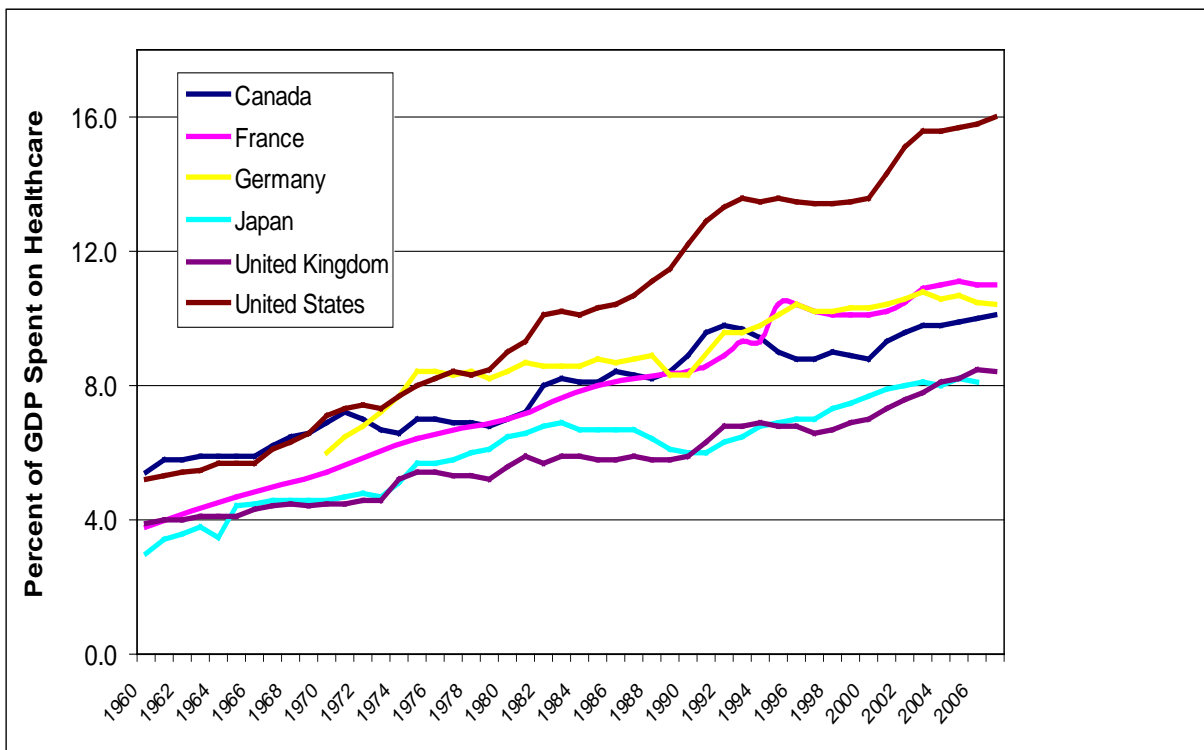


Figure 1. Percent of GDP spent on healthcare. Data for Germany refer to West Germany. Source: OECD.

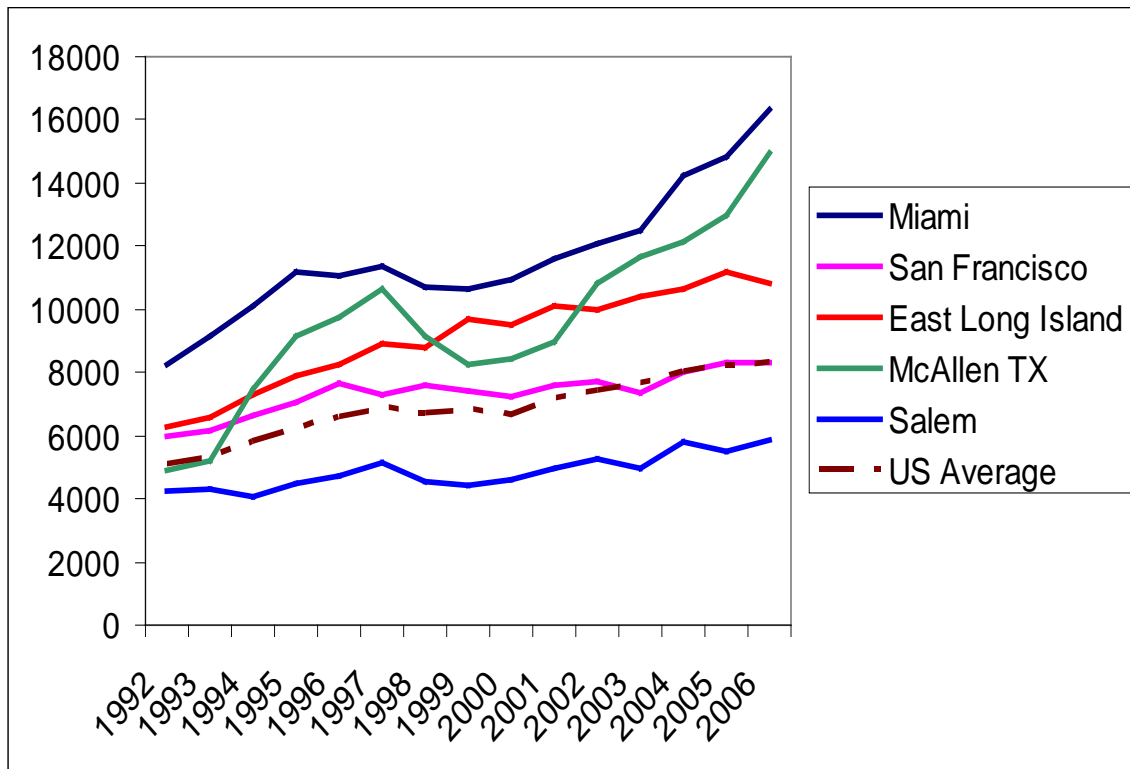


Figure 2: Variations in Medicare Expenditure Growth, Selected Hospital Referral Regions 1992-2006. Source: Dartmouth Atlas of Healthcare (www.dartmouthatlas.org). Estimates are age, sex, and race adjusted, drawn from the 5% Continuous Medicare History Survey, and adjusted by the GDP implicit price deflator, with all prices in 2006 dollars.

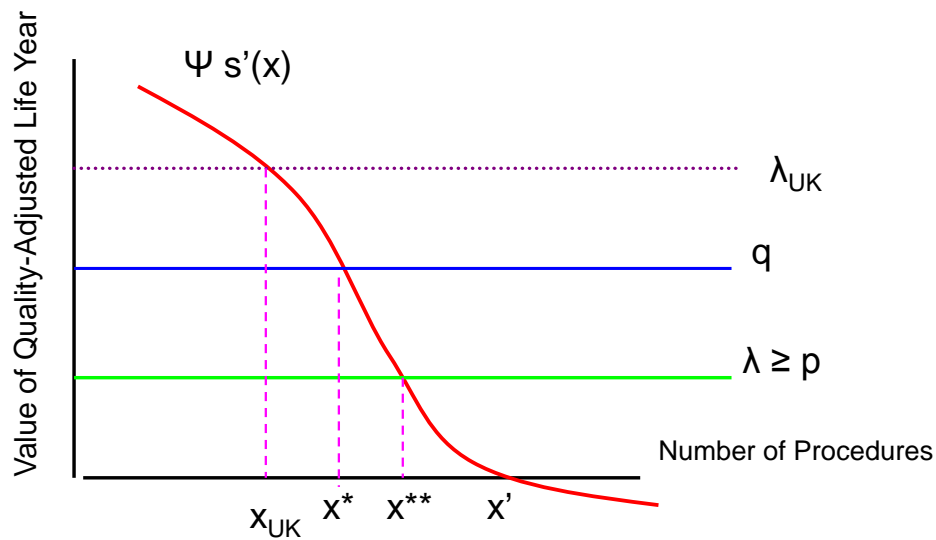


Figure 3: Quantity of health care spending given constraints facing health care providers and the marginal productivity of health care spending. Note: In the figure above curve $\Psi s'(x)$ is the value of life multiplied by the marginal productivity of healthcare spending. In a hypothetical country 'UK' supply constraints are sufficiently stringent that their combined impact is greater than the optimal social cost q ; this country delivers less than the optimal amount x^* . The optimum is at X^* , while a country spending beyond the optimum is where λ , the combined set of quantity restrictions on utilization for the provider, is less than q . Note that λ is at least as large as p , the price facing the consumer; this ensures that the patient's benefits are at least as large as her out-of-pocket payments p for the procedure.

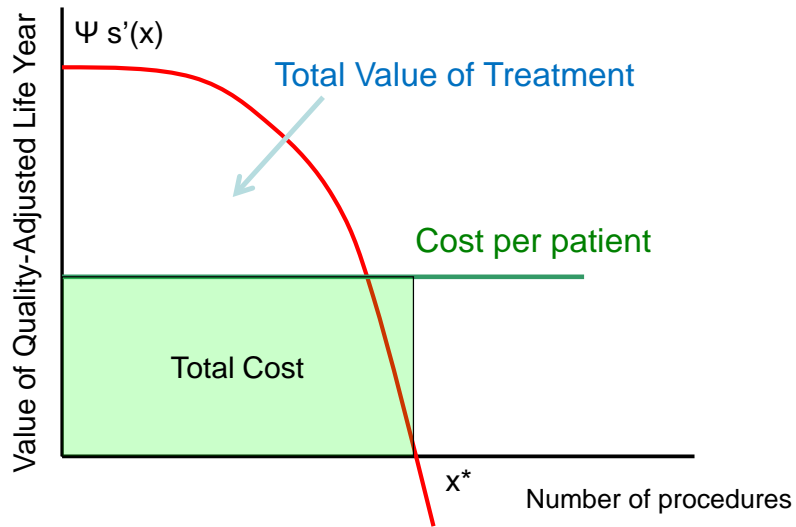


Figure 4: Benefits (area under the curve) and Costs of Category I Innovation Note: The vertical axis is scaled to reflect a constant value per quality-adjusted live year (e.g., \$100,000 per life year).

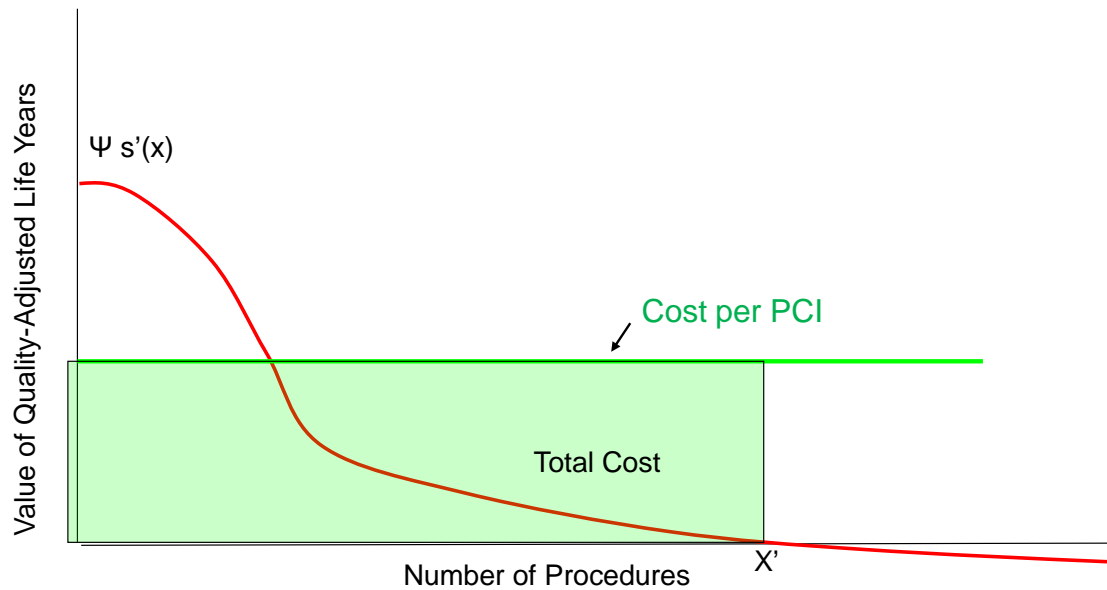


Figure 5: Benefits (area under the curve) and Costs of Category II Innovation Note: The vertical axis is scaled to reflect a constant value per quality-adjusted live year (e.g., \$100,000 per life year).

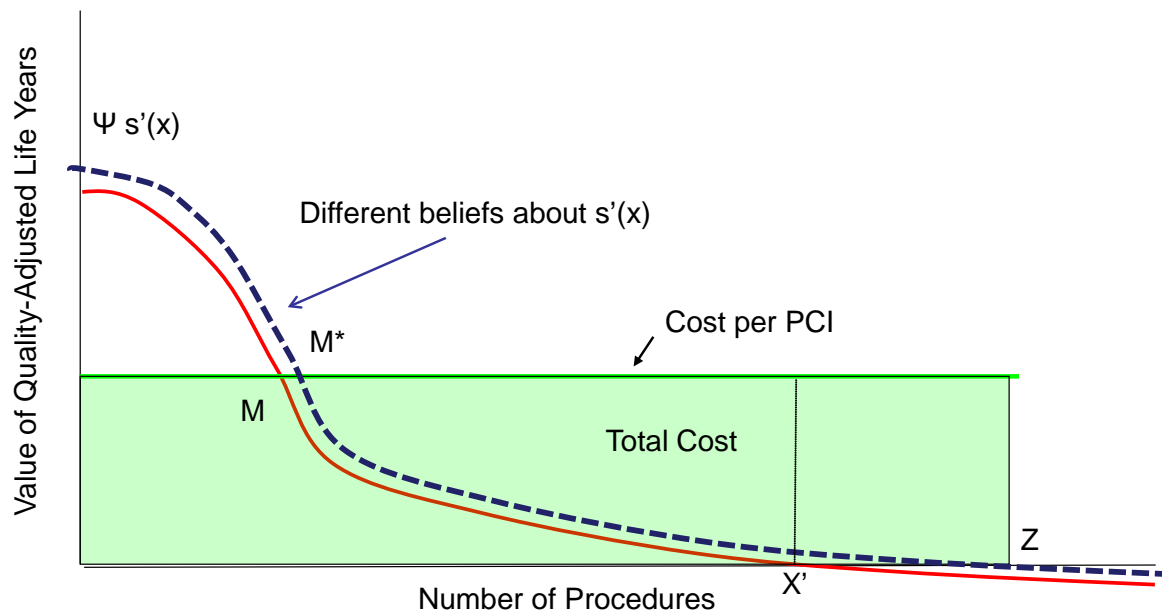


Figure 6: Differences in Utilization arising from Variation in Physician Beliefs or in Demand. The dotted line represents a higher perceived benefit schedule from the procedure, whether because of physician belief or patient demand. Differences in utilization widen where the $-s''$ is small (i.e., between X' and Z) compared to steeper sections of the marginal productivity curve (M versus M'). The vertical axis is scaled to reflect a constant value per quality-adjusted live year (e.g., \$100,000 per life year).

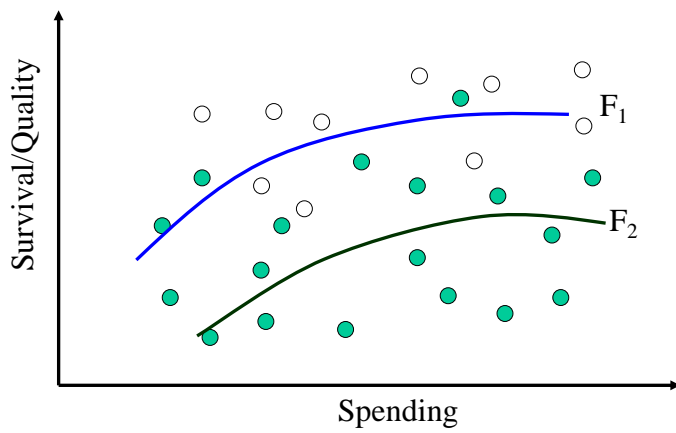


Figure 7: Hypothetical Spending and Outcomes for Hospitals with Different Production Functions Notes: Shaded dots cluster around production function F_2 , while open dots are drawn around production function F_1 .