TECHNOLOGY GROWTH AND EXPENDITURE GROWTH IN HEALTH CARE*

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Abstract

We examine the parallel trends in technology growth and cost growth in health care. A simple model of provider behavior shows that the productivity of treatments depend critically on the heterogeneity of these effects across patients, the precise shape of the health production function, and the cost structure of procedures such as MRIs with high fixed costs and low marginal costs. Using these insights it is informative to think about a (crude) typology of the productivity of medical technologies: highly cost-effective "home run" innovations (aspirin and beta blockers for cardiac care, and anti-retro viral therapy for HIV), treatments that are effective for appropriate patients (surgical interventions for heart attack patients) but offer scope for overuse in less appropriate patients, and "gray area" treatments with uncertain clinical value (ICU days among chronically ill patients). Future productivity growth of the current system will be limited by constraints on health care financing because of high tax burdens and the collapse of private health insurance markets. Nonetheless, there are tremendous potential productivity gains from better coordination of care and information technology.

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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. The business section, on the other hand, features double-digit growth in health care costs, declining health insurance coverage, and gloomy predictions of U.S. Treasury bonds being downgraded to junk-bond status as Medicare threatens implosion.[1] It is perhaps not surprising that there is some ambiguity as to whether these two trends taken together are a cause for celebration or concern.

Economists and other observers often label the source of both trends as technology growth. 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.[2] Unfortunately, simply attaching the label of "technological growth" as a cause of these 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. A better understanding of technological growth in healthcare, including whether it necessarily implies cost-growth and productivity improvements, is the principal goal of this paper.

To better understand the implications of technology growth and diffusion for improvements in health outcomes and increasing costs, we first show that rising income levels can in fact optimally generate rapid health care cost growth, as in Hall and Jones (2007). On the supply side, we then develop a parsimonious model anchored by a simple assumption – that physicians will do everything in their (perceived) power to cure their patient, given

[1] See Stein (2006). Currently, the Medicare Hospital Insurance Trust Fund, which pays for hospital benefits, is expected to be exhausted in 2020 (Centers for Medicare and Medicaid, 2005).

[2] 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."

financial, ethical, or resource constraints. The model can also be used to distinguish among general categories of innovations, ranked in order of their contribution to health care productivity (which is the improvement in outcomes for a dollar increase in costs).[3] Not surprisingly, we find that the greatest contribution occurs for low cost but highly effective treatments: antibiotics for bacterial infection, or aspirin and beta-blockers for heart attack patients. These highly productive innovations may cost money – for example, anti-retroviral drugs for the treatment of people with HIV/AIDS or rescue angioplasty for heart-attack patients. But the key to the high average productivity of such drugs is a strongly negative *second* derivative of the production function, in that benefits quickly turn negative for non-HIV-infected patients. We document the importance of this first category of treatments in the reduction in deaths owing to cardiac care, which in turn has accounted for the majority of survival gains during the past several decades (Cutler, et al., 2006).

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 production function is considerably smaller in magnitude. Angioplasties with stents are a particularly 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 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 where there is little or no benefit. Because there are more people in the latter category than in the former–the second derivative of the production function is small in magnitude – and the U.S. health care system compensates generously for these procedures, average productivity gains from this innovation are diminished substantially.

The third treatment category of technological innovations includes lower (or uncertain) marginal value, and is sometimes characterized as "care management." This relates to treatments for patients who have serious diseases such as pulmonary disorders, congestive heart failure, or diabetes, where the primary goal of the physician is not so much to cure the disease, but instead to keep the patient alive and to maintain quality of life for as long as possible. But how to manage disease is often uncharted territory; there are few or no

[3] See also Wennberg, Fisher, and Skinner (2002).

randomized trials for when pneumonia patients should be admitted to the hospital, or how many specialists should be treating a patient. On average, it appears that in the past decade, productivity in health care spending has been slowing down, even more than one would expect from optimizing models (e.g., Hall and Jones, 2007), with some suggestive evidence that a rise in the third unproductive category of health care costs, associated with fragmented coordination of care, has been a source of differences in growth across regions and over time.

What do these results imply for the future? We don't know whether new health care innovations in the future will deliver the promises of longer and disability-free lifespan, but they are unlikely to reduce costs. Paying for health care will become increasingly costly as private insurance markets require shoring up with government subsidies, or as the public sector accounts for an increasing fraction of health care costs. Baicker and Skinner (2009) suggest that the growing inefficiency from the higher taxes or insurance premiums necessary to pay for the health care will restrict the funding base for future health care cost growth.

On the other hand, there are tremendous potential productivity gains from the more efficient "care management" through the use of computerized information technologies and standards of care based on practice patterns at highly efficient clinics such as Mayo and Intermountain. Nor are these potential cost saving hypothetical; in theory, Medicare could be steered back into near-term solvency if the rest of the country could emulate the low-growth patterns of care in regions like San Francisco (Fisher, Bynum, and Skinner, 2009).

2. Empirical Patterns of Health Care Costs and Outcomes

To motivate our analysis, let us consider some facts that all models of technology and cost growth would have to reconcile: Figure 1 illustrates the striking increase in the share of GDP spent on healthcare, where we restrict our attention to six OECD countries. But there is also considerable variation in growth rates across countries. Using the entire sample of 20 OECD countries for which data exist on health expenditures between 1980 and 2006, the U.S. experienced the greatest growth, from 8.7 to 15.3 percent of GDP, or a change of 6.6 percentage points of GDP. In contrast to the US experience, the mean growth was 2.7 percentage points, but with a standard deviation of 1.6 percentage points. In other words, Denmark, Ireland, Finland, the Netherlands, Norway, and Sweden all grew by less than 2

percentage points of GDP.

It is useful to at least check that U.S. survival rates didn't grow faster than the countries with the more slow-growing health care sectors. Figure 2 shows survival gains in the U.S. relative to a sample of 5 benchmark European countries (Garber and Skinner, 2008). While all countries have experienced average life-expectancy gains, the U.S. has lagged behind, particularly in recent years. We don't place much store in these aggregate cost-effectiveness ratios, but they certainly do not provide much support for the view that the unique U.S. growth in healthcare spending has contributed greatly to survival.

The patterns in Figures 1 and 2 can also be seen within the United States. Figure 3 shows that during 1992-2006, inflation-adjusted per-capita Medicare spending rose at an annual rate of 3.5 percent. But this rapid growth still masked substantial variation in growth rates across regions; San Francisco grew at a rate of 2.4 percent, Salem, OR at 2.3 percent, while Miami grew at 5.0 percent annually. The other two regions we consider, Cleveland and the adjacent Elyria, Ohio, were closer to the mean, although Elyria still grew at a faster rate. Note that the dollar change in Miami between 1992 and 2006, roughly $8,000 (in 2006$), is roughly equal to *total* 2006 expenditures in San Francisco (Fisher, et al., 2009). Confronted with these trends, it is natural to ask whether there is a strong link between spending and health outcomes. Why do some regions or countries grow faster than others? [4] Our paper offers a framework to analyze both questions.

3. A Simple Model of Technology Growth

We start by developing a provider based model of technology growth that yields implications for cost growth and improvements in outcomes, and consequently, to productivity 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

[4] Newhouse (1993) reiterates the message in Schwartz (1987) that it is important to distinguish between factors that contribute to the level versus the growth of healthcare expenditures.

been reflected in a collectivist view of health care. As health care has become more expensive, insurance markets appeared, both to ensure that providers actually got paid (as in the original Blue Cross plans during the 1920s) and to provide health care to the widest range of citizens (as in Bismark's Germany).

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, patients and providers will end up consuming and providing "too much" health care (e.g., 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 sign up for long-term care insurance (e.g., Finkelstein and McGarry, 2005).

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 the concern that the decisions that do occur favor the interests of the physician. 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 (e.g., Fuchs, 1978).

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 and cost-growth nexus for the growth patterns we observe are true for the elderly Medicare population, and in other countries with national health insurance, where adverse selection issues are far less important. 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. The rising fraction of uninsured has not exerted a substantial moderating influence on health care costs, as one would expect if the loss in coverage would have had a large impact on utilization. Nor can typical estimates of price elasticity 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 rapid diffusion of technology (Finkelstein, 2007). This view has its antecedents in Weisbrod's (1991) classic article whose thesis was that the structure of insurance coverage was an integral part of this rapid cost growth. The intuition is straightforward: if you pay for it, they will build it. Our model retains the spirit of Weisbrod's insights and we will return to work later in our paper. Using the above insights as building blocks, we now develop a simple of consumer and provider decision-making whose goal is to characterize and explain the level and growth of technology use, in a way that is consistent with the empirical evidence.

3.1 The Demand for Health Care

We can first develop intuition from a basic 2-period model, where a consumer's utility is based on consumption in the first period, discounted consumption in the second period, and the probability of surviving to the second period – which in turn is influenced by medical spending:

$$V = U(C_1) + \frac{s(x)U(C_2)}{1+\delta} \tag{1}$$

where c is consumption, δ is the discount, $s(x)$ is the probability of surviving to the second period as a function of medical spending x, with $s'(x) \geq 0$ and $s'' < 0$. (More generally, s may be viewed as a "quality of life" indicator that reflects both survival and functioning.) This utility is maximized subject to the budget constraint: $Y = C_1 + px + C_2/(1+r)$ where Y is income, p the consumer price of health care, and r is the interest rate.[5] This maximization problem yields the optimality condition

[5] For more complex models involving investments in health capital, see also Grossman (1976).

(2) $$\frac{\partial U}{\partial C_1} = p\frac{\partial V}{\partial s}\frac{\partial s}{\partial x} = \frac{pU(C_2)}{1+\delta}s'(x)$$

Thus as in Murphy and Topel (2006), the demand for health care (given implicitly by *s'(x)*) depends on the *level* of remaining utility in period 2 divided by the *marginal* utility of consumption U'(C_1):

(2') $$s'(x) = \frac{(1+\delta)U'(C_1)}{pU(C_2)}$$

Equation (2') provides a straightforward answer to how much society should spend on health care. Assume that the price of health care p is equal to its social cost (q), and we can normalize measuring healthcare inputs x such that the social cost $q = 1$. Then the cost-effectiveness ratio – or how much to spend in dollars to gain one year of life – is given by the inverse of the RHS of 2'; that is, $s'(x)^{-1}$ is the (optimal) cost-effectiveness ratio, which in turn depends on both total and marginal utility. More generally when a disequilibrium may exist, we can write the optimal social cost-effectiveness rate as:

(3) $$\Psi = \frac{qU(C_2)}{(1+\delta)U'(C_1)}$$

A strong implication of this first-order condition is that health care expenditures *should* rise over time, and at a rate that may be more rapid than income growth. As income and consumption grows, there will be a more than disproportional decline in the marginal utility of non-medical consumption. For example, if we assume a constant relative risk aversion of 3 for utility, then doubling income would reduce the marginal utility of consumption to $2^{-3} = .16$ times its previous level, 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 z; (Hall and Jones, 2007). It is for this reason that Hall and Jones (2007) suggest that the U.S. could optimally devote as much as one-third of GDP to health care in the future.

A key limitation of this utility-based approach arises because we cannot measure directly

U(C) or year-specific utility. The typical approach to writing utility in these models is that $U(C) = b + C^{1-\gamma}/(1-\gamma)$ where γ is, as above, the Arrow-Pratt constant relative risk aversion. The reason why we need an intercept term *b* is because when $\gamma > 1$, $C^{1-\gamma}/(1-\gamma) < 0$, implying that extra years of life detract from lifetime utility – an embarrassing assumption. Thus b is a free variable, and in practice it is calibrated to match existing evidence on how much to value a human life. The most sophisticated approach developed by Murphy and Topel (2006), suggests that a life-year may be worth as much as $300,000 depending on age, this in turn is 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 estimates ranging from 1 million to 10 million dollars (Dockins, et al., 2004). One "rule of thumb" suggests that life-years should be valued at roughly two times average per capita income (Garber and Phelps, 1997), yielding something closer to $100,000 per life-year.[6] In sum, while the degree of uncertainty about the social value of an extra life-year is high, the implications for changes over time are much stronger. Thus the optimal rate of growth in health care costs reflect the tension between two trends: one is higher income which leads to a greater value of life, and the second is the potential for diminishing returns from spending more on health. A third factor, to which we return later, is the resource costs associated with raising revenue through taxes or other distortionary methods, and their implications for health care expenditures.

Note finally that the consumer is likely to face a price *p* that is well less than the resource cost *q*. Thus, as we develop in greater detail below, we find – not surprisingly -- that the demand for health care will generally exceed the socially optimal level of health care, except in the case of people with low income and without insurance who face the full resource cost *q*.[7]

3.2 A Static Model of Provider Behavior

We next develop a more complex model of physician and provider behavior, one which accords with what physicians say and how they behave in regards to the use of a medical

[6] Although their estimate is highly sensitive to assumed values of risk aversion.

[7] Or more than the resource cost, as sometimes occurs when hospitals charge patients above marginal cost when they are paying out-of-pocket.

technology. After developing this framework, we extend the model to move from technology growth to cost growth. The model arises from a single assumption about behavior:

> *Health care providers maximize the perceived health of their patients, but are sometimes constrained from doing all they want by capacity constraints, ethical judgments, or financial constraints.*

That is, every physician and health care provider wakes up in the morning to save as many lives as they can. There are always exceptions, rogue physicians who game the system at the expense of patients, but most physicians believe that what they are doing is best for their patient. We are therefore trying to avoid the standard models of "supplier-induced demand" in which physicians harm their patients if they are paid enough to do so. While there is remarkable heterogeneity in physician beliefs, as we document below, for the moment assume that there is a single known "production function" $s_t(x_t)$ at time t, and that physicians seek to improve the social value of health, $\Psi_t s_t(x_t)$ to the extent possible.

In practice, there are both explicit and implicit (or hidden) constraints on health care. In the U.S. explicit restrictions are rare, for example cost-effectiveness rules attempted in the Oregon Medicaid program, or in gatekeeper models of health maintenance organizations (HMOs) which required a second opinion or a sign-off for common medical procedures. Implicit restrictions are more common; the limitations of physicians who only have 24 hours in the day, a lack of diagnostic or surgical facilities (or catheterization labs not staffed at night), a fixed number of MRIs or intensive care unit (ICU) beds (at least in the short term). Physicians often do not chafe against these implicit restrictions, simply adjusting their "best practice" to the resources they are accustomed to using.[8]

Physicians also care about the income they make, and may in fact providers may act as if they desired a target income or faced a constraint that the hospital must not lose revenue (see Rizzo and Zeckhauser, 2003, 2007; Newhouse, 1970). We focus on the provider's incentive to make money, which depends on the marginal profitability of doing more, where profitability is extended to implicit costs associated with working very long hours. Assuming that inputs for physician j are subject to a revenue constraint R_j which may include fixed costs:

[8] For example, in the late 1980s New Haven had roughly half of the bed per capita ratio of Boston (Fisher et al, 1994) largely because the dominant hospitals in New Haven made a conscious effort to restrict expansion. Yet physicians in New Haven did not view their hospital capacity as being constrained.

(4) $$m_{jt} W_t + \pi_{jt} x_{jt} \geq R_{jt}$$

where W_{jt} is the average capitated payment per patient and m_{jt} the number of patients seen by the physician (as in the U.K.). Note that the price paid by the patient, p, will be quite different from the profitability of the procedure, π. 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.

Another distinction between social cost q and marginal profitability π arises in the case of procedures such as MRIs, CT-scans, proton-beam accelerators, and other capital goods with large fixed costs of acquiring and maintaining the machine, but low marginal costs of using the machine, at least up to its capacity limit. In theory, the physician or provider would use the machine up to or near the capacity limit, so the odds are that the profitability of incremental use of MRIs would be positive, but the fixed cost of maintaining the machine would be reflected in a reduction in R_{jt}, thus leading to both substitution and "income" effects encouraging its use. The social costs of expanding the use of MRIs would still reflect the amortized marginal cost – that is, the social costs should reflect the fixed costs of installation as well.[9]

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 which they use to provide inputs to individual hospitals and clinics, for example a certain number of artificial knee or hip joints devices (Aaron and Schwartz, 2005). Similarly, some regions may not be allocated as many magnetic resonance imaging (MRI) machines, or cardiac catheterization units. In many cases, physicians adjust implicitly to these constraints, although waiting lists for surgery are often the subject of public demonstrations and political controversy (Aaron and Schwartz, 2005). In other cases, physicians may express an ethical concern against spending too much of the nation's resources, and this consideration too can be modeled as a capacity constraint. Whether implicit or explicit, physicians and hospitals in these cases are operating under quantity constraints, which can be expressed as $x_{jt} \leq X_{jt}$.

[9] An obvious analogy would be airline seats – low marginal cost for empty seats on a flight, but the incremental costs of increasing the number of flights by (say) 4% would include the additional costs of new airplanes.

Finally, we introduce the demand side with the constraint that the individual patient must be better off than the utility level in the absence of the treatment, $\overline{V}_{jt}$. This is admittedly a simplistic way to consider the demand side, but is consistent with empirical evidence (Jacobson, Health Affairs). Thus, at a point in time, the Lagrangian for a given physician is written as:

$$\Im = \Psi_t s(x_{jt}) - \lambda_{jt}(m_{jt}W_t + \pi_{jt}x_{jt} - R_{jt}) - \mu_{jt}(x_{jt} - X_{jt}) + \Phi(V_{jt} - \overline{V}_{jt}) \quad (4)$$

In this formulation $s(x_{jt})$ represents the quantity of health produced by physician j in time t using a level of procedure use, x_{jt}. An alternative formulation is to consider income as a component in the objective function, with the interpretation of λ_{jt} as the marginal tradeoff between provider income and patient benefit. The first-order condition for (4) is written

$$\Psi_t s'(x_{jt}) = \lambda_{jt}\pi_{jt} - \mu_{jt} + \Phi\frac{dV_{jt}}{dx_{jt}} \quad (5)$$

That is, physicians spend up to the point where the social marginal value of health or functioning hits either zero (in an unconstrained world), or a financial constraint, a capacity constraint, a demand-side constraint, or some combination of these. Note that this model assumes that physicians allocate treatments to those who would benefit most.[10] This is illustrated in Figure 4 where the solid lines represent the marginal social value (in dollars) for two different medical technologies A and B when patients ranked in the order of decreasing social benefit. In the absent of constraints, providers will increase these use of both technologies to the point where the marginal social value is zero. The social resource cost is q, and X_A and X_B are the corresponding socially optimal allocations of A and B.

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'* may be negative. This occurs in isolated cases where ethical limits (μ) are nonexistent, for example the cardiac surgeons in Redding, CA who, because of very high reimbursement rates, pulled healthy patients off the golf course for emergency cardiac surgery (Enkoji,

[10] A Roy model of treatment allocation for heart-attacks is developed by Chandra and Staiger (2007), who find evidence that providers rank patients on the basis of diminishing therapeutic benefit and work down this distribution. Baicker, Buckles and Chandra (2007) find this is also true for cesarean section deliveries.

2002).

More generally, there is often considerable uncertainty about the specific 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* patient will benefit from a treatment. In the figure, this would be like a physician thinking that the production function for technology A, actually looks like the one which is labeled as technology B (or more generally, physicians believe it to look like B for a range of patients who're excluded from trials). We will revisit this point in Section 4.3.

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 both the dynamics of change. How does a static model translate to a dynamic framework for technology and expenditures? Our approach is to take the derivative of the first-order equation (5)[11], rearrange and (to simplify) assume that at least initially, patients are experiencing an improvement in utility resulting from their treatment, so the demand side is not binding. Letting $\Delta x_{jt} = x_{jt+1} - x_{jt}$, and equivalently for other variables in the model, we can write:

$$\Delta x_{jt} = \frac{\Delta\Psi_t s_t'(x_{jt}) + \Psi_t \Delta s_t'(x_{jt}) + \lambda_{jt}\Delta\pi_{jt} + \Delta\lambda_{jt}\pi_{jt} + \Delta\mu_{jt} - \Delta\Phi\dfrac{dV_{jt}}{dx_{jt}}}{-\Psi_t s''(x_{jt})} \tag{6}$$

Thus the growth in healthcare real inputs is expressed as the sum of several components. Looking first at the numerator of (6), as income trends upward, one might expect a 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. The second term on the RHS of (6) captures a shift in the survival curve – technological

[11] $\Delta\Psi_t s_t'(x_{jt}) + \Psi_t \Delta s_t'(x_{jt}) + \Psi_t s''(x_{jt})\Delta x_{jt} = \lambda_{jt}\Delta\pi_{jt} + \Delta\lambda_{jt}\pi_{jt} - \Delta\mu_{jt} + \Phi\dfrac{d^2 V_{jt}}{dx_{jt}^2} + \Delta\Phi\dfrac{dV_{jt}}{dx_{jt}}$.

innovations that increase survival holding constant inputs, these in turn imply a movement along the survival production function to reestablish equilibrium first-order conditions.

The primary control over U.S. health care expenditure growth is through the setting of prices, for example reimbursement rates for physician or inpatient services by Medicare and Medicaid (Newhouse, 2003), 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 healthcare 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 (whether the traditional income effect or because of being pushed closer to the target income constraint, as we've written it), leading to the fourth term reflecting offsetting effects, at least for procedures or services that continue to be profitable.

The fifth term reflects changes in capacity constraints. These 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 are present as well in the US; for example in the presence of shortages in quasi-fixed resources such as ICU hospital beds, physicians with specific training, or MRIs. Changes in these resources are of course subject to a whole host of incentives, for example that hospitals would be more likely to expand cardiac catheterization services given that cardiac procedures are compensated at such high rates. Nonetheless, these capacity constraints may also explain why in some cases rates of growth are gradual but persistent.

The final term in (6) reflects 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 or if the marginal benefits from the procedure are fading, but this also raises questions of how much patients really understand about the potential risks and benefits of procedures.

A critical parameter that affects the magnitude and speed of the growth in x is 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 changes over time in utilization.

We illustrate this phenomenon in Figure 5: the solid lines represent the marginal social value (in dollars) for two different medical technologies when patients ranked in the order of decreasing benefit. Technology A has a large value for s″, but B does not. With technology , the scope for 'overuse' is small, as it's easy to observe the falloff in outcomes as the use of this technology is expanded, but that is not the case for Technology B. There are two ways to interpret this figure: (a) as a given providers constraint is relaxed, (from $q_{t=0}$ to $q_{t=1}$), different technologies will contribute differently to cost growth; there is little increase in the use of procedure A, but there are large expansions in the use procedure B. (b) Alternatively, if $q_{t=0}$ and $q_{t=1}$ represent the constraints of different providers, the introduction of a new medical technology that can be used in many patients (technology B) will result in greater cost growth in the provider with the lower constraint (who was already doing more). Therefore, our simple model of technology growth can explain the lack of convergence across countries and providers.

The shape of the production function is likely to be different for different medical technologies, and this possibility motivates the next section.

3.4 From Technology Growth to Cost Growth to Productivity Growth

The above analysis describes the static and dynamic nature of technology use for a given physician. But increases in technology use affect costs and outcomes (and therefore productivity growth) differently. Suppose that we rank medical treatments by their cost-effectiveness, or the ratio of expenditures to the change in survival or quality-of-life, creating a continuum ranging from most cost-effective to least (or negative). To focus the discussion, and to reflect our inability to measure the exact cost-effectiveness measure, we consider three rough categories for discussion: (1) Highly effective care which includes "home run" treatments with cost effectiveness ratios of as little as $50 per life-year (e.g., Cutler, 2004). These are treatments where the incremental increase in costs is quite small relative to the large

improvement in outcomes, but they're not limited to 'low-cost' care. (2) Treatments where there are clear positive gains for a subset of people receiving treatment, but where there is a larger group of people with modest benefit, thus attenuating average productivity. (3) Technologies where the benefits are small, or where practice patterns arise from tradition or rules of thumb, implying that patients may not be correctly ranked on the basis on declining marginal benefit.

4. A Typology of the Productivity of Medical Technologies

4.1 "Home Run" Technologies

The first category of medical technologies includes those that are cost-effective and useful for nearly everyone in the relevant population as would be the case if $-s''$ is large in magnitude (which makes it difficult for overuse) relative to the costs of treatment. 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).[12] Here, the increase in costs for washing ones hands more frequently is low while the corresponding benefit is high. Improved health behaviors are another obvious candidate for this category of innovations, for if one is judging the cost-effectiveness of medical innovations, then perhaps the most cost-effective innovation was the Surgeon General's Report on the risks of smoking in 1964.

Similarly, 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 lead to the remarkable – and sudden -- improvements in outcomes following outbreaks of bacterial meningitis. After the 1950s, there were incremental gains in meningitis mortality, but a large

[12] 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.

portion of the new developments, such as the third-generation cephelosporins, were designed to treat infections that had developed resistance to the first- and second-generation antibiotics.

At the beginning of life, an example of highly cost-effective interventions comes from the introduction of surfactants to treat neonatal acute respiratory distress. 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 80 percent of mortality decline between 1989 and 1990 to this drug. In addition to being a miracle drug for thousands of low infant babies, surfactants also proved to be protective of costs—which declined by 10 percent for survivors, and 30 percent for decedents.

Another type of treatment that would be included in this category is high-cost care but which provides large benefits, so that the cost-effectiveness is large. One example of this type of treatment is Ceradase, a drug developed by Genzyme that provides a critical missing enzyme to patients with Gaucher's disease, a rare genetic disorder. While expensive (initially, it cost upwards of $60,000 per year) it offered a complete cessation of symptoms to children who begin treatment sufficiently early before damage to bones can occur. Because no individual without Gaucher's disease would be administered this drug, the average productivity is extremely high (–s″ is large).

More famously, is the development of anti-retroviral drugs for the treatment of HIV patients to prevent the development of full-blowns 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). Indeed, one study has found that the marginal dollar value to patients in terms of future life expectancy was roughly 20 times the costs of development (Philipson and Jena, 2006), but it is important to realize that these two "blockbuster" pharmaceutical advances are the exception rather than the norm in medical care.

4.2 Potentially Cost-Effective Technologies With Heterogeneity in 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). Such technologies have the largest implications for cost growth. A leading example is angioplasty,

an invasive procedure where 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. The costs depend on who pays for it, but it generally runs above $15,000. 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.[13] Angioplasty has been shown to dramatically improve survival following a heart attack if performed within the first 12 or 24 hours following its onset, and is highly cost-effective for this use (Hartwell, et. al, 2005).[14] But it has been shown to confer no medical benefit when done late. But because the marginal benefits from angioplasty do not decline the way they do for anti-retroviral therapy, there is great scope for 'overuse' at least in the sense of it's marginal benefits not exceeding marginal costs.

During the past several decades, the fraction of patients treated surgically, whether with angioplasty or conventional cardiac bypass surgery, has diffused to about 40 percent of the population of patients with heart attacks. Given relatively modest growth (or even a potential reduction) in the number of heart attacks every year, further growth in the use of survival-producing angioplasty for this well-defined group is likely to be modest. Most of the growth arises in the general population of people with cardiac conditions, and where substantial differences in opinion exist among cardiologists as to what constitutes blockages amenable to surgical intervention. For example, per capita angioplasty and stent rates in Elyria Ohio, were four *times* the U.S. average (New York Times, 2006), which is itself more than twice as large as the average rate in Canada (Lucas, et. al., 2006; Alter, et. al., 2006).

Figure 6 illustrates technology growth in the use of PCI and CABG in the two adjacent health care markets of Elyria and Cleveland. It is difficult to tell a simple story for why the two areas should differ on the basis of patient sickness (and why this would explain a higher level and growth in the use of PCI use in Elyria). But these patterns noted in this figure are

[13] 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).

[14] A review of over 23 trials by Keeley, Boura and Grines (2003) noted the superiority of the intensive intervention over fibrionic (medical) therapy in the hours immediately after a heart-attack. But this benefit is concentrated in primary angioplasty: a recent randomized clinical trial showed no better survival for angioplasty in order to open occluded arteries when performed more than a day or so after the heart attack (Hochman 2007).

consistent with the insights of Figure 5; the benefits from CABG drop rather more quickly than for PCI because of its invasive nature, and that restricts technology growth in bypass. But the marginal benefit curve for PCI is flatter and this offers great scope for overuse. Our model (and Figure 5) emphasizes the role of constraints in explaining technology growth: Elyria was doing more at the start of the period and this is exactly where we expect greater technology growth to occur. While some physicians may claim that the increased technology use in Elyria benefits their patients, recent clinical trials have found no benefit from angioplasty relative to optimal medical therapy for patients with stable coronary disease (Boden et.al., 2007; Weintraub et.al. 2008).[15]

Another category of treatment with very high incremental value for a subset of patients, but whose use is increasingly being driven by our primary assumption – that physicians will, if they can, utilize to the point where the marginal value of additional utilization is zero -- is the use of screening and imaging technologies.[16] 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. Figure 7 notes the growth of physician services per Medicare beneficiary between 1999-2004, by category of spending. Reimbursements for major and minor procedures are small relative to the growth in imaging services, which grew by 45 percent over this time-period. Yet at least one report to Congress suggests low marginal effectiveness of imaging services (MedPAC, 2003; Miller, 2005). The use of digital mammography provides a particularly good example of this combination of high average value for one group of patients – women under age 50, for whom the cost-effectiveness is a very favorable $26,500 per life-year – but quite poor average cost-effectiveness for all women, $331,000 per life-year (Tosteson, et. al., 2008).[17]

Aaron and Schwartz (1987) offer a related, but different, view of technological diffusion

[15] In these trials, "benefit" included survival, a heart-attack or other cardiovascular event, angina frequency and stability, treatment satisfaction, quality of life and physician limitations.

[16] It is tempting to attribute the growth of imaging services to malpractice fears. Baicker, Fisher and Chandra (2006) find support for this mechanism; a 10 percent increase in malpractice liability increases the use of these services by 2 percent. But variation in malpractice pressure only explains 10 percent of state-level variation in the growth of imaging services, suggesting that other factors are more important in explaining the diffusion of this service.

[17] This is because there is no incremental value of digital mammography over standard X-rays for women over age 50.

and cost growth. They note that new technologies involve fewer risks, for example the use of laporoscopy rather than an open surgery to remove inflamed gallbladders, and therefore 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.

4.3 Technologies with Uncertain Effectiveness

This final category attempts to capture the notion that for many treatments, there is remarkably little evidence on effectiveness for its typical use but that scope for harm is small. These treatments contribute to cost-growth because neither physicians nor the clinical literature knows about the shape of the survival function $s(x)$ and because the scope for harm is small. The classic example was a trial published in the *New England Journal of Medicine* on arthroscopic surgery for osteoarthritis of the knee, in which surgeons would 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. Those in the control group received "placebo surgery"— skin incisions and simulated surgery. The trial found no gain either from arthroscopic surgery relative to sham surgery.

For ethical and logistical considerations, it is extremely difficult to conduct trials of this type to establish the efficacy of every medical and surgical therapy. We include other services such as the frequency of office visits, ICU days in the end of life (Figure 8) and referrals to specialists along with imaging services in defining this category of care. For example, whether patient safety is compromised by 6-month revisit rates (for office visits) instead of 3-month revisit rates is not known. Yet there is enormous disagreement across physicians in the appropriate rates of office visits (Brenda Sirovich, et. al., 2006).

Nor does the Food and Drug Administration (FDA) in the U.S. require that specific surgical devices be more effective than some alternative, only that they cause no harm. Thus the requirements for new surgical devices are far less stringent than for drugs. These problems are exacerbated when the "treatment" does not have a well-defined end-point (such as death or hospitalization) associated with measuring the intervention's efficacy. For example, there are a variety of new (and more expensive) artificial hips, but their efficacy is not well understood since even the standard low-cost hips last for several decades, and we won't know

for many years whether these new hips are superior to the less expensive versions.

A final issue relates to differences in preferences across patients. This is most likely to occur where treatments entail both benefits and side-effects entailing loss of quality-of-life. In the context of our model, one might think of the true benefit from treatment k for patient i as being s_{ik} - e_{ik} where e_{ik} measures individual i's side-effects of treatment. In this case, only focusing on s_{ik} may provide the patient with a positive survival benefit (in average quality-adjusted life years) but reduce patient welfare. For example, there are two options for the treatment of early stage breast cancer: mastectomy (complete breast removal) versus lumpectomy (partial breast removal which involves less invasive surgery of the lymph nodes). Both options have been shown to provide similar survival outcomes, but with different complications and side-effects. In these cases, there is no "best" option for all patients; care should be tailored to patient preferences. Yet there is strong evidence that physicians develop rules of thumb for choosing one type of option over another. For example, 48 percent of women with breast cancer in Elyria; in Columbus, Ohio the corresponding rate was 12 percent. It is difficult to believe that patient preferences exhibit such pronounced discontinuities across adjacent geographic areas. Despite the similarity of the two options in terms of effectiveness, a Pareto improvement can occur when people who prefer one option over the other are able to choose their preferred option (e.g., Meltzer, et. al., 2007). We believe that the internet and commercial decision aids offer great promise in helping patients to become better informed about costs and benefits of "preference sensitive" medical options.[18]

5. Aggregate Productivity Improvements

Our discussion so far has focused on the productivity of individual medical treatments. But what can we say about aggregate productivity improvements in healthcare arising from the increased use of all medical technologies? Summing the change in utilization over all technologies yields $\Delta x_t = \sum \Delta x_{kt}$ with an accompanying change in health care expenditures of: $\Delta M_t = \Sigma_k \Delta M_{kt}$. The change in the economy-wide value of the quality-adjusted survival is

[18] Research has also noted that patient preferences for whether one wants to die at home or in the hospital – are uncorrelated with the actual health care intensity (Barnato et.al., 2007; Pritchard, et. al., 2001) suggesting large potential efficiency gains from a better understanding of patient preferences.

approximated by:

(7) $\varphi_t \Delta S_t = \varphi_t \sum_k s_k(x_{kt-1})\Delta x_{kt}$

and the aggregate improvement social value of quality-adjusted survival as:

(8) $\Delta(\varphi_t S_t) = \Delta\varphi_t S_t + \varphi_t \Delta S_t$

The aggregate improvement in survival as estimated in equation 8 is large: Nordhaus (2003) estimated that while market expenditures per capita have grown by 2 percent annually since 1900, the imputed value of health capital has grown at an even faster rate of 2.4 percent (for life expectancy has risen from 47.3 years at birth in 1900 to 77.8 in 2004). Thus the improvement in health, properly valued, has added as much to full "consumption" as traditionally measured consumption.

The key question for economists is to ask whether the increase in aggregate spending made this possible. Studies characterizing average benefits of health care spending, such as Murphy and Topel (2006) and Cutler, et. al. (2006) focus on the ratio of $\Delta M_t / \Delta(\varphi_t S_t)$. In contrast, our discussion has illuminated the sources of increased spending may be quite different from the sources of increased survival: aggregate productivity may have improved because of 'home run' technologies, while costs may have increased because of technologies with uncertain medical benefits. To resolve this issue we first describe the approach considered by Murphy and Topel (2006) and Cutler, Rosen, and Vijan (2006), and then refer to the empirical literature for guidance on which factors may have contributed most to increased healthcare costs and which to improvements in quality-adjusted life years.

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. However, they included as benefits of health care spending the behavioral changes, which cannot in our view, really be attributed to health care per se. The best estimates of the marginal productivity of health care spending is by Cutler, Rosen, and Vijan (2006), who distinguish between behavioral changes including smoking-related deaths and accidental deaths, and health care changes. Their published estimates suggest highly favorable average cost-effectiveness measures of $19,900 per life year from 1960 to 2000. But even these careful estimates are subject to methodological criticism, because the authors

discount future expenditures, they do not discount future life years. Using discounted life years as well as expenditures suggests a different pattern of trends in productivity over time, however (Garber and Skinner, 2008). As Alison Rosen has shown, average cost-effectiveness (in $2000 dollars) was most favorable in the decade of the 1970s ($64,000), but since that time, average cost-effectiveness has climbed steadily, to $159,000 in 1980-90, and $247,000 during 1990-2000.

So did increases in the use of medical technology "cause" these improvements in outcomes? Ford, et. al. (2007) help answer this question by examining the factors that explain the decline in cardiovascular mortality between 1980-2000, which accounted for the vast majority of overall mortality decline during this period. Their results are displayed in Table 1. They found that 56 percent of the reduction was the consequence of behavioral factors such as smoking, drinking, and lower cholesterol and hypertension prevalence without any medical intervention. Diabetes and obesity, on the other hand, were responsible for a 17% increase in mortality during the same period. Another 20 percent of the decline in mortality was the consequence of our first category of treatments, with remarkably low cost-effectiveness ratios: off-patent aspirin, beta blockers, and anti-hypertensives. Thirteen percent of the gains in survival occurred through effective but higher cost pharmaceuticals: ACE inhibitors, anti-cholesterol "statins" and thrombolytics, while just 7 percent derived from "high-tech" surgical interventions such as angioplasty, stents, and bypass surgery (Ford, et. al., 2007).[19] This suggests caution in interpreting ratios involving aggregate survival gains and aggregate health care expenditures (Weinstein, 2005).

While this study categorized sources of improved outcomes, it did not categorize sources of growth in expenditures. We consider this question in Figure 9, which provides a simple typology for *why* one-year inpatient health care costs rose for heart attack patients between 1989 ($14,300) to 2004 ($27,200), all in 2004$. Some of the increase occurred because of the dramatic changes in how heart attacks are treated in the index admission: more money for surgical interventions (PCI and CABG) and a corresponding decline in payments for treating the heart attack medically.[20] These changes over time accounted for about $3,000 of the

[19] These calculations are based on the extensive tables in Ford, et. al. (2007) and available upon request from the authors.

[20] A small fraction of the increase would also be explained by the 2004 heart attack patients surviving longer.

overall $12,900 change, of which at most half would be the consequence of primary reperfusion, our "category 1" innovation. If the remaining spending plus peripheral treatments for congestive heart failure and vascular procedures (related cardiovascular diseases) were category 2, our breakdown would be: $1500 for highly productive innovations (category 1), $3600 for category 2 procedures, and the remainder ($7800) for other procedures with uncertain benefits. Obviously, these are rough estimates and don't even include drug costs (although aspirin and beta blockers would be negligible components of cost growth). Nonetheless, these results are suggestive that the factors driving longevity improvements aren't necessarily those that contribute to cost growth.

One limitation of this discussion is that restricting attention to measuring longevity alone will tend to understate the benefits from medical technology. Hip replacements, knee replacements, and back surgery for disk herniation, are all procedures not expected to improve survival, but instead are designed to improve the quality of life.

6. Paying for Future Health Care

There is evidence that the gradual decline in private health insurance is fueled by growth in health care costs, particularly among workers with the lowest wage rates where health benefits comprise a large and rapidly growing fraction of wages, and for whom a wage offset is difficult (Baicker and Chandra, 2006). There is also evidence that recent increases in the price of employer provided health insurance are not valued by workers—and employers have responded by shifting workers from full-time jobs with health insurance to part time jobs without.[21] In the context of our model, the constraint in Equation (5) that increases in the intensity of care should provide at least a positive overall benefit to consumers (and not just improved survival gains) becomes binding.

If healthier workers, who value health insurance the least, are the first to refuse employer

[21] In Summers (1989), there are no employment effects if workers valued increases in the price of benefits. Baicker and Chandra (2006) examine the effect of rising health insurance premiums (on a margin that is not valued by employees) and find that a 10 percent increase in health insurance premiums reduces the aggregate probability of being employed by 1.6 percent, increases in prevalence of part-time employment by 1.9 percent, decreases wages for workers with employer health insurance by 2.2 percent, and results in reduced hours for workers moved from full time jobs with benefits to part time jobs without.

provided health insurance, the integrity of insurance markets to pool risks could is severely compromised. Similar trends affect the provision of supplemental retirement health insurance—by 2005, fewer than 15 percent of firms offered such insurance, with a strong and continued trend downward. One response to this trend is the imposition of government-financed mandated coverage, as in Massachusetts. While not explicitly a government-run program, it has similar effects in that coverage is guaranteed for everyone, thus making any premiums paid an implicit "tax" rather than a benefit (Summers, 1989).

Thus we expect that the fundamental tension in the future will be the economic (and philosophical) burdens of raising revenue through payroll or other taxes. Currently, the government pays for 60 percent of health care in the U.S., whether directly or indirectly by providing health insurance to its employees or through tax subsidies to insurance premiums (Woolhandler and Himmelstein, 2002). In the limit, a tax-financed universal insurance coverage voucher (such as the plan proposed in Emanuel and Fuchs, 2007) would require a considerably higher tax to finance a bare-bones coverage level. But how would the efficiency considerations of taxation affect the predictions of Hall and Jones (2007) that we should be spending as much as one-third of future GDP on health care?

Return for the moment to the demand side model in Section 3, and expand the utility function in (1) to include leisure ℓ_1 in the first (pre-retirement) period:

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

When a progressive payroll tax funds all health care expenditures, the new budget constraint becomes

(6) $$(1-\ell_1)w(1-\tau) = C_1 + \frac{C_2}{1+r}$$

where τ is the marginal tax rate and w the wage rate. Ignoring other government expenditures, the budget constraint for the government (in per capita terms) is qx = $(1-\ell_1)w\tau$.[22] The first-order condition in (2) is now somewhat different:

[22] In this very simple model, health care spending only occurs once at the end of period 1, to avoid dying and provide good functioning in retirement during period 2.

(2') $$s'(x) = \frac{(1+\delta)U'(C_1)}{pU(C_2)}\Omega$$

where $\Omega = [\tau w(1-\ell_1)]/[\tau w(1-\ell_1) - w\tau d\ell_1/d\tau]$, and which 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 (c.f. Equation 5). Baicker and Skinner (2009) have implemented a general equilibrium overlapping generation model calibrated to match reasonable empirical values to show that introducing financing constraints through the tax system results in slower growth than suggested in conventional representative agent models. These effects are likely to be even larger in the presence of heterogeneity across income groups. Indeed, Getzen (1992) has suggested that the key component explaining health care cost growth is not consumer demand, or even the extent of population aging, but the country's ability to finance health care services.

7. Discussion

There are no easy solutions to the problem of rising costs in health care. 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 probably too simplistic and tells us little about whether such cost 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 the Medicare and Medicaid systems. The key point is that extraordinary growth in health care costs are neither inevitable nor necessarily beneficial for overall productivity gains. Instead, they are the aggregated outcome of a large number of interrelated decisions regarding the adoption of new technology, and perhaps more importantly, the diffusion of existing technology across a wide group of potential patients. It is this process of diffusion to the point where the majority of patients receiving treatments are those with low marginal value that leads to stagnating productivity gains.

Second, there is wide heterogeneity in the productivity of medical treatments, ranging from aspirin for heart attacks and surfactants for premature births, to stents for stable angina, or feeding tubes for patients with dementia. This underlies our distinguishing among three different types of treatments, arrayed by their contributions to productivity gains. Perhaps not surprisingly, the first high-productivity group appears to be the largest contributor to survival and functioning gains, while the third low-productivity group or with uncertain benefits, is the primary contributor to health care cost growth. It is admittedly tautological to observe that countries or systems of care that speed the diffusion of the first group of innovations, and discourage the growth of the third group, are most likely to exhibit high aggregate productivity growth.

Third, continued pressure on private US insurance markets will make it increasingly likely that the government will occupy a central role in the future health care system, whether through mandates, subsidies, or by direct financing (Leonhardt, 2009). Such a model would have several advantages over the present system (not least by undoing large inefficiencies in the labor market by untying health insurance from employment, the promise of reduced administrative costs, and providing, in principle, the opportunity to only reimburse productive therapies). But there are also fundamental concerns about whether centralization would dramatically improve the productivity of healthcare. Other countries are straining to balance budgets in the face of increasing health care costs, but in nearly every other country, expenditures are 11 percent of GDP or less, as compared to 16 percent for the U.S.

One important limitation of this paper is that we have not addressed the question of induced innovation – how does the structure of payments affect the willingness of pharmaceutical and device firms to develop new treatments? Weisbrod (1991) argued that the willingness of the U.S. insurance programs to reimburse for these new innovations had led to dramatic growths in expensive technological innovations. Amy Finkelstein (2007) made a different point – that the introduction of Medicare in 1966 lead to a far more rapid *diffusion* of existing technologies, such as cardiac laboratories, to a wider group of hospitals, particularly those in the South. While the evidence is less clear on whether innovation occurs differentially because of specific incentives from insurance markets (see Acemoglu and Linn, 2004; Acemoglu, Cutler, Finkelstein and Linn, 2006)), we would still expect a far more rapid rate of innovation when there is an implicit promise that large insurance companies will pay

for those innovations.

On the other hand, we would also expect that those marginal innovations would provide less value per dollar. Even in the absence of widespread insurance coverage, low-cost effective innovations such as beta blockers, or even high-cost but highly effective treatments such as anti-retroviral pharmaceutical treatments, could still be worth developing given the exceedingly high value per dollar paid for the treatment.

We return to the earlier essay by Weisbrod (1991), where he painted an optimistic view of 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 text.)

Weisbrod was perhaps too optimistic about PPS; in retrospect it had not fundamentally changed the incentives to innovate, as it created new DRGs for new technologies (McClellan, 2006), exempted certain capital costs from the expenditure cap (Newhouse, 2002), which thereby failed to discourage capital spending (Acemoglu and Finkelstein, 2006). Much of the growth in the health care sector has occurred through the diffusion of procedures to the larger population (i.e., the rapid growth in stents), outpatient ambulatory surgical centers, physician-based imaging centers, and home health care. Indeed, the PPS system as it exists discourages cost-saving quality improvements. In one case, a back pain clinic began to steer patients low-cost to rehabilitation, rather than sending them to the hospital immediately for diagnostic tests and potential back surgery (Fuhrmans, 2007). 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.

But the fundamental message in Weisbrod is still correct – only when health care is reimbursed on the basis of fundamental value will innovations be directed at highly cost effective treatments, whether they improve health outcomes substantially at reasonable cost, or (as Weisbrod notes above) by reducing costs without affecting quality adversely.

Information technology has been one widely touted approach to effecting these efficiency gains (Walker, et. al., 2005). But information technology is more likely a necessary and not sufficient condition to improving health care productivity (CBO, 2008).

The greatest potential for this type of productivity improvements comes from the management of chronically ill patients. The nearly two-fold differences in longitudinal costs observed across academic medical centers in the care for patients with heart attacks are largely due to discretionary decision-making about how frequently patients should be seen, how often similar patients are referred to subspecialists, whether patients are cared for in the hospital, and the intensity of diagnostic testing and imaging procedures (Fisher, et. al., 2004). Differences in spending aren't due to "what" is provided, since nearly all academic medical centers have access to the latest technology, but in how it is provided.

Measurement of outcomes and costs requires identifying both the responsible provider or providers and the patients (or population) whose care is to be measured. While current efforts in the U.S. marketplace tend to focus on individual physicians and institutional providers (e.g. hospitals, nursing homes), such an approach has serious limitations when trying to examine outcomes: sample sizes for individual physician practices are small, while any serious illness, whether acute or chronic requires the care of multiple physicians and often multiple institutional settings. Indeed, the most serious gaps in quality are a consequence of flawed transitions and poor coordination for such patients and differences in costs across hospitals and regions largely reflect how many institutional and professional resources are brought to bear on the care of similar patients (Fisher, 2004; Cebul et al., 2008). Reducing the size of our third (low-productivity) category of health care expenditures, and ensuring high-productivity measures are used, will require identifying entities with adequate sample sizes that can take responsibility for integrating care over time and across different providers. Some work has been done with the creation of explicit "accountable care organizations" (ACOs) such as the Mayo Clinic or Kaiser, as well as implicit physician/hospital ACOs based on the observed stability with which even solo practice physicians are loyal to a hospital/physician network. Thus such an ACO could come much closer to the ideal expressed by Weisbrod: a single entity which could potentially gain (or reward patients) by keeping cost growth low while providing high quality care (see Fisher et al., 2009).

Ensuring this standard for efficiency also would make it that much easier to justify and allow for growth in health care expenditures – when most of health care growth derives from the first and even the second group, health care cost growth is not a cause for concern, but instead for celebration. The primary concern is that the inability to both identify and discourage the unrestricted growth of this third category of low-value health care expenditures will imperil future productivity growth in the non-health, as well as the health sector of the U.S. economy.

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Cost	*Intervention*	*Number of Deaths Avoided/ Postponed*
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 dollars)	Angioplasty / stents / bypass	25,630 (7%)

Table 1: Factors Causing the Decline in Cardiovascular Mortality, 1980-2000

Source: Ford, et al., 2007.

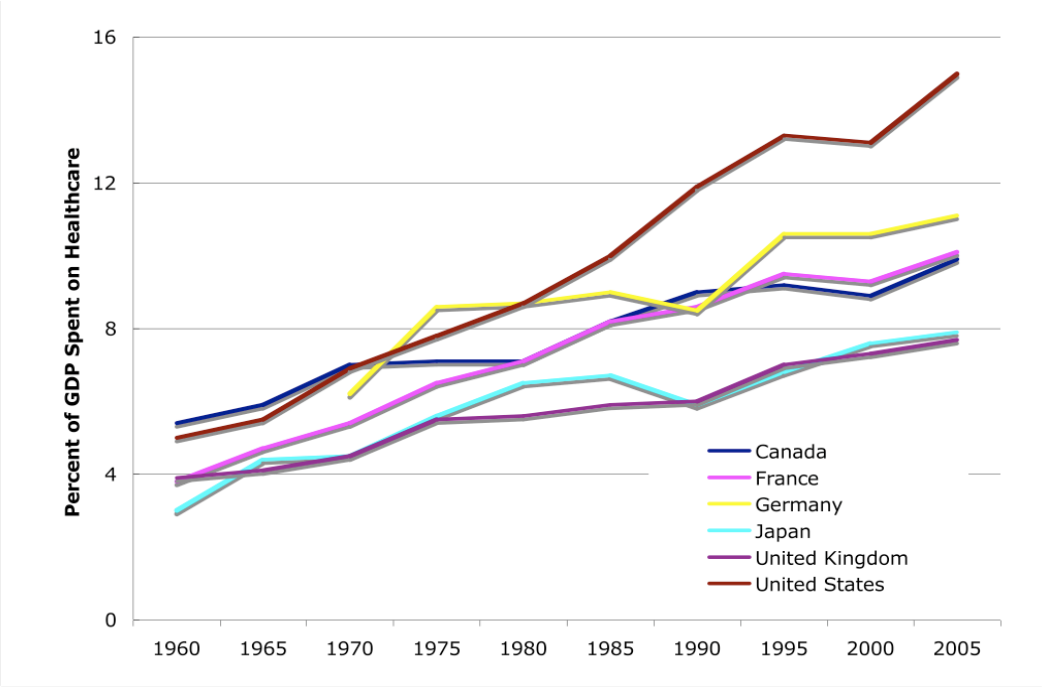
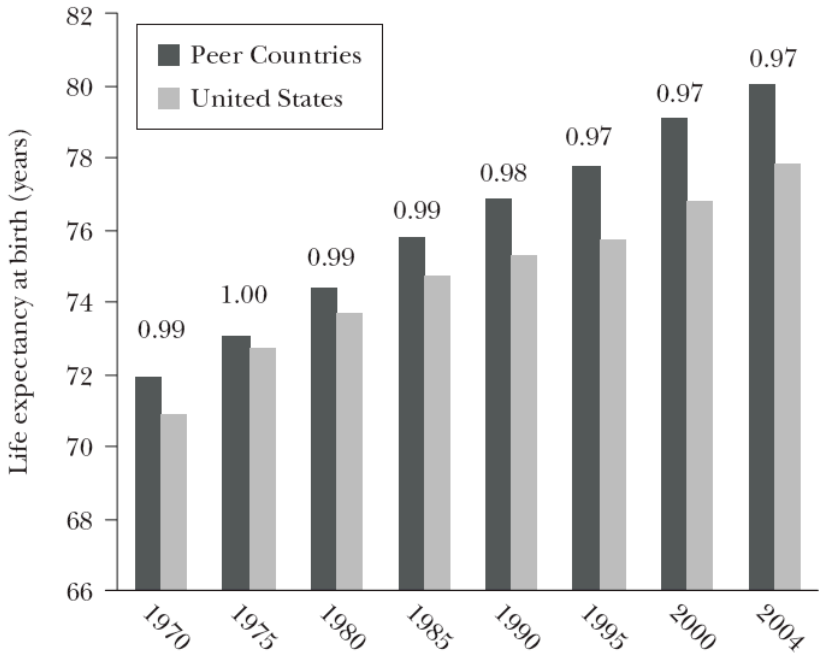


Figure 1. Percent of GDP spent on healthcare.

Data for Germany refer to West Germany. Data for 2005 are estimates based on actual expenditures through 2004. See OECD (2005) for other countries.

Relative Life Expectancy at Birth in the U.S. and Peer Countries: 1970–2004



Source: OECD (2008).
Note: "Peer countries" include Canada, France, Germany, Japan, Switzerland, and the United Kingdom. Ratio of U.S. to Peer Country life expectancy written above bars.

Figure 2. Relative Life Expectancy at Birth in the US and Peer Counties: 1970-2004

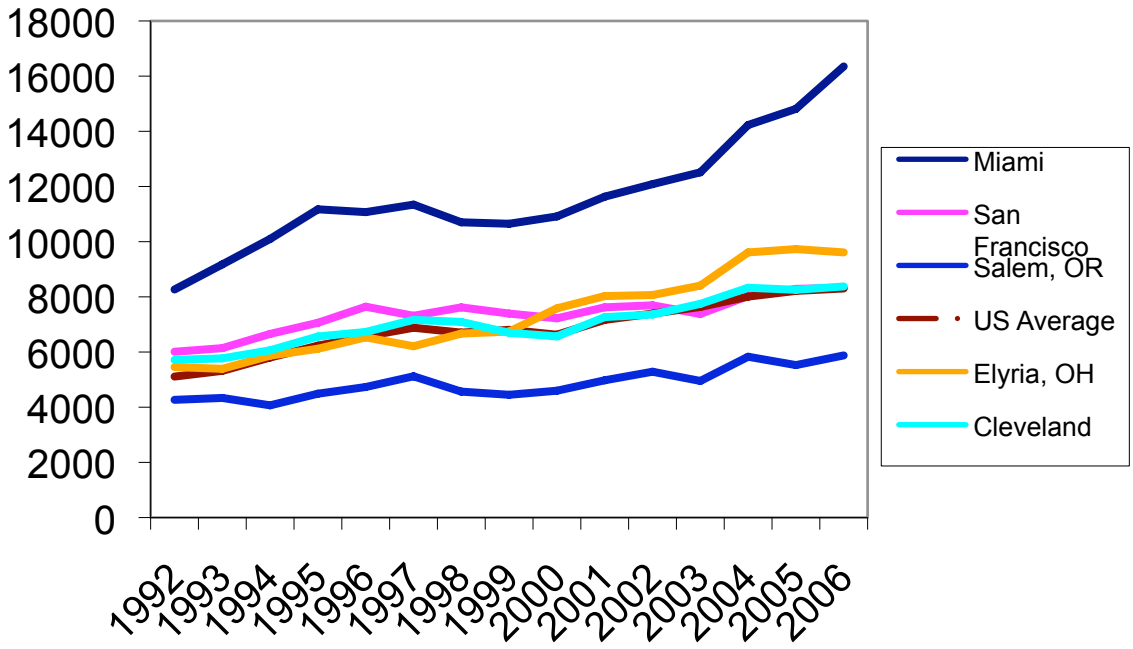


Figure 3: Per Capita Age-Sex-Race Adjusted Medicare Expenditures, 1992-2006.

Note: Adjusted for inflation using the GDP Implicit Price Deflator, expressed in 2006 dollars.

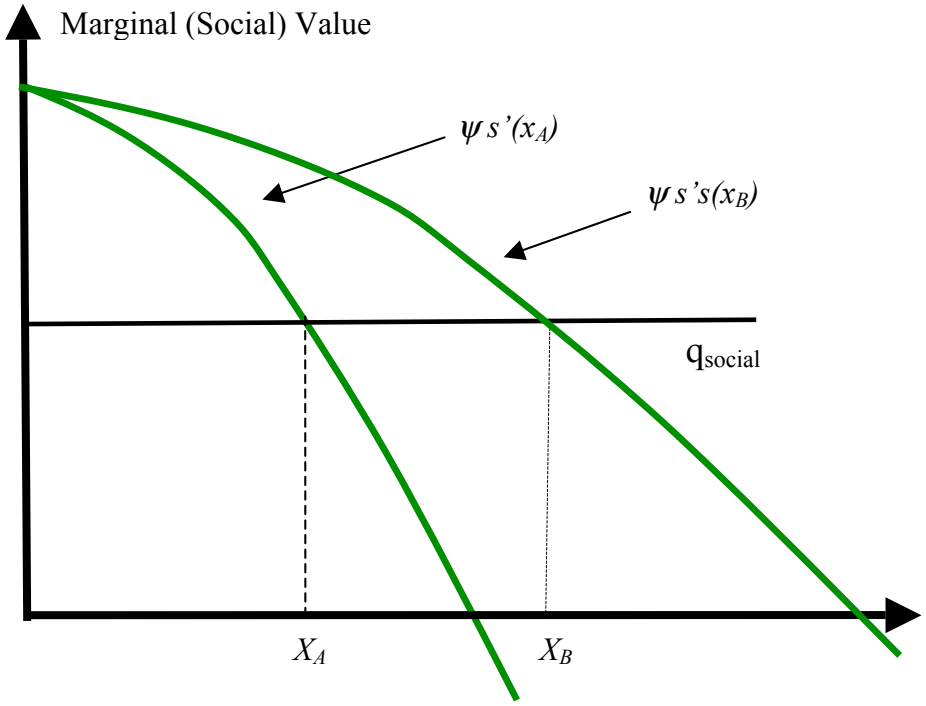


Figure 4. Technology Growth from different medical technologies.

Note: The solid lines represent the marginal social value (in dollars) for two different medical technologies A and B when patients ranked in the order of decreasing benefit. In the absent of constraints, providers will increase these use of both technologies to the point where the marginal social value is zero. The social resource cost is q, and X_A and X_B are the corresponding socially optimal allocations of A and B.

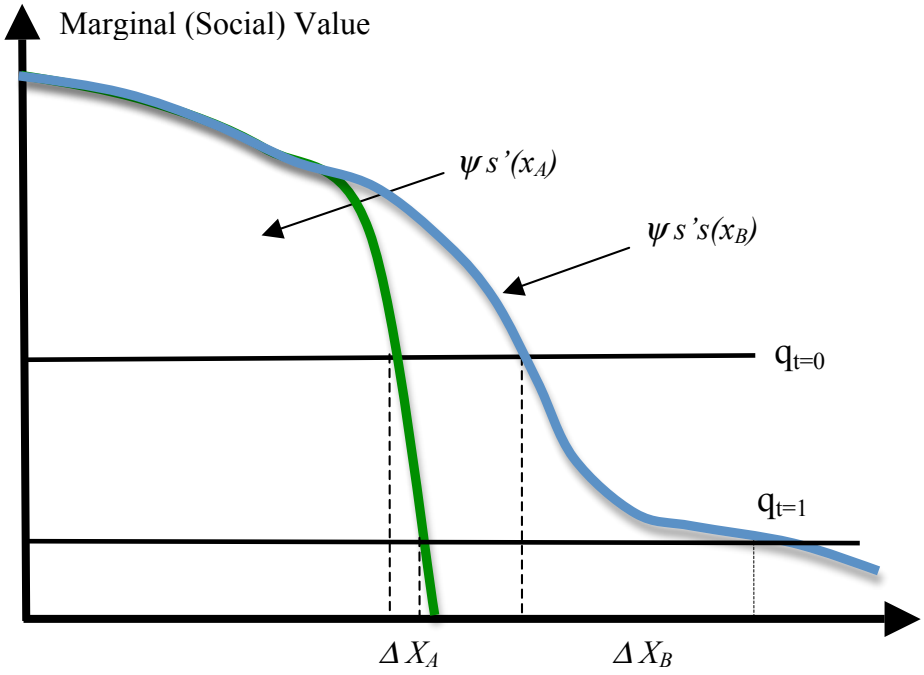


Figure 5. Technology Growth over Time

Note: The solid lines represent the marginal social value (in dollars) for two different medical technologies A and B when patients ranked in the order of decreasing benefit. There are two ways to interpret this figure: (a) as a given providers constraint is relaxed, (from $q_{t=0}$ to $q_{t=1}$), different technologies will contribute differently to cost growth; there is little increase in the use of procedure A, but there are large expansions in the use procedure B. (b) if $q_{t=0}$ and $q_{t=1}$ represent the constraints of different providers, the introduction of a new medical technology that can be used in many patients (technology B) will result in greater cost growth in the provider with the lower constraint.

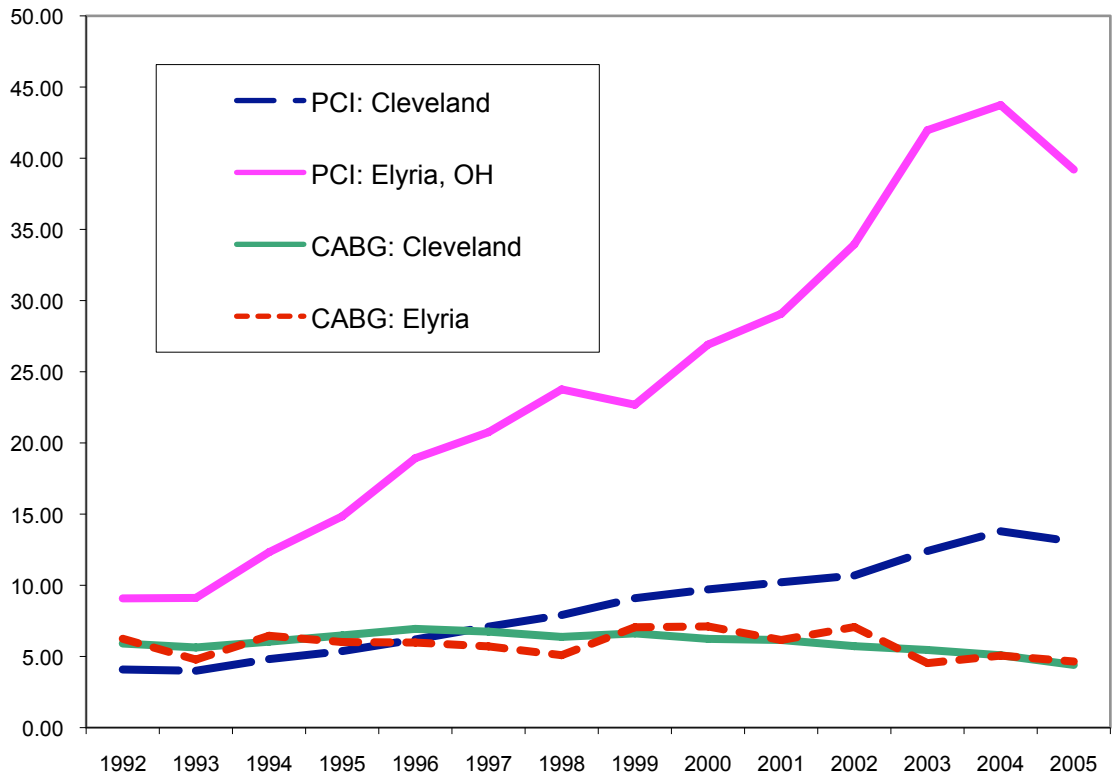


Figure 6: Technology Growth in PCI (Angioplasty, including with stenting) and CABG (Bypass) in Cleveland and Elyria, OH.

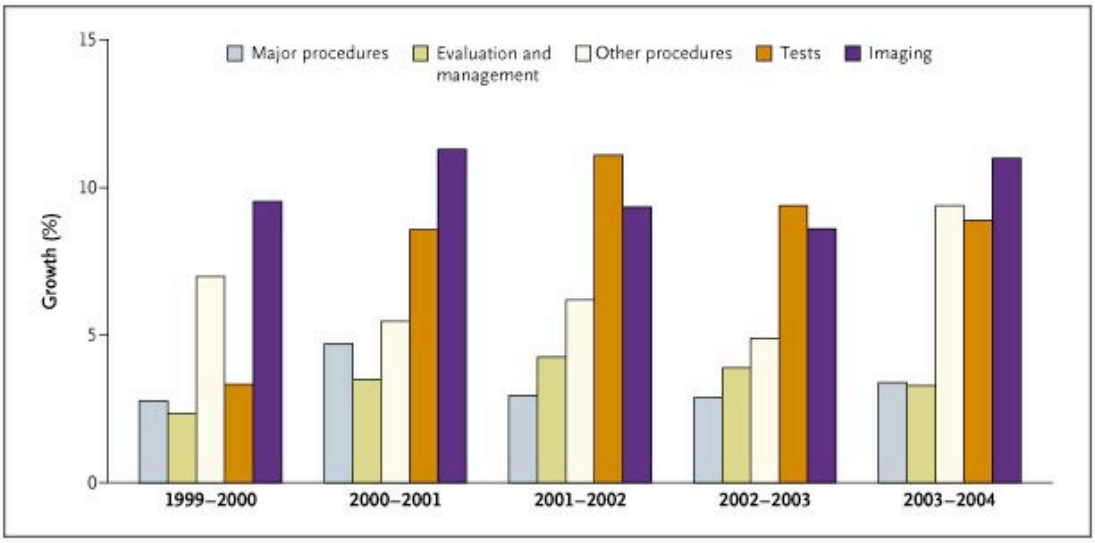


Figure 7. Growth in the Expenditures on Physician Services per Beneficiary, 1999–2004.

Note: Evaluation and management service includes office visits and hospital visits. The category "Tests" excludes imaging. Source: Iglehart (NEJM 2006)

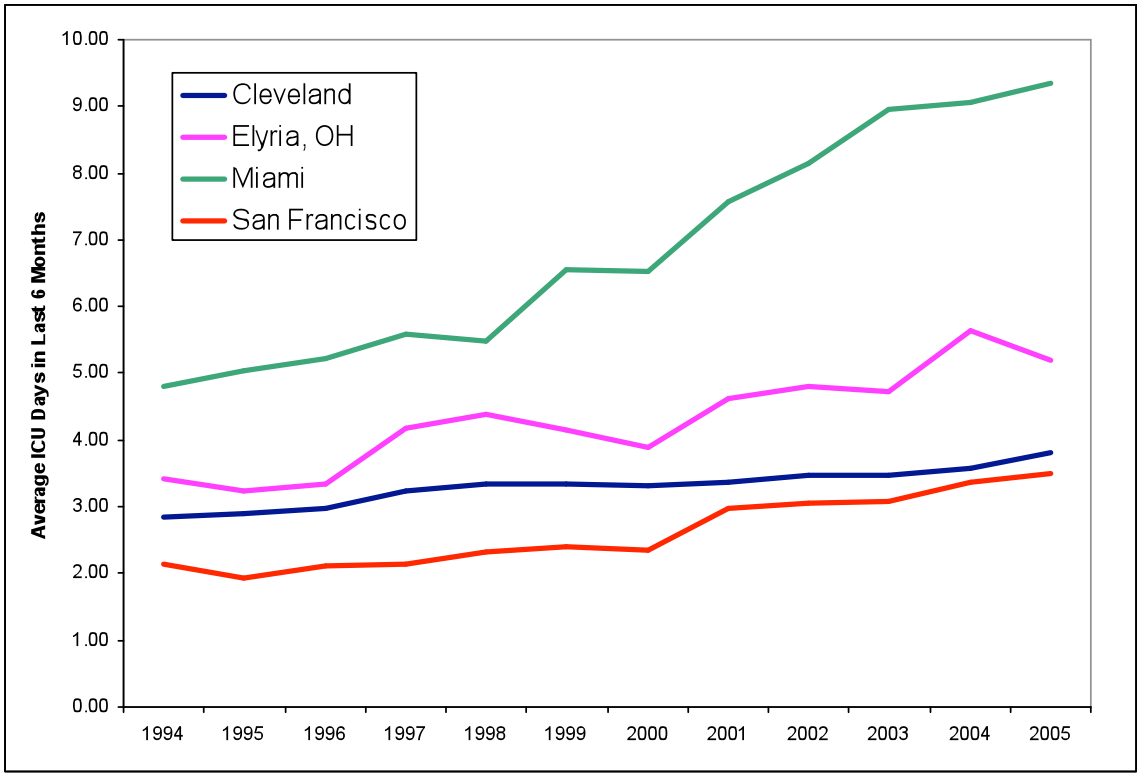


Figure 8. Technology Growth in the use of Days spent in an Intensive Care Unit in the Last Six Months of Life.

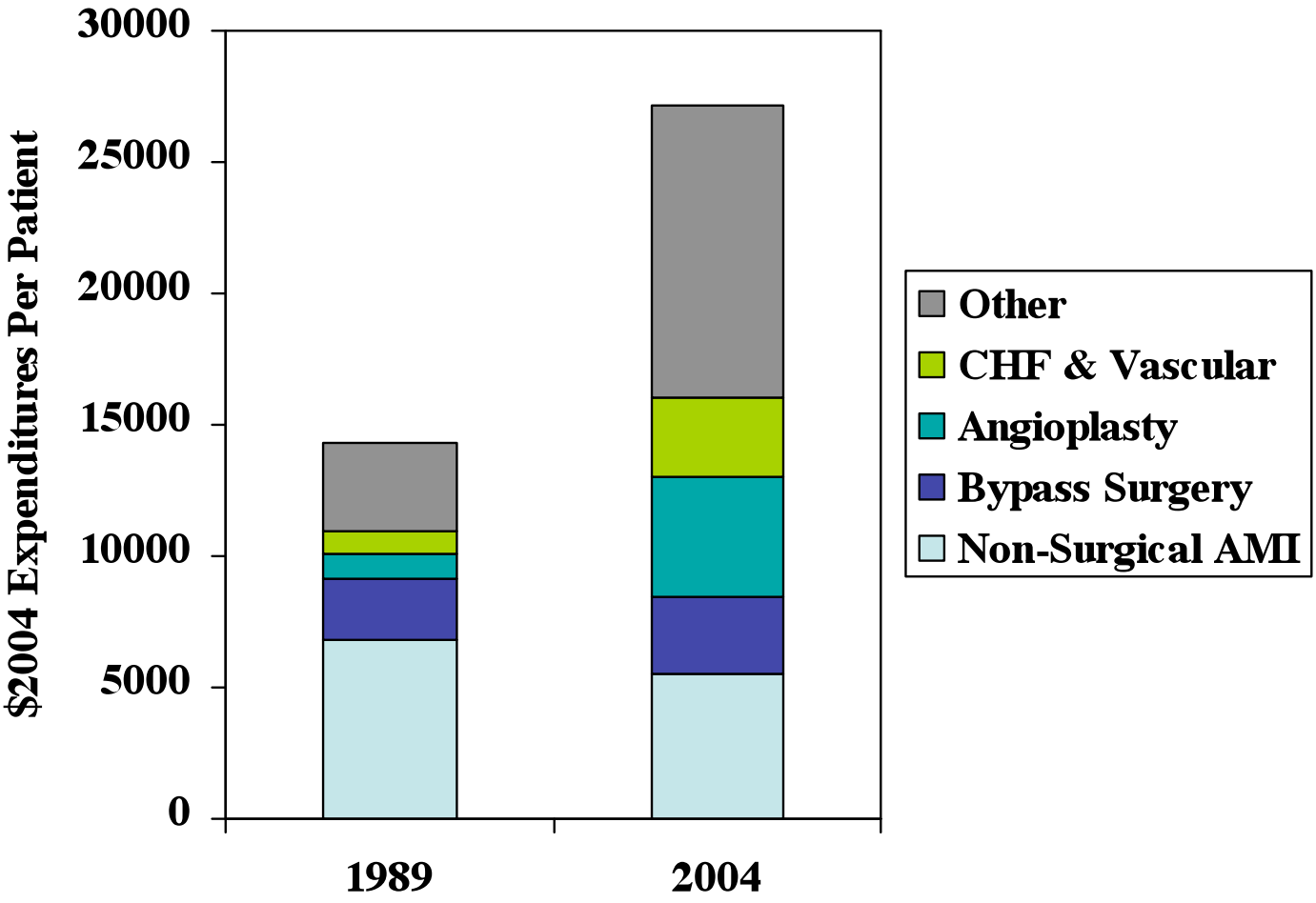


Figure 9: 1 year spending on Medicare heart-attack patients by type of service provided.