

Is Technological Change In Medicine Always Worth It? The Case Of Acute Myocardial Infarction

Waste and inefficiency are not inevitable by-products of technological growth.

by **Jonathan S. Skinner, Douglas O. Staiger, and Elliott S. Fisher**

ABSTRACT: We examine Medicare costs and survival gains for acute myocardial infarction (AMI) during 1986–2002. As David Cutler and Mark McClellan did in earlier work, we find that overall gains in post-AMI survival more than justified the increases in costs during this period. Since 1996, however, survival gains have stagnated, while spending has continued to increase. We also consider changes in spending and outcomes at the regional level. Regions experiencing the largest spending gains were not those realizing the greatest improvements in survival. Factors yielding the greatest benefits to health were not the factors that drove up costs, and vice versa. [*Health Affairs* 25 (2006): w34–w47 (published online 7 February 2006; 10.1377/hlthaff.25.w34)]

IN A SERIES OF IMPORTANT PAPERS, David Cutler, Mark McClellan, and their colleagues argue persuasively that the benefits from many technological innovations more than justify the rising costs of health care.¹ Although they recognize the presence of waste in the U.S. health care system, the policy message is clear: Don't kill the golden goose of future medical advances in pursuit of short-sighted cost savings.

Cutler and McClellan summarized research for five diseases, but the most striking evidence came from the rapid decline in mortality following heart attacks or acute myocardial infarction (AMI). Briefly, they found that between 1984 and 1998, the costs of treating heart attacks rose by \$10,000 in real terms, but life ex-

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pectancy increased by about one year. In short, technological innovations in the treatment of cardiac disease provided terrific value for the dollar; in this case, the rising costs were “worth it.”²

In contrast to the studies by these authors and others studying the benefits of technological advances in health care, another set of studies calls into question the assumption that spending more on medical care leads inexorably to improved outcomes.³ These have focused on differences in costs and outcomes across regions.⁴ Elliott Fisher and his colleagues, for example, found that Medicare patients in regions with higher health care spending levels do not experience better health outcomes, nor do they gain better access to care or report greater satisfaction. More recently, a study using state-level data demonstrated a negative association between quality of care and health care spending.⁵

This paper strives to reconcile these two seemingly contradictory sets of findings by returning to the original analysis on AMI mortality and spending by Cutler, McClellan, and their coauthors, but with an expanded data set that stretches from 1986 to 2003. We first ask whether the survival gains observed in the earlier data have continued into the current century: Have recent increases in health care costs still been worth it? We then ask whether regions experiencing the most rapid improvements in health outcomes were also those experiencing the most rapid increases in costs. Were there specific regional characteristics, such as early adoption of low-cost, highly effective treatments such as beta-blockers, aspirin, and reperfusion, or a reliance on care by multiple medical specialists, that might have been associated with unusually rapid survival gains or with unusually low spending increases? In the final section we suggest a simple framework that reconciles the two prevailing views of health care technology.

Study Data And Methods

■ **Data.** Medicare Part A hospital claims data from 1986–2003 were merged with the Medicare Denominator File through 2003 to create a longitudinal cohort of fee-for-service (FFS) enrollees age sixty-five and older coded with having a new AMI.⁶ During 1986–1991 the sample of Part A data was 20 percent of the FFS Medicare population, rising to 100 percent since 1992. Patients with a code of “old MI,” or those identified from the panel data as having had an AMI previously, were excluded from the sample.⁷ Overall, there were 2,872,050 valid AMI events. For pedagogical reasons, we find it helpful to present our results in terms of survival, or the percentage of AMI patients surviving to one year following their AMI. Spending data are available only through the end of 2003, so one-year survival and spending data are analyzed from 1986 to 2002.

■ **Methods.** The primary analysis followed that of Cutler and McClellan by using just the Medicare Part A hospital expenditures, correcting for inflation using the U.S. implicit price deflator and expressing all results in 2003 dollars.⁸ Both spending and survival rates were determined for the same one-year horizon. We also per-

formed secondary analysis using a smaller sample of Part B spending data: a 5 percent sample for 1993–1997 and a 20 percent sample for 1998–2002.

To adjust for both secular and cross-sectional differences in health status, we adjusted survival rates and spending for a variety of comorbidities (diabetes, diabetes with complications, pulmonary disease, liver disease, liver disease with complications, dementia, nonmetastatic cancer, metastatic cancer). Also included were age-sex-race effects consisting of five age categories (65–69, 70–74, 75–79, 80–84, and 85+) interacted with sex and with two race variables (black and nonblack), and the type of MI (inferior, anterior, subendocardial, and other).

The regression analysis explains survival and spending as a linear function of demographic variables, comorbidities, type of AMI, and year categorical variables.⁹ All estimated survival and spending measures are expressed in terms of the representative patient with average characteristics during the entire period of analysis using the ADJUST command in STATA version 9. Thus, the regression adjusts for changes over time in the severity of the disease, demographic changes in the Medicare population, and general increases in price levels.

The regional unit of analysis is the Hospital Referral Region (HRR), which was constructed for the *Dartmouth Atlas of Health Care* to reflect Medicare patients' actual hospital migration patterns for tertiary care.¹⁰ There are 306 HRRs in the United States, and each must include at least one hospital that performs cardiac surgery and neurosurgery. Each U.S. ZIP code is assigned to an HRR depending on the hospital at which the majority (or in some cases, the plurality) of Medicare enrollees seek their hospital care, so the HRR may cross county or state boundaries. Individuals were assigned to HRRs depending on their ZIP code of residence, not whether they were actually admitted to hospitals in those HRRs.

Region-specific measures of annual survival rates and cost measures were constructed from the estimated linear regressions mentioned previously that control for comorbidities and demographics. We interpreted these region-year-specific measures as the risk-adjusted survival rate and spending for the representative Medicare AMI patient in that region and year. Regions will differ both with regard to their initial adjusted survival and spending and with respect to changes over time in these variables, but our approach will, as far as possible, ensure that the results reflect regional practice patterns rather than regional differences in patient characteristics. We used these adjusted measures in both the cross-sectional analysis (using just 2002 data) and the longitudinal analysis that examines changes over time (1986–2002).

There are a variety of approaches to treating patients with AMI, and as we show below, regions differed dramatically in their adoption of treatment strategies as well as their reliance upon multiple physicians per patient. We hypothesized that regional differences in the diffusion of new treatment strategies will be associated with survival gains and spending increases during 1986–2002. Note that we conducted our hypothesis tests at the regional level rather than at the in-

dividual patient level. Unobservable aspects of specific patients will lead to unmeasured confounding factors and resulting biases. Differences across regions, on the other hand, are small with regard to the average severity of heart attacks, but large with regard to treatment strategy.

In the regression analysis, we focused on two region-level dimensions of care. The first was an index of low-cost, highly effective treatments for AMI: aspirin at discharge, beta-blockers at discharge, and reperfusion within twelve hours of admission (whether surgical reperfusion or thrombolysis). Aspirin reduces platelet aggregation and is known to reduce the risk of mortality following AMI.¹¹ Beta-blockers are an inexpensive drug that by blocking the beta-adrenergic receptors reduces the demands upon the heart; they have been known since the mid-1980s to be effective in reducing post-AMI mortality by 25 percent or more.¹² Compliance in the use of beta-blockers has lagged among many regions, even as late as 2000–01.¹³ Reperfusion encompasses either thrombolytics—“clot-busting” drugs designed to improve blood flow in the blocked arteries—or percutaneous transluminal coronary angioplasty (PTCA) within twelve hours of the AMI, again with well-established reductions in the risk of death.¹⁴

Measures were the percentage of patients in each region deemed ideal for treatment who actually did receive treatment, and were based on chart reviews from the Cooperative Cardiovascular Project (CCP) survey and reported in the *Dartmouth Atlas of Cardiovascular Health Care*.¹⁵ These data were available only for 1994–95, but these were years marked by a remarkable divergence in the adoption of these treatments. For example, beta-blocker prescription at discharge among ideal heart attack patients was 20 percent in San Antonio, Texas; 42 percent in Orange County, California; and 82 percent in Rochester, New York. Thus, 1994–95 data allowed us to identify early and laggard adopters.¹⁶ Regional quality was determined by the number of quality measures for which that region was above the national median. The quality measures range from 1 (below median for all three measures) to 4 (above median for all three measures).

Our second dimension of care was the average number of different physicians treating the patient within one year following the AMI, averaged across all patients in the HRR in 1994–95. This both measured the degree of reliance on specialists and provided a marker for continuity of care. There are potential gains from the specialization of medical knowledge, but there are also “network” costs associated with the larger number of interactions necessary among physicians who are coordinating a patient’s care.¹⁷ For example, when four physicians are treating a given patient, there are $[4 \times 3] / 2 = 6$ possible interactions (whether communication among physicians or potential for drug-regimen interactions). With eight physicians, the number of potential interactions rises to twenty-eight—a 367 percent increase. The potential adverse effects are illustrated in a recent *Newsweek* column written by the wife of a severely ill man:

The cardiologist told me that Doug was doing reasonably well, and I naively took solace in this mild pronouncement. That is, until a lung specialist zipped into the room, put his stethoscope to Doug's chest and said, "He's not getting any better. He's worse. He may die. Any questions?" I was too stunned to be coherent.

Later a nephrologist informed me that Doug's kidneys were failing and he needed dialysis. I told this doctor what the prior two specialists had said, hoping he could reconcile their conflicting reports. Instead, he plied me with questions about their findings that I could not answer.¹⁸

In other words, the apparent lack of communication among the specialists could attenuate (or even offset) the advantages of specialization.¹⁹

We hypothesized that regions where quality measures were adopted early would experience the greatest improvement in survival with small influences on Medicare spending. By contrast, we hypothesized that a larger number of separate physicians should have uncertain effects on survival (depending on whether the network effects overwhelm the gains from specialization) but were likely to be associated with more rapid spending increases during the period. We did not estimate a traditional economic "production function," in part because we did not have sufficient data on inputs in each year during 1986–2002. Instead, we tested whether characteristics of regions in 1994–95 were predictive of productivity growth; that is, whether survival gains were high relative to spending growth during the period 1986–2002.

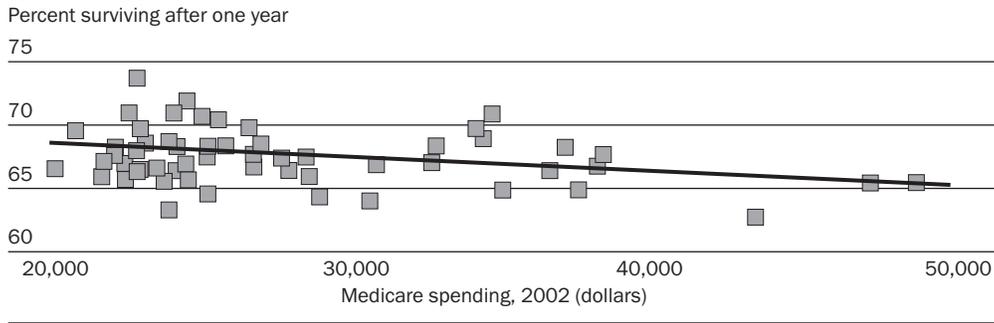
To quantify the importance of these two region-level measures (quality of treatment and number of different physicians), we estimated a least-squares regression at the HRR level. The dependent variable was the risk-adjusted change, 1986–2002, in one-year survival, one-year spending, or one-year log (or proportional) spending. The index of quality was entered flexibly with separate categorical variables for the quality index from 1 to 4, and for quartiles (or twenty-fifth-percentile groupings) of the average number of different physicians per patient, with all estimates reported using the ADJUST command in STATA 9.

The Cross-Sectional Evidence

Exhibit 1 displays the association between 2002 Medicare spending and adjusted 2002 one-year survival for the fifty-six larger HRRs with at least 250 cases of AMI in the base year of 1986, along with the predicted regression line. There were very wide differences across regions: In Knoxville, Tennessee, adjusted one-year survival was 69.7 per 100 AMI patients, with adjusted one-year spending of \$20,720. By contrast, in New York City, risk-adjusted survival was 65.6 per 100 AMI patients, with spending of \$47,133. In the entire sample of 306 HRRs, the (weighted) correlation coefficient between survival and expenditures was $-.33$ ($p < .001$).²⁰ As in previous studies, there is no evidence that higher spending levels are associated with better outcomes.

Focusing on just Part A (inpatient) spending could be misleading, because some regions could provide a greater fraction of care through Part B (physician).

EXHIBIT 1
Association Between Adjusted One-Year Survival After Acute Myocardial Infarction (AMI) And One-Year Spending, By Hospital Referral Region (HRR), 2002



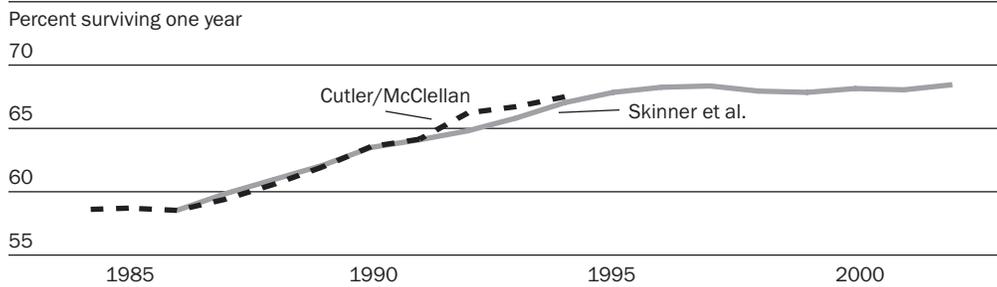
SOURCE: Authors' calculations using Medicare claims data.
NOTES: Each square represents an HRR with at least 250 people experiencing a heart attack in 1986 (n = 56). The sample is the elderly fee-for-service Medicare population (age sixty-five and older), and both survival rates and spending are adjusted for age, sex, race, comorbidities, and the severity of the heart attack.

However, the correlation between total (Parts A and B) spending and survival is similar (correlation coefficient = $-.36, p < .001$), largely because Part A and Part B spending are themselves so highly correlated (correlation coefficient = $.77, p < .001$). In sum, these results are at least consistent with the interpretation that U.S. health care is on the “flat of the curve,” where spending more does not yield additional health benefits; indeed, it seems to imply (from the least-squares regression line) that more spending yields worse health outcomes.

The Time-Series Evidence On Survival

Exhibit 2 displays two measures of year-specific survival rates. The first is for the period 1984–1994 from the original Cutler and McClellan study, converted to

EXHIBIT 2
Adjusted One-Year Survival For Elderly Medicare Beneficiaries With An Acute Myocardial Infarction (AMI), 1984–2002



SOURCES: Data generating the dashed line (1984–1994) are from D.M. Cutler and M. McClellan, “Is Technological Change in Medicine Worth It?” *Health Affairs* 21, no. 5 (2001): 11–29. Data generating the solid line (1985–2002) are from the authors' calculations using Medicare claims data.

NOTE: The vertical axis measures the percentage of elderly Medicare beneficiaries who survive the index AMI; this is equal to 100 minus the percentage one-year mortality.

survival rates.²¹ The second is based on our own data analysis for the period 1986–2002, using data on survival through the end of 2003. There is a close correspondence between the two series during the overlapping years. What is perhaps most surprising is the flattening of mortality following 1996, a result also found in Medicare claims data during 1996–1999 by Arlene Ash and colleagues.²² This might appear puzzling, given both continued diffusion of treatments such as beta-blockers and continued technological developments such as stents—cylindrical wire mesh inserted in the arteries to maintain blood flow following angioplasty. However, by the mid-1990s the diffusion of aspirin—perhaps the largest contributor to improvements in survival during this period—had begun to slow, while a meta-analysis of stents during this period did not show significant mortality effects.²³

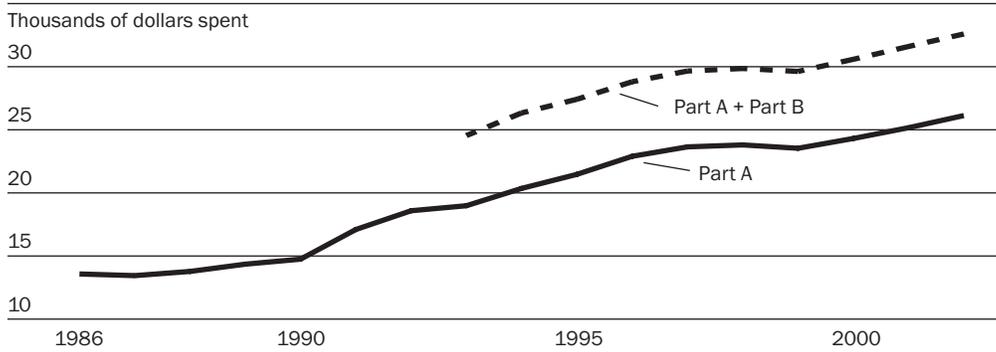
The Time-Series Evidence On Spending

Exhibit 3 displays the corresponding trend in average Part A Medicare annual spending during 1986–2002, and the corresponding combined Part A and Part B spending during 1993–2002. Although the rise in Medicare spending slowed during the late 1990s, largely because of the Balanced Budget Act (BBA) of 1997, it has since resumed an upward trend.

As a simple benchmark, we note that Part A spending increased by \$12,399 during 1986–2002 (in 2003 dollars). At the same time, expected one-year survival has risen by 9.8 per 100 AMI patients. Using the adjustment in the 1998 study by Cutler and colleagues to transform one-year mortality to expected life years, the average cost-effectiveness ratio is \$20,806 per life year, which in 2003 dollars means that the health care costs over the entire period were “worth it” in the sense

EXHIBIT 3

Adjusted One-Year Medicare Spending For Elderly Medicare Beneficiaries With An Acute Myocardial Infarction (AMI), 1986–2002



SOURCE: Authors’ calculations using Medicare claims data.

NOTES: The vertical axis measures risk-adjusted real Medicare spending following the index AMI for each year, 1986–2002. All expenditures are adjusted for inflation using the gross domestic product (GDP) deflator. The line labeled “Part A + Part B” includes Part B (physician) spending from 1993 to 2002. Part A covers hospital spending.

of meeting standard cost-effectiveness criteria. Since 1996, however, the cost-effectiveness ratio for Part A spending was just under \$300,000, a number well above the traditional cost-effectiveness hurdle and thus no longer “worth it.”

Still, we are left with a puzzle: Why do the cross-sectional data tell such a different story from the time-series patterns from 1986 to 2002? A better understanding of this puzzle can be gained by considering region-specific changes over time in survival and spending, to which we turn next.

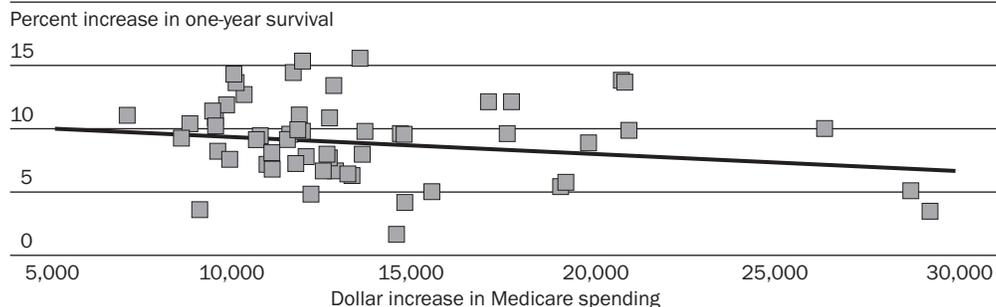
Regional Changes In Survival And Spending

One simple hypothesis is to ask whether regions that experienced the greatest cost increases during 1986–2002 also experienced the greatest gain in survival during the same period. We consider this question using both graphical and statistical approaches. As before, in the graph we include only regions with at least 250 AMI patients in 1986, while the statistical analysis uses all data at the HRR level, weighted by the number of AMI patients in 1986.

Exhibit 4 shows the average real dollar increase in one-year spending per patient between 1986 and 2002 on the horizontal axis and the average increase in survival (per 100 patients) on the vertical axis. Every region benefited from the technological revolution in heart attack treatment. But some regions experienced much greater benefits than others did. Also, every region experienced an inflation-adjusted spending increase, again more in some regions than in others.

If simply spending more on health care improved survival, we would expect a positive association between survival and spending, with regions lining up from the southwest to the northeast of the graph. However, if anything, the association is reversed: Regions experiencing the greatest spending increase during 1986–2002 tended to lag behind in survival gains.

EXHIBIT 4
Change In Survival And Change In Medicare Spending, By Hospital Referral Region (HRR), 1986–2002



SOURCE: Authors’ calculations using Medicare claims data.

NOTES: Each square represents an HRR with at least 250 people experiencing a heart attack in 1986 (n = 56). The sample is the elderly fee-for-service Medicare population (age sixty-five and older), and both survival rates and spending are adjusted for age, sex, race, comorbidities, and the severity of the heart attack.

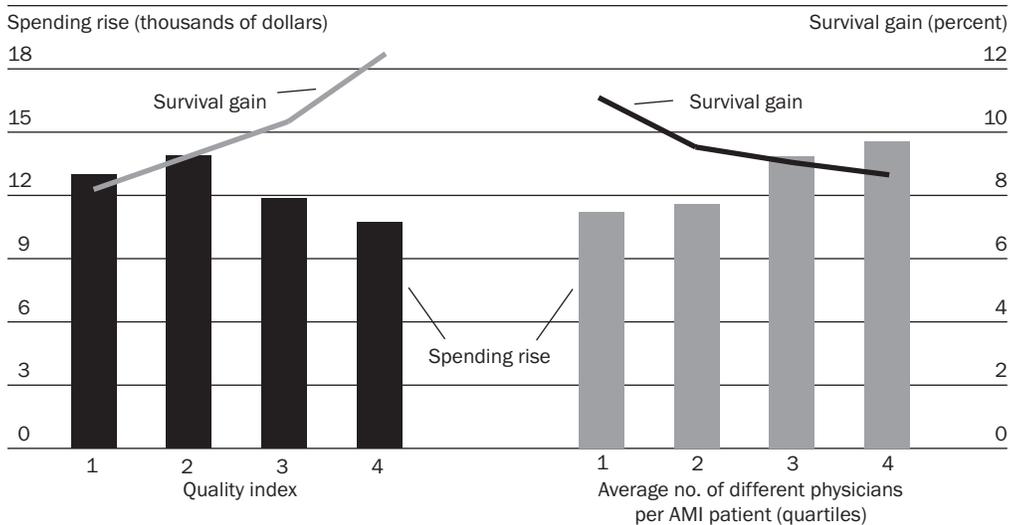
The graphical result is borne out in statistical correlations using the entire data set. The correlation coefficient between growth in survival and in expenditures is $-.21$ ($p < .001$). These dollar increases reflect changes both in reimbursement rates across regions and in the quantity of care provided. Focusing just on quantity, we created an index of the billing weights from the inpatient diagnosis-related groups (DRGs). This index is not affected by either regional differences in reimbursement rates or changes in reimbursement rates. Again, the correlation coefficient is $-.14$ ($p = .02$). Finally, the correlation between the proportional growth rate in spending and in survival is $-.04$ ($p = .49$). At best, there is no association between spending growth and survival gains.

Factors Associated With Changes In Regional Mortality And Spending

Exhibit 4 suggests that large differences exist in regional productivity. Highly productive regions in its upper left quadrant are those that experienced rapid growth in survival but below-average spending growth. Low-productivity regions in the lower right quadrant experienced above-average spending increases with below-average survival gains. Can our two variables from 1994–95—the quality index and the average number of different physicians—predict which regions ended up in the high- or low-productivity quadrants of Exhibit 4?

Regression results are shown in Exhibit 5. Recall that regional quality was de-

EXHIBIT 5
Association Of Regional Quality Of Care For Acute Myocardial Infarction (AMI) And Average Number Of Physicians Per AMI Patient (Quartiles) With Changes In Survival And Spending, 1986–2002



SOURCE: Authors' calculations using Medicare claims data.

NOTE: Bars denote spending rise (in thousands of dollars), and lines show percentage increase in number of AMI patients surviving to one year.

terminated by the number of quality measures for which that region was above the national median. The left-hand section demonstrates a significantly greater improvement in survival among regions that had by 1994–95 adopted high-quality treatment strategies for heart attacks, from 8.1 per 100 patients in the lowest-quality regions to 12.5 per 100 patients in the highest quality regions ($p = .01$). Spending grew more slowly (by \$2,262) in the highest-quality regions than in the lowest-quality regions, although the result was marginally significant ($p = .06$).

The right-hand section of Exhibit 5 shows the equivalent associations according to quartiles of the average numbers of different physicians visiting each patient. There are wide differences in these numbers, ranging from 4.8 different physicians per patient in Portland, Oregon, to 9.2 different physicians in Philadelphia, Pennsylvania. Here, though, the pattern is different: The improvement in survival was lower in regions with the highest number of different physicians (a survival gain of 8.7 per 100 AMI patients, versus 11.2 in the lowest areas, $p = .06$), while spending increases were \$3,331 higher ($p = .001$).

The left-hand section of Exhibit 5 controls for the average number of different physicians, while the right-hand section holds the quality index constant. The cumulative effect of varying both quality and the average number of physicians is large in magnitude and highly significant. The “highest-productivity” regions (those with the best quality and lowest average number of physicians) are predicted to experience better survival growth (7.0 per 100 AMI patients) and lower cost increases (\$5,593) than the “lowest-productivity” regions.

Discussion

Dramatic progress has been made in the treatment of heart attacks among the elderly during the past two decades. Between 1986 and 2002 the average one-year survival rate following AMI increased by nearly 10 per 100 elderly AMI patients at an estimated cost of less than \$25,000 per life year saved. But underlying these numbers is tremendous heterogeneity across time and space: There was little improvement in survival after 1996, despite continued growth in costs, and there was much variation in survival gains across regions and over time, with regional gains that were (if anything) negatively related to costs. These facts and others like them have generated a debate over the value of additional medical care spending. On the one hand, aggregate trends in patient outcomes suggest that the technological innovations were “worth it.” In contrast, the apparent lack of any strong association between costs and patient outcomes or quality of care across regions suggests that aggressive cost-control policies might benefit society by eliminating unnecessary medical care for patients in high-cost regions.²⁴

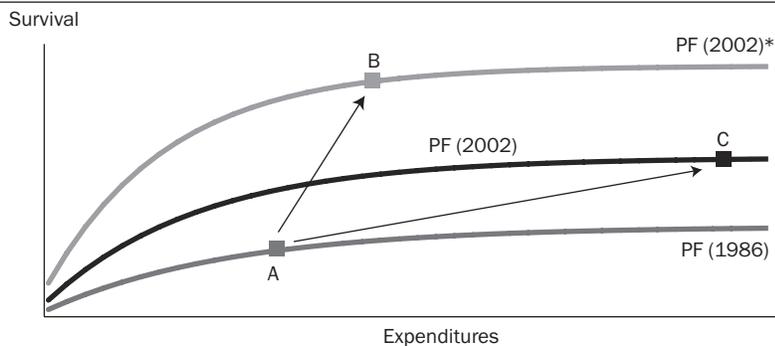
One approach to reconciling the two views in this debate is “flat of the curve”: Changes in patient outcomes over time reflect valuable technological change in medicine, but incremental spending across regions (beyond some minimum) provides little benefit or could even harm patients through medical errors or iatro-

genic disease.²⁵ But “flat of the curve” explanations are not sufficient to explain the patterns we found. Simple overuse of unnecessary treatments cannot explain why high-spending regions are less likely to provide inexpensive but effective treatments as found in the Fisher studies and studies by Katherine Baicker and Amitabh Chandra. Similarly, the “flat of the curve” hypothesis is not consistent with our findings that areas with lower gains in survival and higher cost growth lagged behind in adopting relatively low-cost, noninvasive treatments.

We suggest a different approach. Local regions where patients receive their care differ along numerous dimensions; thus, each develops its own local constrained “production function” relating spending to health outcomes.²⁶ The bottom curve in Exhibit 6 shows a representative constrained production function in 1986. During 1986–2002, the constrained production function shifted to one of the upper curves showing the relationship between spending and survival in 2002. But the nature and magnitude of this upward shift might vary over time, just as it varies across regions. For example, in our hypothetical regions shown in Exhibit 6, the early adopters of high-quality, low-cost care moved from A to B on the more-efficient, constrained production function, denoted PF (2002)*. Other regions failed to adopt efficient care (or adopted more less-efficient treatments) and moved from A to C on the less-efficient, constrained production function, PF (2002). This model reconciles the cross-sectional evidence: There is a negative correlation between spending and survival, as can be seen by comparing points B and C. But it also reconciles the time-series evidence: On average, everyone is better off, but the regional gains are not correlated with regional spending increases.

A key assumption is that uneven diffusion of cost-effective innovations is a key factor driving differences in patient costs and outcomes.²⁷ Support for this view comes from Paul Heidenreich and McClellan, who concluded that the vast majority of the increase in thirty-day survival following AMI between 1975 and 1995 was

EXHIBIT 6
Technological Change In The Treatment Of Heart Attacks: A Graphical Analysis



SOURCE: Authors’ original work.
NOTES: PF denotes a constrained production function; see text.

the consequence of low-cost treatments such as aspirin, beta-blockers, angiotensin-converting enzyme (ACE) inhibitors, and thrombolytics.²⁸ Furthermore, both observational and clinical trial evidence suggests that use of these noninvasive treatments reduces the incremental benefit of more-expensive treatments such as invasive surgery.²⁹ Therefore, adoption of such innovations might have caused a reduction in health care costs for many patients and thus resembled more closely those advances—such as seen in computers—that both reduce costs and improve quality.

The policy implications of this new approach are also quite different. In the “flat of the curve” approach, spending in high-cost regions could be reduced without an obvious adverse impact on outcomes. However, our new model does not preclude the possibility that sharp cutbacks in low-efficiency, high-cost regions could adversely affect quality of care.³⁰ Instead, policies should be directed toward improving productivity: restructuring hospital resources, improving the efficiency of physician treatment patterns, and accelerating the diffusion of highly effective treatments. Put more simply, the benefits of health spending depend on how one spends the money.³¹ It is reassuring that our views are in concordance with those of Cutler and others, who also recognize the potential excess costs arising from marginally efficient modes of care and coordination problems.³²

It is important to note that our new view does not apply solely to “low-tech” effective treatments such as aspirin and beta-blockers, but rather it applies equally to any highly effective treatment, whether high-tech or low-tech. Indeed, we have found in earlier research that regional rates of high-tech surgical treatments such as angioplasty and back surgery are not correlated with per capita Medicare spending.³³ This paper has not examined diffusion in surgical interventions, but preliminary results suggest that this was not the primary cause of spending growth during the study period.

The benefits of health care technology are often substantial. However, as health care costs continue to rise, squeezing consumers, producers, and the federal budget alike, principles of accountability—that each incremental dollar should provide something of real value to patients—become increasingly important. That some regions could implement technological innovations at remarkably low cost is a reminder that waste and inefficiency are not inevitable by-products of technological growth. Thus, efforts to develop measures of quality and efficiency that can encourage hospitals or provider groups to adopt low-cost, highly effective care, while discouraging incremental spending with no apparent benefits, might allow us to keep the golden goose of technological progress alive and well nourished.

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NOTES

1. See D.M. Cutler and M. McClellan, "Is Technological Change in Medicine Worth It?" *Health Affairs* 20, no. 5 (2001): 11–29; and D.M. Cutler, *Your Money or Your Life: Strong Medicine for America's Health Care System* (New York: Oxford University Press, 2004). The pioneering study is D.M. Cutler et al., "Are Medical Prices Declining? Evidence from Heart Attack Treatments," *Quarterly Journal of Economics* 113, no. 4 (1998): 991–1024.
2. The typical hurdle for cost-effectiveness studies is \$50,000–\$100,000 per life year, with some arguing that society places even greater value on life years. See P.A. Ubel et al., "What Is the Price of Life and Why Doesn't It Increase at the Rate of Inflation?" *Archives of Internal Medicine* 163, no. 14 (2003): 1637–1641.
3. See E.R. Berndt et al., "The Medical Treatment of Depression, 1991–1996: Productive Inefficiency, Expected Outcome Variations, and Price Indexes," *Journal of Health Economics* 21, no. 3 (2002): 373–396; F. Lichtenberg, "The Expanding Pharmaceutical Arsenal in the War on Cancer," NBER Working Paper no. 10328 (Cambridge, Mass.: National Bureau of Economic Research, February 2004); and papers in *Measuring the Gains from Medical Research: An Economic Approach*, ed. K. Murphy and R. Topel (Chicago: University of Chicago Press, 2003).
4. E.S. Fisher et al., "The Implications of Regional Variations in Medicare Spending, Part I: The Content, Quality, and Accessibility of Care," *Annals of Internal Medicine* 138, no. 4 (2003): 273–287; and E.S. Fisher et al., "The Implications of Regional Variations in Medicare Spending, Part 2: Health Outcomes and Satisfaction with Care," *Annals of Internal Medicine* 138, no. 4 (2003): 288–298. For a formal instrumental variables analysis, see J. Skinner, E. Fisher, and J. Wennberg, "The Efficiency of Medicare," in *Analyses in the Economics of Aging*, ed. D. Wise (Chicago: University of Chicago Press and NBER, 2005), 129–157.
5. K. Baicker and A. Chandra, "Medicare Spending, the Physician Workforce, and Beneficiaries' Quality of Care," *Health Affairs* 23 (2004): w184–w197 (published online 7 April 2004; 10.1377/hlthaff.w4.184).
6. An AMI corresponded a hospital admission with a primary diagnosis code of 410x0 or 410x1, where x ranges from 0 to 9.
7. Other exclusions included the inability to match to a regional category, and if patients were enrolled in a health maintenance organization (HMO) at the time of the heart attack.
8. Council of Economic Advisers, *Economic Report of the President 2005* (Washington: U.S. Government Printing Office, 2005).
9. A linear rather than logistic approach for mortality was used to facilitate the (linear) decomposition of overall changes into regional-specific changes.
10. J.E. Wennberg and M.M. Cooper, eds., *The Dartmouth Atlas of Health Care* (Chicago: American Hospital Association, 1999).
11. Second International Study of Infarct Survival (ISIS-2), Collaborative Group, "Randomised Trial of Intravenous Streptokinase, Oral Aspirin, Both, or Neither among 17,187 Cases of Suspected Acute Myocardial Infarction: ISIS-2," *Lancet* 32, no. 8607 (1988): 349–360.
12. See S. Yusuf et al., "Beta Blocked During and After Myocardial Infarction: An Overview of the Randomized Trials," *Progress in Cardiovascular Diseases* 27, no. 5 (1985): 335–371.
13. S.F. Jencks, E.D. Huff, and T. Cuerdon, "Change in the Quality of Care Delivered to Medicare Beneficiaries, 1998–1999 to 2000–2001," *Journal of the American Medical Association* 289, no. 3 (2003): 305–312.
14. International Society and Federation of Cardiology and World Health Organization Task Force on Myocardial Reperfusion, "Reperfusion in Acute Myocardial Infarction," *Circulation* 90, no. 4 (1994): 2091–2102.
15. Several HRRs were excluded from the analysis because of insufficient sample size in the quality indicators. See J. Birkmeyer and D. Wennberg, eds., *Dartmouth Atlas of Cardiovascular Health Care* (Hanover, N.H.: Dartmouth Medical School, 2000).
16. This follows the terminology in E.M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995).
17. K. Murphy and G. Becker, "The Division of Labor, Coordination Costs, and Knowledge," *Quarterly Journal of Economics* 107, no. 4 (1992): 1137–1160; and K. Baicker and A. Chandra, "The Productivity of Physician Specialization: Evidence from the Medicare Program," *American Economic Review* 94, no. 2 (2004): 357–361.
18. D. Payne, "I Shouldn't Have Had to Beg for a Prognosis," *Newsweek* (22 August 2005), 16.
19. One concern with our measure of network effects is that the average number of different physicians simply reflects unmeasured confounding factors; sicker patients require more physicians. However, there was essentially no correlation at the regional level between an index of AMI severity—predicted mortality—and the average number of different physicians (correlation coefficient = .06, $p = .33$).
20. A large and statistically significant negative correlation exists even when the high-spending regions (such

- as the rightmost three regions in Exhibit 1) are excluded.
21. We are grateful to David Cutler for providing these data.
 22. See A.S. Ash et al., "Using Claims Data to Examine Mortality Trends Following Hospitalization for Heart Attack in Medicare," *Health Services Research* 38, no. 5 (2003): 1253–1262. Alternatively, it could be that during the later 1990s, the rising fraction of Medicare enrollees in HMOs resulted in fee-for-service patients who were increasingly sicker. However, one study shows little evidence that after comorbidities were adjusted for (as we do), HMO patients were more likely to survive AMI; see H.S. Luft, "Variations in Patterns of Care and Outcomes after Acute Myocardial Infarction for Medicare Beneficiaries in Fee-for-Service and HMO Settings," *Health Services Research* 38, no. 4 (2003): 1065–1079.
 23. See P.A. Heidenreich and M. McClellan, "Trends in Treatment and Outcomes for Acute Myocardial Infarction: 1975–1995," *American Journal of Medicine* 110, no. 3 (2001): 165–174. A meta-analysis of stents did not find any significant impact on mortality; see M.M. Zhu et al., "Primary Stent Implantation Compared with Primary Balloon Angioplasty for Acute Myocardial Infarction: A Meta-Analysis of Randomized Clinical Trials," *American Journal of Cardiology* 88, no. 3 (2001): 297–301.
 24. See Note 4.
 25. See, for example, D.M. Cutler, "Walking the Tightrope on Medicare Reform," *Journal of Economic Perspectives* 14, no. 2 (2000): 45–56.
 26. The production functions are constrained because lack of knowledge and skills, or poor organizational structure, could prevent health care systems from attaining the efficient (and perhaps hypothetical) "best practice" production function.
 27. D.M. Berwick, "Disseminating Innovations in Health Care," *Journal of the American Medical Association* 289, no. 15 (2003): 1969–1975. There is a parallel literature in macroeconomics that stresses the role of the diffusion of innovations in long-term differences in country income and growth. See S.L. Parente and E.C. Prescott, "Barriers to Technology Adoption and Development," *Journal of Political Economy* 102, no. 2 (1994): 298–321; and J. Skinner and D. Staiger, "Technology Adoption from Hybrid Corn to Beta Blockers," NBER Working Paper no. 11251 (Cambridge, Mass.: NBER, April 2005).
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 33. J.E. Wennberg, E.S. Fisher, and J.S. Skinner, "Geography and the Debate over Medicare Reform," *Health Affairs* 21 (2002): w96–w114 (published online 13 February 2002; 10.1377/hlthaff.w2.96).