Has Managed Care Affected the Availability of Medical Technology?

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Foreword

In the early 1970s, when the national debate on rising health care costs began to take center stage, many observers suggested that managed care would provide just the antidote needed to lower double digit increases in annual costs. Indeed, modified reimbursement procedures for federally funded programs, combined with widespread adoption of managed care in the private sector, did provide the cost growth relief that budget analysts in both the public and private sectors desired. In the mid-1980s, however, health care scholars began to note that these cost-containment strategies were likely to provide only temporary relief. They argued that once administrative inefficiencies were squeezed out of the system, the imperative of health technology breakthroughs would again drive health care costs toward double digit growth—as new technologies were developed, doctors and patients would want to use them, and costs would rise proportionately.

At this point, the jury is still out on whether the dramatic reductions in cost growth recorded in the 1990s will continue into the next decade.

In this report, Joanne Spetz and Laurence Baker address one aspect of the question, examining whether health maintenance organizations (HMOs) have reduced the availability of medical technology in hospitals. The authors investigate whether competition within metropolitan markets throughout the nation has led to a reduction in the package of technologies offered by providers. In other words, has investment in technology at the hospital level been curtailed in order to lower the cost profile of the provider?

The authors conclude that there is no difference in technology availability or growth between cities where HMOs have a strong market share and cities where they have a low market share. This suggests that managed care has not slowed the overall growth of technology. HMO providers appear to be offering, on average, the same package of technology as that offered by non-HMO providers. Although this analysis was conducted at the national level, the message for California is clear. HMOs show no obvious tendency to reduce the provision of services that require high technology, and thus rapid growth in health care costs may return in the coming years.

Spetz and Baker review three possible approaches to technology management and conclude, as have others before them, that the solution is a very tough trade-off—do nothing (let managed care run its course), regulate new technologies, or implement some form of service rationing. None of these choices is attractive, but the authors believe that the earlier warnings about technology-driven costs are quite likely to come true, and some hard choices will have to be made.

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Summary

Through the 1980s, health expenditures in California and throughout the United States grew rapidly, outpacing the annual rate of growth in the economy as a whole. More recently, however, health care expenditure growth has slowed. Between 1993 and 1996, for example, growth in the U.S. gross domestic product and growth in health care expenditures were nearly identical.

There is an emerging consensus among researchers who study health care markets that managed care played a key role in slowing the growth in health care cost during the early 1990s. HMOs have reduced the unnecessary use of medical care by using gatekeepers to regulate the use of certain services, encouraging the practice of preventative medicine, and reducing average length of stays in hospitals. Managed care plans have also tried to lower physician and hospital earnings by bargaining for discounted medical care with providers. But, it is not clear whether managed care will be able to keep cost growth low. It may be that managed care produced one-time savings, and that rapid cost growth will

return in the near future. There is a limit to how much length of hospital stays can be reduced and how few services physicians provide before the quality of health care becomes too low for consumer and legal standards. An insurer that does not meet a minimum standard of quality will not attract patients and may suffer from malpractice lawsuits. Whether managed care can achieve a long-term reduction in health care cost growth depends on whether it can control the underlying factors that cause cost growth.

There is a strong consensus that technology diffusion—the development of new technologies and their introduction into medical practice—is one of the most important factors driving long-term health expenditure growth. To better understand the role managed care can play in bringing about long-term cost savings, this study examined whether health maintenance organizations (HMOs) are associated with changes in the availability of medical technology. We compared the availability of technology among hospitals in metropolitan areas in the United States with high levels of HMO penetration to its availability in metropolitan areas with low levels of HMO penetration. We also explored the relationship between hospital competition and HMO penetration, because HMOs could have different effects on the availability of technology depending on the number and competitiveness of hospitals in an area.

Technology Trends Index

Virtually all previous studies of technology adoption have examined individual technologies one at a time. This is appealing for some types of research, but for our study this was a drawback because focusing on individual technologies does not support discussions about general technology trends. In the hope of providing some aggregate information about technology change, we created technology indices to measure the aggregate availability of a range of new technologies in hospitals. Our indices are weighted sums for the number of technologies and services available in a hospital, where the weights are the percentage of hospitals in the country that do *not* possess the technology or service. The key attribute of these indices is that they can be expanded by the addition of new technologies and will increase more with the addition of technologies that are relatively rare than with the addition of technologies that are common. Services and equipment that are rare, either because they are expensive, new, or difficult to implement, are more likely to be considered “high tech” and receive more weight in our indices.

We created our indices using a set of technologies and weights that are defined in a base year. We then computed index values for each hospital and year using the fixed set of technologies and weights. For example, we defined a list of technologies available in 1983, determined their relative rarity in 1983, and then computed index values for hospitals in all years using the 1983 list and the 1983 weights. With the weights fixed, an increase in the index value signifies the addition of new technologies at a particular hospital.

We created our indices using three different years of the American Hospital Association’s (AHA’s) *Annual Survey of Hospitals* to define the technology list and weights. We began with an index based on technologies reported in every year from 1983 to 1993. As new technologies are developed and diffuse through the hospital industry, the 1983 list of technologies will eventually fail to appropriately measure the availability of more-recent high-tech equipment and services. The 1983 list and weights are also not likely to reflect the relative costs of new technologies and older technologies. Thus, the 1983 technology list and weights will eventually become a poor indicator of the current state of the world and will need to be updated. To update our measurement of technology, we created two other indices: one with technologies reported from 1987 to 1990, with 1987 weights, and another with technologies reported from 1991 to 1993, with 1991 weights. The 1987-weighted list includes all of the technologies included in the 1983 list, plus three additional technologies. The 1991-weighted list includes all of the technologies from the 1983 and 1987 lists, plus several additional technologies.

Is the HMO Market Share Associated with Technology Availability?

To examine the relationship between the HMO market share and technology availability, we computed the average index values for hospitals in each of 261 Metropolitan Statistical Areas in the United States for each year from 1983 through 1993. We categorized each market as having high or low HMO activity based on estimates of the percentage of the population enrolled in HMOs in 1993. "High-HMO" cities were defined as those with HMO penetration in the top 25 percent of all cities in 1993. This turned out to be all cities in which at least 19.3 percent of the population was enrolled in an HMO. The remainder were defined as "low-HMO" cities. Classifying market areas based on their 1993 HMO market share identified cities that also tended to have high market shares in earlier years and high market share growth rates over time. A large percentage of California's cities have high levels of HMO penetration—over two-thirds of California's cities are in the national high-HMO category. Thus, we should expect that HMOs' effects on technology availability would be particularly important in California.

We used regression analyses to examine the effect of HMO activity on the mean technology index score. The regressions control for a number of potentially confounding factors, including measures of population demographics, characteristics of the area health care system, and characteristics of area hospitals. The results suggest that managed care has not slowed the growth of technology. Particularly in recent years, average index values increased as rapidly in high market share areas as in low market share areas. We also performed some analyses including only technologies that were actively diffusing during the time period we examined. The results of our analyses of these diffusing technologies also provided no reason to believe that HMOs have slowed aggregate technology growth.

The Role of Hospital Competition

One factor that could influence the ability of managed care to affect technology availability is competition among hospitals. HMOs might have less bargaining power in markets with a few dominant hospitals than in markets with many competing hospitals. Hospitals also might compete more aggressively for contracts with insurers in more competitive markets. This competition could take the form of either lower prices or a "medical arms race."

We used data on the number of hospitals and the size of hospitals in 1993 to categorize cities as high competition or low competition. We examined the effects of HMOs in high- and low-competition cities using our regression models. It does not appear that HMOs affect general technology availability in cities with either high or low levels of hospital competition. However, the availability of newer technologies may have been affected in highly competitive cities. When we examined only diffusing technologies, we found slower growth in technology availability between 1983 and 1991 among high-HMO cities with competitive hospital markets. Between 1991 and 1993, however, there was more rapid growth in technology availability in these same cities. Whether this recent change is a transitory or permanent relationship is unknown.

It should be noted that HMO market share and hospital competition can be closely related, because HMOs may influence the behavior of hospitals and hospital competition may influence the decisions HMOs make about entry into markets. Since these two variables are probably correlated, our regression analyses may not be able to accurately determine the separate contribution of HMO concentration and hospital competition.

Aggregated Indices Versus Individual Technologies

Examining aggregated index data can have important advantages but may miss variation in the individual constituent technologies. We took four of the technologies that are included in our indices and examined them individually. We found that high HMO market share is associated with increased availability of open heart surgery and cardiac catheterization but that high-HMO cities experienced marked declines in the availability of diagnostic radioisotope services based in hospitals. We found no relationship for neonatal intensive care. These results illustrate a couple of important lessons. First, while the findings from the indices suggest that HMO activity had little or no effect on technology advancement overall, there is evidence that some technologies were affected by HMO activity. Second, while the indices did not respond to hospital competition, there may be important relationships between HMO activity and hospital competition for some individual technologies. We stress that while indices can nicely summarize aggregate movements, they can miss effects that occur for individual technologies.

Conclusions and Policy Implications

To the extent that our indices capture high-cost technologies, managed care does not appear to have contributed to cost savings by restricting aggregate growth in technologies. If managed care cannot slow long-term cost growth, it may be difficult for managed care to bring about long-run reductions in health care cost growth. While these findings do not provide reason to believe that managed care slowed the overall growth in new technology availability in the late 1980s and early 1990s, managed care may have had important effects on individual technologies.

As noted above, long-term health care cost growth is unlikely to be controlled without a slowing of the diffusion of technology. Thus, policymakers need to consider limiting tech availability in order to restrain health care cost growth. But, this will require a considerable amount of consensus-building since many consumers of health care demand high-technology services.

We outline three possible approaches to technology management. The first is to do nothing and see if managed care and other practices of the past several years will reduce technology availability in the future. Given our results, it does not appear that this is likely to be a successful strategy. Further, it is not clear that the public wants health care cost reduction to be under the control of health care organizations that are increasingly motivated by profit.

A second option would be to regulate the availability of new technologies and encourage the consolidation of services into fewer centers, each producing higher volumes of services. There are several mechanisms the government could use to consolidate services and limit the diffusion of technologies. First, certificate-of-need regulations, which existed in California through the mid-1980s, could be reenacted and might succeed if there is sufficient public will to support their mission. Alternatively, the state could establish minimum service volumes for particular technologies and services and refuse to license facilities that do not meet volume requirements. Finally, policymakers could provide financial incentives to hospitals to close low-volume units, establish referral centers, and consolidate operations. On the one hand, regulatory approaches that consolidate services can be risky because reducing the number of service providers in a region could produce monopolies for the hospitals that provide the limited technologies. Monopolies could lead to increased costs and reduced availability of services. On the other hand, strong regulation may also hold out the best hope of achieving substantial changes in technology availability.

For the third approach, when the state serves as insurer, the state could consider following the lead taken by Oregon with its Medicaid insurance plan: Policymakers could develop a priority list of services based on both impartial cost-benefit analysis and public opinion and use this list to explicitly ration care, which would affect technology purchase decisions. While this policy is appealing because it forces the debate to be public, it has been met with numerous legal challenges. More important is the question of whether the public can be comfortable with such explicit rationing of health care. In California, this would work only for Medi-Cal and other state-financed programs.

The current pattern of managed care does not seem likely to result in future reductions in the availability of technology. Thus, it appears that controlling long-term health care cost growth will require a change in behavior by managed care insurers or new public cost-containment policies.

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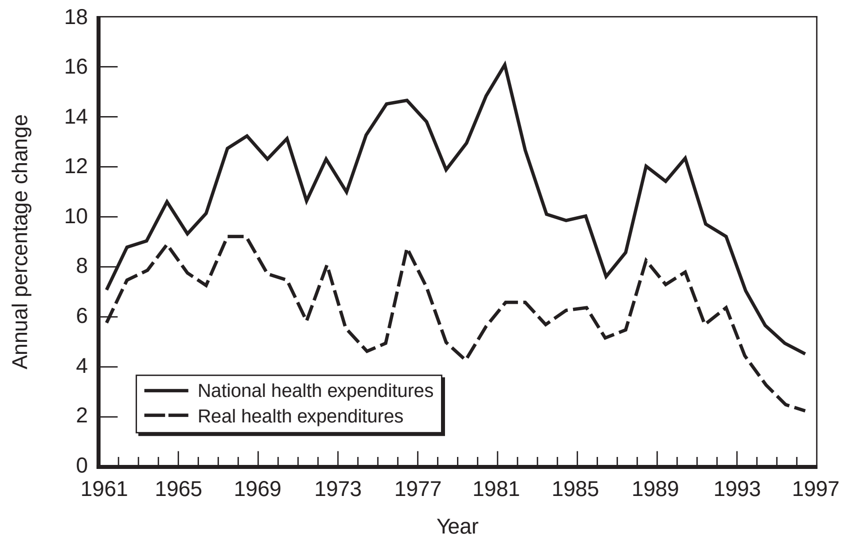
1. Introduction

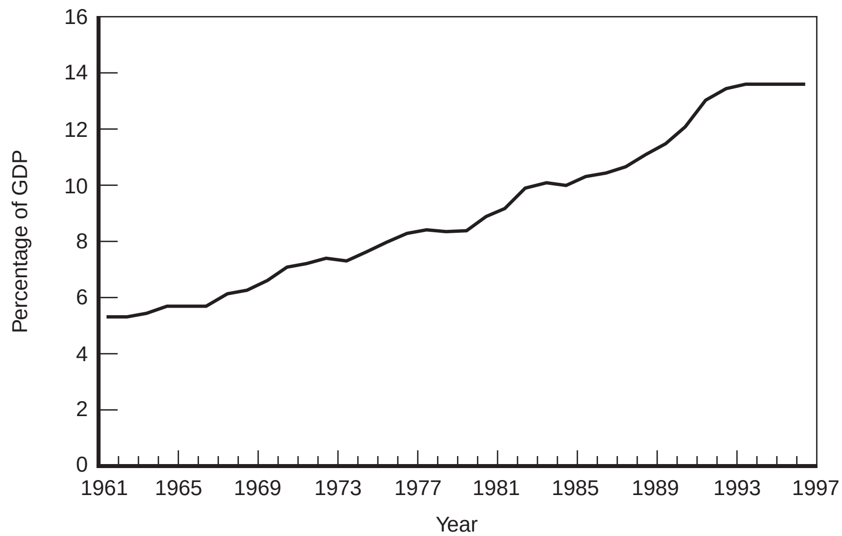
Through the early 1990s, two trends emerged in the health care industry in California and the United States. First, health care costs—which include expenditures for hospitals, physicians, pharmaceuticals, equipment, administration, and research—grew at lower rates than in the previous three decades, rising an average of 6.8 percent a year from 1991 to 1996 instead of the average 11.5 percent annual increases experienced in the prior 30 years (Figure 1; Health Care Financing Administration, 1998). This decline in cost growth occurred primarily because of slower growth in spending on hospitals, physician services, administration, and home health care (Levit et al., 1998a). The annual health care cost increases of the 1960s, 1970s, and 1980s were larger than annual growth in national gross domestic product (GDP), meaning that the health care sector grew faster than the economy as a whole. In recent years, however, GDP and health care cost growth have been nearly identical, and health care has composed a stable share of our economy (Figure 2).



SOURCE: Health Care Financing Administration, 1998.

Figure 1—Annual Percentage Change in National Health Expenditures, 1961–1996

Second, health maintenance organizations (HMOs) and other managed care plans grew rapidly and became important dominant providers of health insurance in many regions of the United States. HMOs insured only 4 percent of the U.S. population in 1980; they insured nearly 14 percent by 1990 and over 20 percent in 1995 (Group Health Association of America, 1995). HMOs insured over 38 percent of California's population in 1995, giving California the third-highest HMO penetration in the United States. Many observers attribute the national decline in health care cost growth to the cost-containment efforts of managed care plans and new reimbursement programs in government-funded programs like Medicare and Medicaid (Levit et al., 1998b; Miller and Luft, 1994; Zwanziger and Melnick, 1996; Zwanziger



SOURCE: Health Care Financing Administration, 1998.

Figure 2—National Health Expenditures As a Share of GDP

et al., 1994). California has been touted as a mature managed care market, and reductions in health care costs in California are considered the natural result of this status (Zwanziger and Melnick, 1996; Zwanziger et al., 1994).

Recent reports have created concern about whether this slowing of cost growth will persist. Reports in the *New York Times* and *Wall Street Journal* state that employers are facing increases of nearly 10 percent in the price of HMO insurance—the highest increases since 1992 (Freudenheim, 1998). Traditional fee-for-service health plans are likely to endure even larger price increases. Most managed care insurers claim that their fee increases are resulting from increasing costs of physicians, hospitals, pharmaceuticals, and other technologies (Freudenheim, 1998; Winslow, 1998). Moreover, some health plans faced large losses in

1997. Kaiser Permanente, the national's largest health plan, suffered a first-ever deficit of $270 million that year, and several other major insurers experienced similar or even larger losses.

If the price of health care for private insurers increases, it is likely that government insurance programs such as Medicare and Medicaid will also experience faster cost growth. A return of high inflation in health care costs would change the debate over the regulation of managed care and, possibly, health care policy in general. To determine whether health care costs are likely to rise in the future, we must understand why costs have risen so rapidly in the past and assess whether managed care can control the causes of health care cost growth.

Has Managed Care Reduced Health Care Cost Growth?

A central question in many policy debates is the extent to which the recent slowing in health care cost growth can be attributed to managed care. Few would dispute that managed care can reduce expenditures to at least some extent, and many of the ways managed care can reduce costs are well documented. HMOs have reduced the unnecessary use of medical care by using gatekeepers to regulate the use of certain services, encouraging the practice of preventative medicine, and reducing the average length of stay in hospitals. Managed care plans have also tried to lower physician and hospital earnings by bargaining for discounted medical care with providers.

Researchers who have examined the relationship between managed care and health care costs have used two approaches. Many have performed direct comparisons of cost growth between managed care and other insurers. These studies generally found that although HMO costs were lower than the costs of traditional insurance plans, long-run cost growth was similar between HMOs and other insurers (Luft, 1980; Newhouse et al., 1985). Other researchers have compared regional markets with different levels of HMO penetration. These studies usually found that increased HMO penetration was associated with slower cost growth (Gaskin and Hadley, 1997; Robinson, 1996; Zwanziger et al., 1994; Baker, 1997). Chernew et al. (1998) suggested that the market-level effect of managed care exists because the cost-containment pressures provided by managed care also affect cost growth among non-HMO insurers.

The consensus appears to be that managed care did play a role in reducing health care cost growth in the early 1990s. However, it is unclear whether managed care will be able to keep cost growth low. Managed care may have produced one-time savings. There is a limit to how much the length of hospital stays can be reduced and how few services physicians can provide before the quality of health care becomes too low for consumer and legal standards. An insurer that does not meet a minimum standard of quality will not attract patients and may suffer from malpractice lawsuits. Whether HMOs can achieve a long-term reduction in health care cost growth depends on whether HMOs can control the underlying factors that cause cost growth. One of the most important factors driving long-term cost growth appears to be technology diffusion.

Technology As a Cause of Health Care Cost Growth

Many factors can lead to increases in health care costs above the rate of inflation. Demographic changes, the rapid spread of health insurance since the 1960s, and increased use of “defensive medicine” have all been blamed for rising health care costs. However, most analysts believe a large share of health care cost growth resulted from increases in the intensity of medical care caused by the introduction and rapid diffusion of new medical technologies (Fuchs, 1972; Warner, 1978; Goddeeris, 1984; Goddeeris and Weisbrod, 1985; Robinson and Luft, 1985; Luft et al., 1986; Schwartz, 1987; Noether, 1988; Weisbrod, 1991; Newhouse, 1993; Greenspan, 1998; Chernew et al., 1998). Fuchs (1996) found that 81 percent of health economists believe that a major share of rising health care costs can be attributed to increasing development, adoption, and use of new medical technologies. One driver of rapid technology diffusion is health insurance. People with health insurance demand more health care than is optimal because their insurance reduces their out-of-pocket expense below the true cost of health care. As individuals and physicians seek the most advanced medical care available, total health care expenditures rise, and these rising costs are billed to insurers. Because most Americans receive health insurance from their employers or the government, they are insulated from increases in the price of insurance that result from their preference for high-technology health care.[1] Pharmaceutical and medical device firms continue to develop expensive technologies because they know that well-insured Americans will purchase their products with little attention to cost.

Additionally, individuals with health insurance have little incentive to consider the prices charged by different hospitals and physicians when selecting a health care provider. They do consider the quality of medical

[1] It was only relatively recently that employers became concerned about the high cost of providing health insurance to employees. They now place pressure on insurers to keep insurance premiums low, and managed care is one method insurers use to do so. See Dranove, Shanley, and White (1993) for a description of this change.

providers, however. Several researchers have found that the perceived quality of care provided by a hospital is a significant determinant of choice of hospital (Luft et al., 1990a; Phibbs et al., 1993; Hodgkin, 1996). Patients and physicians often do not know mortality rates and other outcome statistics of hospitals, but they can observe whether a hospital offers sophisticated medical technologies. The existence of specialized services appears to be a signal to physicians, insurers, and the public that a hospital provides high-quality specialized medical services. Thus, hospitals might compete for patients by offering increasingly sophisticated services (Cohen and Lee, 1985; Noether, 1988; Robinson, 1988; Adams et al., 1991; Bronstein and Morrisey, 1991). Excessive quality competition is often described as a "medical arms race." Because medical arms races have their roots in competition among hospitals, most research on this issue attempts to determine whether technology diffusion is faster in more competitive areas than in less competitive ones. The results are mixed. Some studies have found a greater diffusion of technologies in more competitive markets (Rapoport, 1978; Wilson and Jadlow, 1982; Romeo, Wagner, and Lee, 1984; Luft et al., 1986; Robinson, Garnick, and McPhee, 1987; Teplensky et al., 1995), while others have found that the medical-arms-race effect is small or nonexistent when markets are defined broadly (Duffy, 1992; Dranove, Shanley, and Simon, 1992).

Other factors could be responsible for rising health care costs, such as the aging of the population, the spread of health insurance, growth in defensive medicine caused by malpractice litigation, and increasing administrative costs. However, existing research suggests that these are not as important as technology diffusion. Schwartz (1987) and Newhouse (1993) reviewed these possibilities and concluded that, while these other factors have increased health care costs, they cannot account for a substantial share of health care cost inflation. The most plausible explanation for the majority of health care cost growth advanced by these studies is technology diffusion, which highlights the importance of the incentives embodied in traditional insurance plans as drivers of technology adoption and health care costs.

Managed care may alter these incentives in a variety of ways, which could alter the technology diffusion process. If managed care slows technology diffusion, it could, in turn, help bring about longer-term reductions in cost growth. If managed care does not adequately control the diffusion of technology, it is unlikely that managed care will cause a continuing reduction in health care cost growth (Schwartz, 1987; Newhouse, 1993; Greenspan, 1998). While some analysts think managed care can reduce excess diffusion of technology (Hillman, 1986; Warner, 1978), others have argued that HMOs may not affect, or may even increase, technology use (Schwartz, 1987; McLaughlin, 1988). In fact, Chernew, Scanlon, and Hayward (1998) found that quality has a greater effect on hospital choice for HMO enrollees than for non-HMO patients, suggesting that HMO penetration does not reduce, and may even increase, the incentive for hospitals to engage in a medical arms race. Understanding the net effect of managed care on technology adoption requires empirical analysis.

This Report

We seek this understanding by examining whether HMOs are associated with changes in the availability of medical technology. We compare the availability of technology among hospitals in metropolitan areas in the United States with high levels of HMO penetration to metropolitan areas with low levels of HMO penetration. We also explore the relationship between hospital competition and HMO penetration—HMOs could have different effects when there are many hospitals versus when there are few hospitals. Our analysis considers both aggregate measures of hospital technology use and individual technologies.

The next chapter reviews the literature on how the financial relationships between insurers, physicians, and hospitals might affect hospital adoption of technologies. We then discuss our data and our aggregated measure of technology availability—the Saidin indices. These indices are used to compare patterns of technology availability across markets in the United States and in California specifically. Detailed analyses of national data help us determine whether the growth of managed care has affected technology adoption and use. We conclude by discussing the implications of our findings for the cost and quality of medical care in California and the United States.

2. What We Know About Health Care Policy and Technology Availability

Certificate of Need Programs

How the rapid diffusion of health care technology might be slowed has been the focus of policy discussions for two decades. Several conferences were held in the 1970s to examine the importance of technology in the rapid rise in health care costs (Altman and Blendon, 1979; also see Collen, 1972). Policymakers responded to the belief that the development and diffusion of medical technology was causing health care cost inflation by implementing certificate-of-need (CON) regulations. In 1974, Congress passed the National Health Planning and Resources Development Act, which required states to institute programs regulating hospital acquisitions of technologies and services (Bryce and Cline, 1998). Under CON regulations, hospitals were expected to demonstrate a community need for a service before purchasing it. By the early 1980s, most policymakers and researchers believed CON regulations were ineffective in controlling the diffusion and cost of new technologies (Banta, Burns, and Behney, 1983; Cromwell and Kanak, 1982; Noether, 1988; Bryce and Cline, 1998). The federal act mandating that states operate CON programs was repealed in 1986, and California and many other states ended their programs at that time. Chernew, Hayward, and Scanlon (1996) note that personnel at California's Office of Statewide Health Planning and Development did not consider the state's CON program to be an effective regulation.

Prospective Reimbursement

At the same time that the federal government mandated CON programs, several states developed "prospective reimbursement" (PR) programs to finance health care. In these programs, a hospital receives a prospectively determined payment for each patient, with the payment varying by diagnosis. New York's PR program is the oldest, established in 1970, and it applies to all insurance programs except Medicare. Washington, Maryland, New Jersey, Connecticut, Massachusetts, Colorado, Rhode Island, and Wisconsin also established similar programs of varying scope in the 1970s. Many analysts expected that these programs would control the diffusion of technology. Warner (1978) argued that limiting total inpatient revenues would provide hospitals with an incentive to invest in cost-saving technologies, whereas limits on capital expenditures do not differentiate between cost-increasing and cost-saving investments. Cromwell and Kanak (1982) and Romeo, Wagner, and Lee (1984) found limited evidence that PR programs slowed the diffusion of technology in the 1970s. Prospective reimbursement's effectiveness varies significantly by state, with some states' programs having no effect on technology adoption. In 1983, the federal government implemented prospective reimbursement for Medicare patients with the introduction of the Prospective Payment System (PPS). It is unclear whether this had an effect on technology adoption.

Managed Care and HMOs

In the 1980s, attention turned to managed care and health maintenance organizations as mechanisms to slow health care cost inflation and to mitigate the medical arms race. While PR programs provide a diagnosis-specific payment for each patient, HMOs usually make a single payment for medical care for a period of time or have negotiated reimbursement schedules for the provision of care. HMO enrollments have grown dramatically over the past two decades, reaching 20 percent in 1995. In California, HMO enrollment increased from 17 percent of the insured population in 1980 to 38 percent in 1995 (Group Health Association of America, 1995).

HMOs have not been the only important development in health insurance. In 1982, California was the first state to enact "selective contracting" legislation. Prior to 1982, non-HMO insurance companies were prohibited from interfering with a patient's choice of health care provider. The 1982 legislation allowed insurance companies to negotiate with physicians and hospitals for reduced fee schedules in exchange for providing financial incentives for patients to choose preferred providers. Since the passage of selective contracting legislation throughout the nation, these "preferred provider organizations" (PPOs) have grown rapidly, as have related insurance systems. There are many different contractual arrangements between physicians, hospitals, and insurance companies; some with financial incentives to change patterns of care provision and some with direct controls, such as utilization review programs and strict referral systems. More than 80 percent of California's insured population was insured by managed care plans (HMOs and PPOs) by 1990. California has been a leader in national growth of managed care (Zwanziger and Melnick, 1996).

Many changes in hospital care have been attributed to the increased use of managed care, including declines in inpatient admissions, lower average length of hospital stays, a more severely ill patient population, and slower growth in the employment of nursing personnel (Melnick and Zwanziger, 1988; Zwanziger and Melnick, 1988; Keeler et al., 1990; Goldfarb and Coffey, 1992; Dranove, Shanley, and White, 1993; Hodgkin and McGuire, 1994; Buerhaus and Staiger, 1996; Spetz, 1996). HMOs and PPOs try to avoid expensive hospitalizations by using nonsurgical treatments and ambulatory surgery when possible; thus, many hospitals have altered the quantity and types of services they provide.

Hillman (1986) argued that capitated and prospective payment programs might effectively control the adoption of technology, and thus long-term cost growth, because individual hospitals would have incentives to reduce the cost of meeting patients' health care needs. However, other analysts have argued that the relationship between managed care and technology diffusion and use is not so clear. McLaughlin (1988) reviewed the literature and theory of the relationship between hospital competition, insurance, and health care costs. She concluded that the evidence does not support the idea that HMOs reduce quality competition or technology proliferation. Whether HMOs change the nature of competition among hospitals depends on many factors. When HMO penetration in a community is high, hospitals need to attract contracts with HMOs in order to maintain demand for their services. HMOs, in turn, want to be competitive for contracts with firms that purchase insurance for their employees. Firms want to offer health insurance plans perceived to be of high quality in order to attract and retain employees. Thus, HMOs have an incentive both to reduce the cost of insurance *and* to provide high-quality health care to their enrollees. If hospitals try both to lower costs and to provide high-quality care—real or perceived—it is unclear what effect the rise in managed care will have on the adoption of costly new technologies that increase the perceived quality of care. However, managed care should encourage the adoption of advances that are both cost reducing and quality enhancing.

The potential for managed care to reduce long-term health care costs depends not only on its ability to abate the medical arms race but also on its ability to change the demand for high-technology medical care by insured patients. Even if managed care results in the elimination of duplicative facilities and services, only a fraction of total health care spending would be reduced, because the demand for high-quality medical care would persist (Schwartz and Joskow, 1980). Schwartz (1987) and Newhouse (1993) argued that HMOs have limited ability to affect the rate of technologic change or diffusion of technology simply because the public demands access to medical technology. Consistent with this, research from the mid-1980s suggested that cost growth among HMOs was not different from health care cost growth in general (Luft, 1980; Newhouse et al., 1985).

A small number of studies have examined whether HMOs and other managed care plans are effectively reducing the diffusion and use of technology in the United States. Most of these studies focused on a set of technologies that might illustrate the effect of HMOs on broad patterns of technology adoption and use. For example, Cutler and Sheiner (1997) studied the relationship between state-level HMO penetration and the adoption of 19 different technologies from 1980 to 1995. They found that states with high-HMO market shares tended to have lower levels of technology availability in later years, consistent with the view that HMOs have slowed technology adoption. Cutler and McClellan (1996) found a similar effect of HMOs on the adoption of angioplasty by individual hospitals. In their case study, Hill and Wolfe (1997) observed an increase in joint purchases of magnetic resonance imaging (MRI) and lithotripsy as managed care programs evolved in Wisconsin. Baker and Wheeler (1998) suggested that areas with high-HMO market shares have fewer MRIs.

For each study that finds that technology adoption and use decreases as HMO penetration rises, there is another study that finds the opposite. Chernew, Fendrick, and Hirth's (1997) study of adoption of laparoscopic cholecystectomy found no systematic difference between HMOs and non-HMO insurers. Similarly, Bryce and Cline (1998) argued that market incentives have not ameliorated an oversupply of extracorporeal shock wave lithotripsy, magnetic resonance imaging, cardiac catheterization, organ transplantation, and neonatal intensive care in Pennsylvania. They concluded that hospitals might be increasing their purchases of new technologies in order to be more competitive in a managed care environment. Chernew et al.'s (1998) review of the literature on health care cost growth and medical technology concluded that "the evidence that managed care will control technology diffusion is mixed at best."

The research presented here attempts to improve our understanding of whether managed care is affecting technology availability using national data. This book improves on the work done by other researchers in several ways. First, this study is a market-level analysis. As noted above, studies of health care costs typically find that managed care reduces cost growth across markets, but not across individual insurers (Chernew et al., 1998). Because we examine the availability of technology in markets, we accommodate for the possibility that the penetration of HMOs has a market-wide effect, rather than an effect only on those insured by HMOs. Cutler and Sheiner (1997) took a similar approach. However, their analysis defined markets as states; we focus on city-level HMO penetration and technology availability, thus better examining the effect of managed care within logically defined markets. Cutler and Sheiner (1997) also examined 19 individual technologies and drew conclusions from patterns observed among the diverse technologies they considered. We consider both an aggregated index of technology availability and individual technologies. Our findings are particularly relevant to California, since California has been a leader in the growth of managed care.

3. Data and Methods

Measuring the Availability of Technology

To examine the effect of HMO penetration on the adoption and use of medical technology, we used data collected by the American Hospital Association (AHA) from 1983 through 1993. The AHA *Annual Survey of Hospitals* provides information about services available, number of patients admitted, ownership, teaching status, revenues, and costs at hospitals in the United States. The survey also indicates whether a hospital has each of a set of technologies. We compared these data with similar information available in California's Office of Statewide Health Planning and Development's *Hospital Disclosure Report* to validate the accuracy of the AHA data for the California sample; details about this comparison and corrections made to the data are presented in Appendix A.

Virtually all previous studies of technology adoption have examined individual technologies one at a time. This is appealing both because technology availability is measured at the level of individual technologies, and thus represents a natural unit of analysis, and because it allows separate conclusions to be drawn for each individual technology. However, focusing on individual technologies also has drawbacks. In many discussions of the effects of managed care on technology adoption, the notion of health care technology encompasses the broad sweep of new innovations, the rate at which they occur, and the speed with which they are acquired and put into practice. Questions about technology call for measures that provide information about technology change broadly, but studies of individual technologies are not optimal for drawing aggregated inferences.

In the hope of providing some aggregate information about technology change, we used technology indices to measure the aggregate availability of a range of new technologies. Our indices are weighted sums of the number of technologies and services available in a hospital (from a predetermined list), with the weights being the percentage of hospitals in the country that do *not* possess the technology or service. Spetz (1995) termed this type of index a "Saidin" index. The key attribute of a Saidin index is that it increases with the addition of new technologies and will increase more with the addition of technologies that are relatively rare than with the addition of technologies that are common. Health care technologies that are rare—either because they are expensive, new, or difficult to implement—are considered "high tech" and receive more weight in Saidin indices.

The term "health care technology" is generally poorly defined and can refer to a range of advances in medical knowledge that are implemented in patient care, potentially including everything from new equipment and procedures to changes in the organizational structure of institutions. Our approach was to identify a set of items in hospitals that are commonly identified as "health care technologies" and can be identified in survey data. In some cases, we measured the presence of specific infrastructure items like MRI scanners. In other cases, we used the presence of certain types of services, such as neonatal intensive care units, that are likely to signal the presence of particular advanced infrastructure items. The technologies considered for the Saidin indices are thought to be cost-increasing technologies, although it is not possible to easily distinguish cost-increasing from cost-saving technologies and services. For example, an expensive MRI may detect conditions that if treated later will lead to more costly interventions.

Most of the technologies included in the indices are primarily provided by hospitals. A few of the technologies, such as diagnostic radioisotope facilities, have been moved from hospitals to freestanding ambulatory care centers and laboratories in some cities. Unfortunately, data do not exist to examine the total availability of these technologies, since nonhospital settings do not provide systematic data to any agency or organization.

We created the Saidin indices using a set of technologies and weights that are defined in a base year. We then computed index values for each hospital and year using the fixed set of technologies and weights. For example, we defined a list of technologies available in 1983, determined their relative rarity in 1983, and then computed index values for hospitals in all years using the 1983 list and the 1983 weights. With the weights fixed, an increase in the index value signifies the addition of new technologies at a hospital.

Some researchers have used Guttman scales to aggregate technologies. Guttman scales were originally developed by social psychologists for the measurement of attitudes and were first introduced to health care research by Edwards, Miller, and Schumacher (1972). The Guttman scale for hospitals is a unidimensional measure in which a higher value represents a broader and/or more sophisticated level of services. The scale is defined by a set of technologies and services that might be provided by hospitals, with rarer technologies being assigned higher Guttman values. The scaling assumes a sequential acquisition of technologies and services, and a hospital is assigned the Guttman score of the highest-scoring technology the hospital provides. For example, if dialysis is less commonly offered by hospitals than ultrasound, Guttman scales assume that a hospital providing dialysis will also provide ultrasound. We believe that the Saidin index is a more robust measure of aggregate technology availability, but we repeated our analysis using Guttman scales to measure technology. Appendix B provides more detail about the theory and methods for developing Saidin indices and Guttman scales. Our findings were similar regardless of which method we used (see Appendix D).

We created Saidin indices using three different years of the AHA's *Annual Survey of Hospitals* to define the technology list and weights. We began with an index based on technologies reported in every year from 1983 to 1993, weighted by the proportion of hospitals not having the technology in 1983. The first column of Table 1 summarizes the technologies in our 1983-based Saidin index. The value in the column is the percentage of hospitals in 1983 that indicated that they did *not* have the technology. We termed the index based on the 1983 list and relative rarities "Index 83."

As new technologies are developed and diffuse through the hospital industry, the 1983 list of technologies will not appropriately measure the

Table 1

Technologies and Their Weights in the Saidin Technology Indices

	1983	1987	1991	Included in Rising Index?
Included in Index 83				
Ambulatory Surgery	21.8	17.1	18.6	
Blood Bank	34.4	36.9	40.0	
Cardiac Catheterization Lab	84.4	80.7	75.0	✓
CT Scanner	66.4	48.2	37.6	✓
Diagnostic Radioisotope	40.6	45.0	46.0	
Emergency Medicine Department	15.4	16.9	19.5	
Hemodialysis	77.5	76.1	76.7	
Histopathology Lab	38.9	41.8	43.1	
Megavoltage Radiation Therapy	85.6	84.8	83.6	✓
Neonatal ICU	79.7	71.7	71.7	✓
NMR/MRI	97.7	92.2	82.5	✓
Open Heart Surgery	89.7	87.6	85.1	✓
Organ Transplant	95.0	95.0	90.5	✓
Radioactive Implants	79.8	79.4	79.0	
Respiratory Therapy	16.5	18.0	20.1	
Therapeutic Radioisotope	78.5	78.8	78.3	
Ultrasound	30.1	25.1	26.5	
X-Ray Radiation Therapy	84.2	84.7	83.8	✓
Added to Index 87				
COPD Unit	—	41.7	41.5	
Extracorporeal Shock-Wave Lithotripsy	—	96.8	93.9	
Trauma Emergency Service	—	83.6	88.9	
Added to Index 91				
Coronary Angioplasty	—	—	82.5	
Non-Invasive Cardiac Assessment	—	—	47.1	
Orthopaedic Surgery	—	—	34.8	
PET Scanner	—	—	98.5	
Stereotactic Radiosurgery	—	—	95.4	
SPECT Scanner	—	—	80.2	

NOTE: Weights were based on 6,506, 6,425, and 6,176 hospitals in 1983, 1987, and 1991, respectively.

availability of new high-tech equipment and services. This older list and weights are also not likely to reflect the relative costs of new technologies and older technologies. Thus, the fixed technology list and fixed weights eventually become a poor indicator of the current state of the world and need to be updated. To update our measurement of technology, we created two other indices: one with technologies reported from 1987 to 1990, with 1987 weights ("Index 87"), and another with technologies reported from 1991 to 1993, weighted according to 1991 ownership levels ("Index 91"). The 1987 list included all of the technologies included in the 1983 list, plus three additional technologies shown in the second panel of Table 1. The 1991 list included all of the technologies from the 1983 and 1987 lists and added the technologies shown in the bottom panel of Table 1. The second and third numeric columns of Table 1 show the percentage of hospitals with each technology in 1987 and 1991, respectively.

Another way we could have focused our analysis on technologies that are relatively new was to create a separate Saidin index that considered only technologies that are rare or are currently diffusing. These technologies are almost exclusively provided by hospitals rather than by nonhospital clinics and laboratories. The fourth column of Table 1 indicates which technologies were deemed appropriate for a "rising" (currently diffusing) technology index. 1983 weights were used to construct this index.

Mean values for Index 83, Index 87, and Index 91 for all urban hospitals that provided sufficient data are shown in Figure 3. The means of the 1987 and 1991 indices are higher than that of 1983 because the later indices include more technologies. The mean values of the indices rise slightly over time, as expected when technology diffuses across

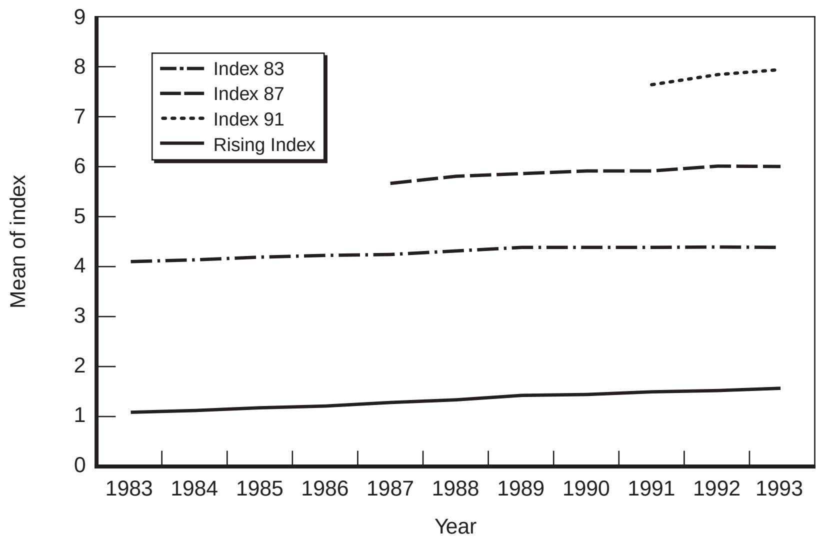


Figure 3—Means of the Technology Indices, All Hospitals

hospitals over time. A one-point rise in the 1983 index could be associated with the addition of one rare technology and one common technology, such as the addition of megavoltage radiation therapy (weight = 85.6) and respiratory therapy (weight = 16.5). A one-point increase could also be caused by the addition of several more-common technologies or services, such as an ultrasound, a histopathology laboratory, or a blood bank. It is unlikely that a hospital would add a high-weight service such as open-heart surgery without already providing lower-weight services.

Since a one-point increase in the Saidin index could indicate several different possible changes in technology availability, some of the details of technology decisionmaking may be lost. An index that summarizes the effect of managed care on a set of technologies may provide useful aggregate information but may also miss important individual effects. To examine the possibility that managed care might have different effects on the availability of different technologies, we followed our analysis of the Saidin indices with an analysis of the adoption of four specific technologies. These technologies illustrate a range of effects that managed care can have. The results suggested that the effects of managed care can vary and that caution should be exercised in applying the conclusions drawn using broad index data to individual technologies.

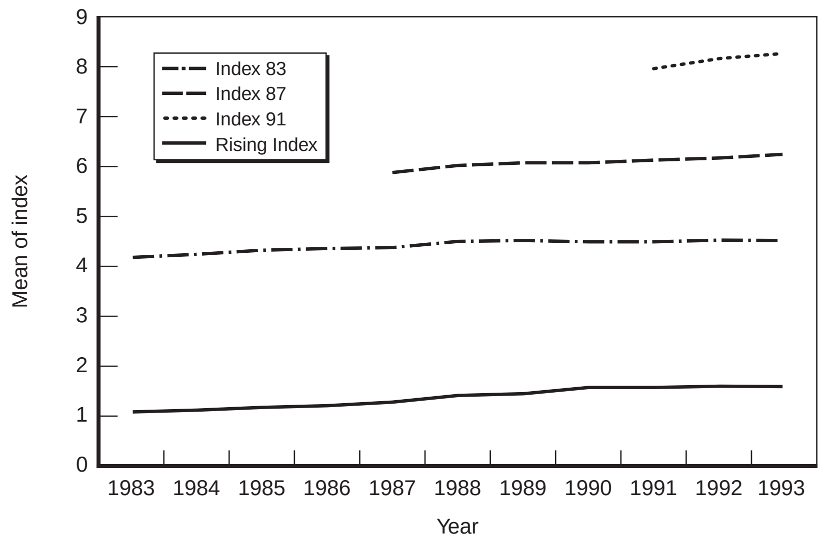
It would be ideal to study the use of medical technologies as well as their availability, because the use of technology is directly related to health care costs. Unfortunately, reliable data are not available about the use of a broad range of technologies. As cited above, some researchers have examined the use of individual technologies and services, but these studies do not enable us to draw broad conclusions about the effect of managed care on technology use and, thus, costs. Technology availability provides information about the use and cost of medical technology in two ways. First, once a clinically beneficial technology is available to patients, they use it. As described above, there is little financial incentive for patients to demand anything other than the most sophisticated services available. Second, the installation and maintenance of medical technology is expensive, whether or not the technology is being fully utilized. Thus, this study of the availability of medical technology provides substantial information about the likely cost of technology.

Examining HMO Penetration

To determine whether the growth of managed care is affecting the availability of technology, we examined the relationship between HMO penetration in a city and the availability of technology in that city. A hospital's decision to make technologies and services available will depend on many factors, such as the level of competition among hospitals, the demographics of the community, and the hospital's own size and resources. By studying differences across cities, we can learn whether HMO penetration is associated with higher *overall* levels of technology availability rather than with an *individual* hospital's technology decisions.

We identified a set of Metropolitan Statistical Areas (MSAs) in which at least one hospital provided technology information in each year from 1983 to 1993. The 261 MSAs that met this criterion tended to be larger, have more hospitals, and have higher HMO market shares than the MSAs that were excluded. We computed the mean value of the technology indices for each of the MSAs for each year; the means of the city-level indices are presented in Figure 4.

Next, we classified cities as "high-HMO" or "low-HMO" based on the share of the population insured by HMOs. High-HMO cities were defined as those with HMO penetration in the top quartile of all cities in 1993—at least 19.3 percent. The remaining three quartiles are low-HMO cities. Classifying market areas based on their 1993 HMO market share identified areas that also tended to have high market shares in earlier years and high market share growth rates over time. HMO market shares are strongly correlated over time. Table 2 reports the correlation between 1994 HMO market share and HMO market share in 1983, 1985, 1990, and 1992. Because MSA-level data are not available before 1990, state-level estimates, based on Interstudy (1995) survey data, were used for earlier comparisons. In all cases, the correlations were quite high, even over relatively long time periods.



SOURCE: Our calculations based on American Hospital Association data.

Figure 4—Means of City-Level Technology Indices

Because HMOs grew very slowly prior to the early 1980s, 1994 HMO market shares were also highly correlated with the growth rate of HMO activity between 1983 and 1994. For example, the state-level correlation

Table 2

Correlations Between 1994 HMO Market Share and Market Shares for Other Years

	Market Definition	
	State	MSA
1992 HMO market share	0.85	0.75
1990 HMO market share	0.80	0.75
1985 HMO market share	0.79	—
1983 HMO market share	0.73	—
Change in market share, 1983–1994	0.78	—
Number of observations	51	320

between 1994 HMO market share and the 1983–1994 change in HMO market share was 0.78.[1]

In principle, the availability of technology could be modeled as a function of current and lagged levels of HMO market share and/or changes in market share over time. However, in practice, the high correlations between HMO levels and growth rates do not permit separate identification of these effects. In addition, city-level data on HMO penetration are not available for most MSAs prior to 1990. Ideally, we would like to examine the relationship between all types of managed care health insurance and technology availability. However, data about non-HMO managed care plans are not available for most major cities.

The estimates of HMO market share on which we relied were constructed using data from the Group Health Association of America (GHAA) (now called the American Association of Health Plans). For each HMO in the United States, total enrollment and service area (specified by county) were obtained from annual surveys conducted by the GHAA. The results of the surveys were published in the 1994 National Directory of HMOs (GHAA, 1995). Virtually all HMOs reported their enrollment, and less than 2 percent failed to report their service area. In cases where market area data were not available from the survey, market areas were determined by reference to subsequent directories and/or telephone contact.

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[1]We examined multiple HMO penetration categories (e.g., four categories representing quartiles of HMO penetration in 1993); our conclusions were no different than those reported here. A fixed-effects regression model cannot be estimated for the full 1983–1993 panel because city-level HMO penetration is not available before 1990.

The next step was to distribute the enrollment of each HMO among the counties in its service area. Initially, this was done by distributing enrollment proportionally to county population. Since HMO enrollment may be concentrated near HMO headquarters, or since HMOs may locate their headquarters in areas where their enrollment is concentrated, more-complex estimates that incorporate both county population and distance from HMO headquarters were constructed. The correlation between estimates produced by the two methods is approximately 0.97. Estimates that incorporate both population and distance were used in this study.

Once enrollments had been distributed over service areas, we computed the total number of enrollees in each county by summing over the set of HMOs serving that county. Using the set of county enrollment estimates, we computed market share estimates as the proportion of the population enrolled in HMOs. These estimates were aggregated to the MSA level for analysis. While geographically detailed independent data on HMO market share for the whole country for these years are not available, estimates based on this algorithm were compared with estimates for selected MSAs reported by the GHAA in 1991 (Bergsten and Palsbo, 1993) and reported by Interstudy in 1994 (Interstudy, 1995). The algorithm performed relatively well in these comparisons (Baker, 1995).[2]

Using these data, we divided our sample into high-HMO and low-HMO cities. The group of high-HMO cities consisted of the top

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[2]Since the county service areas on which the series are based are quite accurate, it is likely that the series themselves are also quite accurate. Nonetheless, any allocation mechanism that produces enrollment estimates will almost certainly lead to measurement error in some cases. Aggregating market shares to the MSA level should dampen the effects of any misestimation of market shares that may have occurred at the county level.

quartile of cities, ranked by HMO penetration. The group of low-HMO cities consisted of all other cities. We relied on 1993 data to create the groupings, but we examined the sensitivity of our findings to variation in the year used for indexing and found that the results were not sensitive to the year used (see Appendix D). In the 65 high-HMO cities, at least 19.3 percent of the population was insured by an HMO in 1993. Table 3 presents mean HMO penetration for the two subsamples for California and the United States. Average HMO penetration in the 196 low-HMO cities was 7.9 percent in 1993, while average penetration in high-HMO cities was over 30 percent. HMO penetration was higher in California in every year in both high-HMO and low-HMO cities. A large share of California's cities have high levels of HMO penetration—over two-thirds of California's cities are in the national high-HMO category. Thus, it should be expected that HMOs' effects on technology availability would be particularly important in California. We did not analyze California

Table 3

Mean HMO Penetration in High-HMO and Low-HMO Cities

	Low-HMO Cities		High-HMO Cities	
Year	Mean	Std. Dev.	Mean	Std. Dev
United States[a]				
1990	6.5%	0.057	24.8%	0.097
1991	6.7%	0.055	25.5%	0.097
1992	7.1%	0.056	27.3%	0.094
1993	7.9%	0.057	30.2%	0.091
California[b]				
1990	6.7%	0.041	33.0%	0.107
1991	7.3%	0.042	33.6%	0.105
1992	8.8%	0.043	35.8%	0.097
1993	10.3%	0.045	37.7%	0.100

[a]196 low-HMO cities; 65 high-HMO cities.

[b]6 low-HMO cities; 14 high-HMO cities.

separately because there is not enough variation in HMO penetration across the state to permit multivariate analyses.

Controlling for Other Factors That Affect Technology

Many factors other than HMO penetration could affect the availability of technology within a city. It is possible that relationships observed between technology availability and HMO penetration might be caused by differences in demographics, the economy, or the hospital industry. We estimated multivariate ordinary-least-squares regression equations to control for these potentially confounding factors. We tracked technology availability in markets controlling for (1) measures of population demographics (including the log of population, the log of population per square mile, per-capita income, and the percentage of population over age 65);[3] (2) characteristics of the health care system (including the log of the number of physicians per capita, the log of the number of hospital beds per capita, the mean number of hospital admissions per capita, and the coefficient of variation of admissions per capita); and (3) characteristics of area hospitals (including the number of hospitals with a residency program, the number affiliated with a medical school, the number that are Council of Teaching Hospitals (COTH) members, the proportion of hospitals that are members of a health system, the proportion that are for-profit, the proportion that are

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[3]We also considered the percentage of the population insured by Medicaid as a measure of income distribution and poverty in the city. Unfortunately, these data were not available from the Bureau of Health Professions' *Area Resource File* for a significant share of cities in certain years. The results of the analysis did not change significantly when Medicaid information was added to the model, even with the abridged sample.

government-owned, and the average distance between hospitals).[4] A set of year dummy variables controls for time trends. In this model, the effect of HMOs is captured by a dummy variable for high-HMO areas. The high-HMO market share dummy is interacted with year dummies to allow separate effects of HMOs in each year.

The control variables that pertain to the hospitals in each city were created from the AHA's *Annual Survey of Hospitals*. Data about the cities were obtained from the Bureau of Health Professions' *Area Resource File* and the U.S. Bureau of the Census. Table 4 presents summary information about demographics and the hospital environment for the cities included in our analysis.

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[4] We used logarithms of population, population per square mile, physicians per capita, number of hospitals, and average distance between neighboring hospitals, because the distributions of these variables are skewed.

Table 4

Summary Statistics for Cities Included in the Analysis

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1983
Demographic characteristics											
Population (100s)	6071	6125	6211	6291	6371	6451	6510	6569	6674	6760	6846
	(9626)	(9679)	(9825)	(9957)	(10107)	(10213)	(10306)	(10402)	(10525)	(10637)	(10751)
Population (100s)/square mile	2.93	2.95	2.98	3.01	3.04	3.07	3.09	3.11	3.16	3.19	3.23
	(2.86)	(2.87)	(2.91)	(2.93)	(2.97)	(3.00)	(3.02)	(3.05)	(3.08)	(3.10)	(3.13)
Percentage over age 65	11.13	11.31	11.47	11.63	11.83	11.95	12.15	12.22	12.28	12.35	12.41
	(2.98)	(2.98)	(3.00)	(3.02)	(3.03)	(3.03)	(3.05)	(3.19)	(3.19)	(3.21)	(3.24)
Income per capita (nominal)	11117	12092	13042	13637	14406	15313	16324	17353	17794	18779	19763
	(1704)	(1898)	(2172)	(2360)	(2530)	(2771)	(2977)	(3000)	(3058)	(3119)	(3267)
Physicians per capita	0.19	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.22	0.22	0.22
	(0.14)	(0.14)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)
Hospital characteristics											
Number of hospitals	9.66	9.62	9.52	9.22	9.39	9.31	9.20	9.06	8.91	9.39	9.07
	(13.30)	(13.01)	(12.59)	(12.11)	(12.20)	(11.92)	(11.70)	(11.36)	(11.11)	(12.35)	(11.54)
Miles between neighbors	8.25	8.18	8.17	8.26	8.30	8.21	8.29	8.33	8.22	8.51	8.66
	(5.64)	(5.12)	(5.12)	(5.28)	(5.40)	(5.30)	(5.40)	(5.44)	(5.26)	(5.24)	(5.72)
Average admissions	10635	10512	10219	10161	10164	10350	10563	10832	11076	11264	11389
	(3259)	(3165)	(3061)	(3131)	(3153)	(3241)	(3404)	(3472)	(3546)	(3589)	(3539)
Coef. of variation—admissions	0.71	0.72	0.72	0.72	0.73	0.74	0.74	0.74	0.74	0.73	0.74
	(0.27)	(0.27)	(0.27)	(0.26)	(0.26)	(0.27)	(0.27)	(0.27)	(0.27)	(0.26)	(0.26)
Number with residency	3.15	3.12	3.14	3.12	3.08	3.08	3.08	3.12	3.10	3.11	3.02
	(4.61)	(4.59)	(4.61)	(4.64)	(4.58)	(4.57)	(4.61)	(4.62)	(4.56)	(4.49)	(4.31)
Number with medical school	3.02	2.92	2.94	2.93	2.90	3.25	3.23	3.08	2.78	2.99	3.01
	(4.38)	(4.29)	(4.36)	(4.31)	(4.27)	(5.01)	(5.01)	(4.62)	(4.10)	(4.59)	(4.59)
No. with COTH membership	1.23	1.32	1.33	1.33	1.25	1.26	1.17	1.12	1.13	1.12	1.15
	(2.45)	(2.55)	(2.58)	(2.57)	(2.49)	(2.50)	(2.38)	(2.23)	(2.23)	(2.26)	(2.27)
Percentage in health systems	21.5	28.1	34.6	41.2	40.0	42.1	42.2	45.5	51.1	50.3	52.7
Percentage government-owned	16.9	16.1	15.4	15.1	15.3	15.2	14.9	15.0	14.9	14.8	15.2
Percentage for-profit owned	12.5	12.6	13.1	14.0	14.4	13.9	13.9	13.3	13.0	13.2	13.4

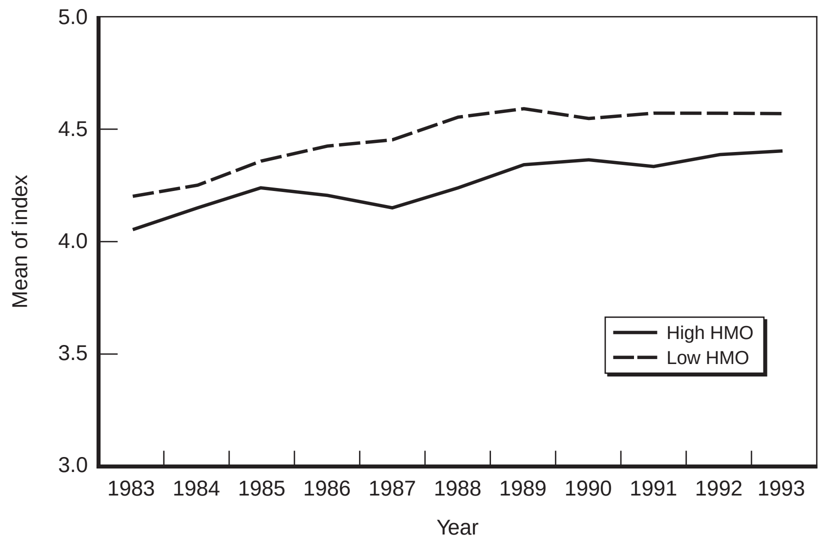
NOTES: Standard errors are in parentheses. There are 261 cities in the sample.

4. Technology Availability and HMOs

Average Technology Levels in High- and Low-HMO Cities

Our analysis of the effect of HMOs on the availability of medical technology began with a comparison of average city-level technology availability in hospitals without controlling for other factors that might affect technology availability. Figure 5 presents the average of city-level mean Saidin indices based on 1983 weights for high- and low-HMO markets from 1983 to 1993. In 1983, high-HMO cities had a lower mean technology level than did low-HMO cities. Through the mid-1980s, technology availability appears to have grown more slowly in high-HMO markets, but this difference is not statistically significant.

As noted above, the index based on the 1983 list of technologies and weights does not capture newly emerging technologies. Figures 6 and 7 present the means of Index 87 and Index 91 for high- and low-HMO

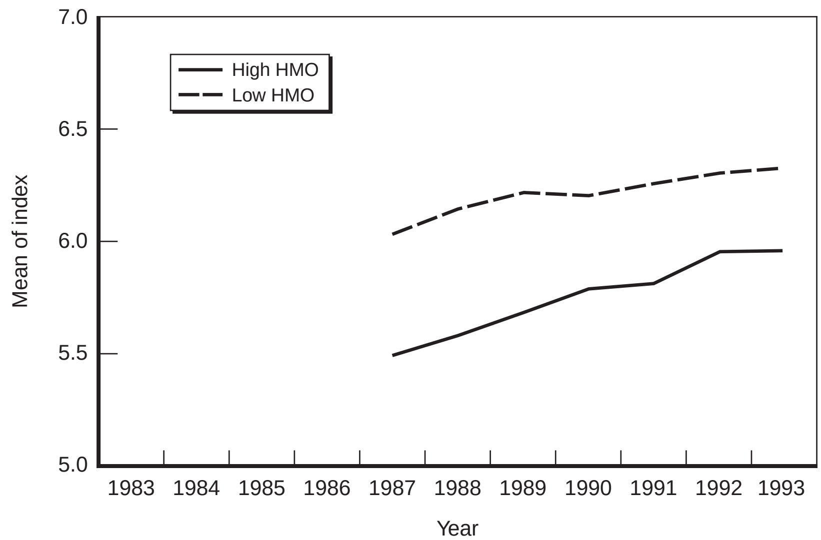


SOURCE: Our calculations based on American Hospital Association data.

Figure 5—Mean Level of Technology in High-HMO and Low-HMO Cities, 1983–1993, Basic Technology Index 83

cities. Because these indices are updated to include technologies added to the AHA survey, they are more likely to reveal differences in the availability of new technologies caused by managed care. As was seen with the 1983 Saidin index, however, Figures 6 and 7 do not reveal statistically significant differences between high- and low-HMO cities in the growth of the availability of technology. High-HMO cities have lower average technology levels throughout the time period we examined.

Managed care might have different effects on hospital decisions regarding technologies that have already diffused than on technologies that are currently diffusing. The rising technology index enables us to see if HMOs slow the diffusion of new or rare technologies. Figure 8



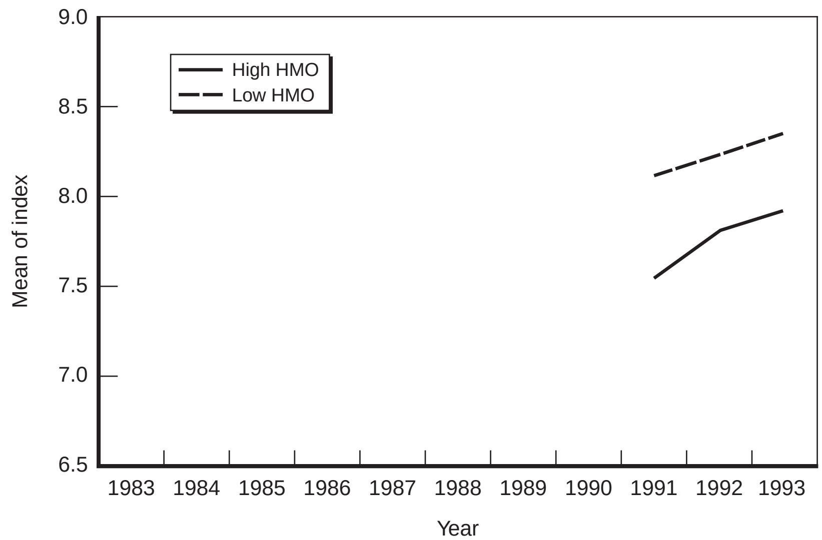
SOURCE: Our calculations based on American Hospital Association data.

Figure 6—Mean Level of Technology in High-HMO and Low-HMO Cities, 1983–1993, Basic Technology Index 87

graphs the mean of this index for high- and low-HMO cities. Between 1983 and 1987, high-HMO cities appear to have slightly slower growth than low-HMO cities. However, this difference is not statistically significant and disappears after 1987.

HMOs and Technology Availability, Controlling for Other Factors

The patterns observed in the means of the city-level Saidin indices might be associated with changes in demographics, the economy, or the hospital industry. Figures 9 through 12 present predicted values of the city average technology indices, controlling for the hospital and market

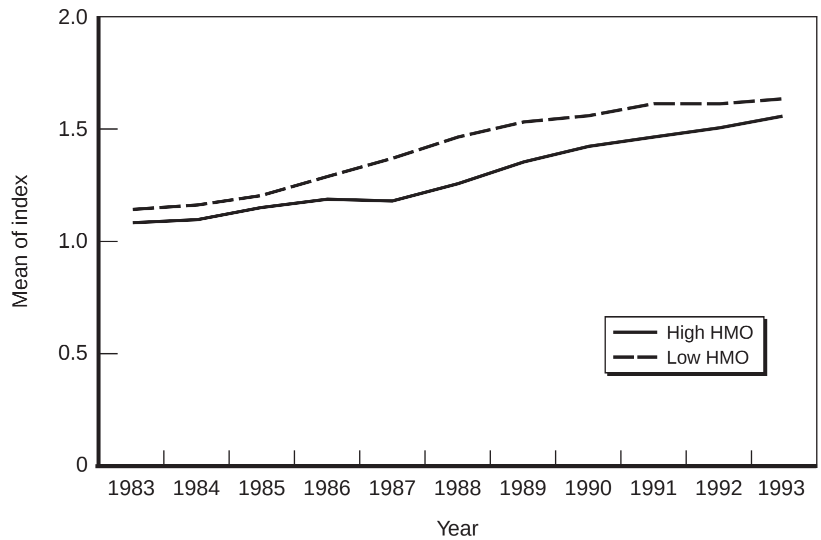


SOURCE: Our calculations based on American Hospital Association data.

Figure 7—Mean Level of Technology in High-HMO and Low-HMO Cities, 1983–1993, Basic Technology Index 91

characteristics described in Chapter 3, using multivariate ordinary-least-squares regression models.[1] As seen in these figures, cities with high levels of HMO penetration did not experience significantly different growth in technology availability than cities with lower HMO penetration. For Index 83, high-HMO cities appear to have a slightly higher technology level than low-HMO cities. After 1986, low-HMO cities display greater average technology availability. However, none of the differences between high- and low-HMO cities was statistically significant.

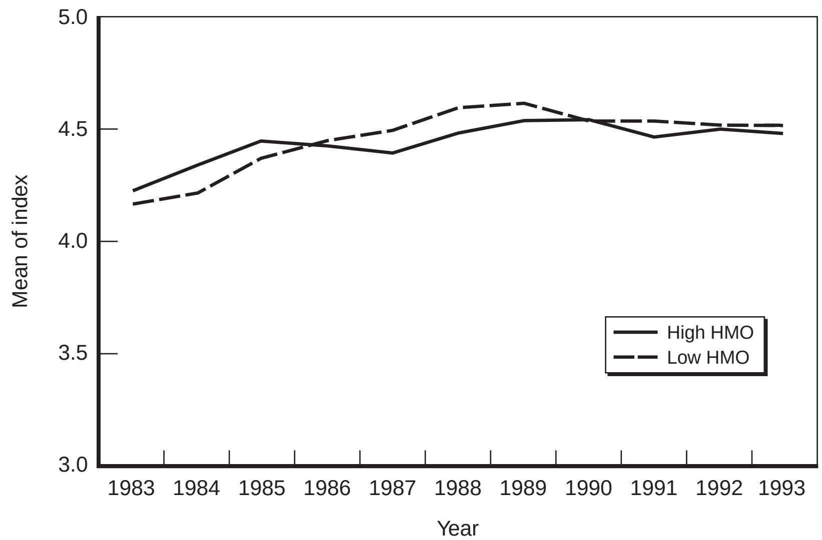
[1]The predicted values are computed at the mean of the independent variables. Complete regression results are presented in Appendix C. The standard errors presented here were not corrected for heteroskedasticity; heteroskedasticity corrections generally increase the standard errors and do not change the conclusions reached in this report.



SOURCE: Our calculations based on American Hospital Association data.

Figure 8—Mean Level of Diffusing Technology in High-HMO and Low-HMO Cities, 1983–1993, Diffusing Technology Index 83

Figures 10 and 11 present the predicted values of Index 87 and Index 91. From 1987 through 1993, high-HMO cities had higher expected average technology levels, controlling for demographic and market characteristics. The graph of Index 87 suggests that high-HMO cities might have experienced slightly higher growth rates of technology between 1987 and 1993, but the differences between predicted technology levels are not statistically significant except in 1989. There were no statistically significant differences between high- and low-HMO cities in the availability of technology between 1991 and 1993 as measured by Index 91.

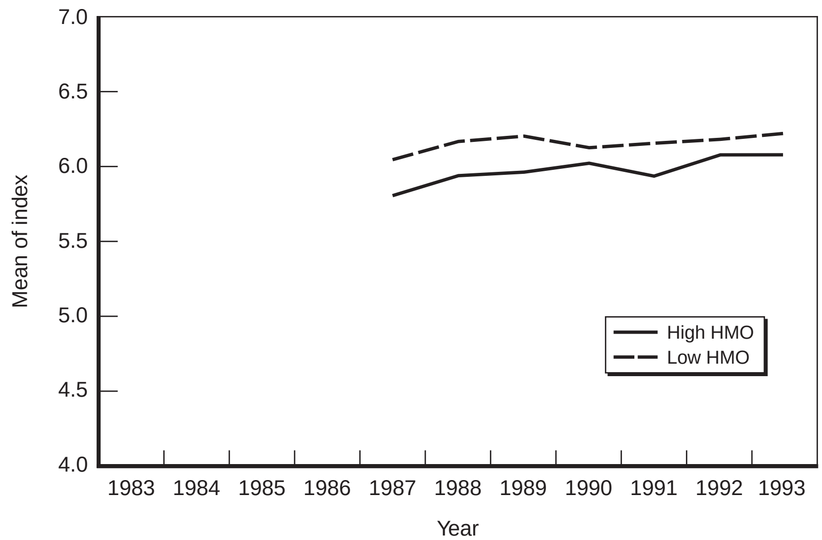


SOURCE: Our calculations based on American Hospital Association data.

Figure 9—Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics, Basic Technology Index 83

The index of technologies that are diffusing also indicates that there was no difference in technology availability or growth between high- and low-HMO cities. Figure 12 presents the predicted values of this index from the regression model described above. As with Index 83, high-HMO cities had slightly higher technology levels from 1983 to 1986 and then had lower levels from 1987 to 1993. None of these differences was statistically significant.

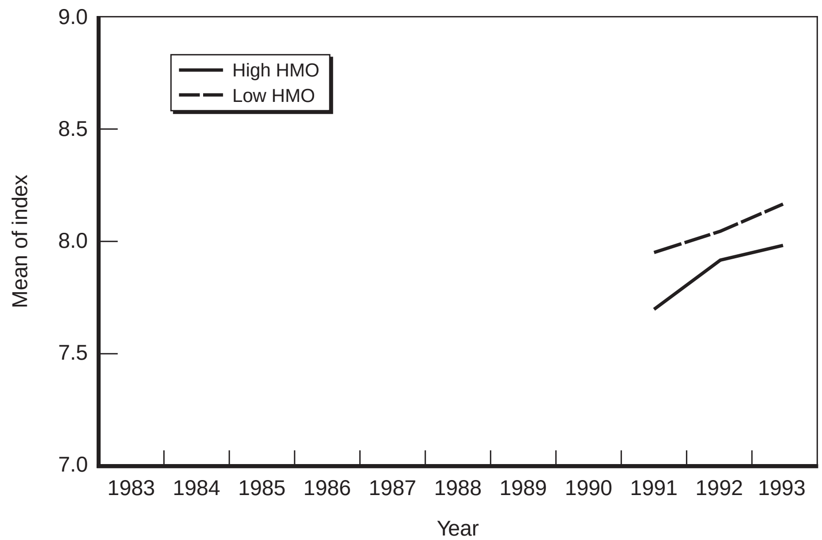
The coefficients of the control variables in these equations generally follow our expectations. The mean technology level in a city rises as the average number of admissions in the city's hospitals increases. Higher variation in the number of admissions across hospitals within a city also was associated with a lower average technology level, probably because



SOURCE: Our calculations based on American Hospital Association data.

Figure 10—Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics, Basic Technology Index 87

the smaller hospitals in that city did not invest in technology, while the largest hospitals maintained high levels of technology. Average technology levels were higher in cities with more physicians per capita and with more hospitals with residency programs. A larger population was associated with a lower mean Saidin index, holding other characteristics constant. This suggests that population growth does not itself lead hospitals to provide more-sophisticated services, but that population growth's effect on the number of hospital admissions and other characteristics can increase availability of technology. Cities with a higher share of hospitals with membership in health care systems also tended to have higher average levels of technology availability. Finally,

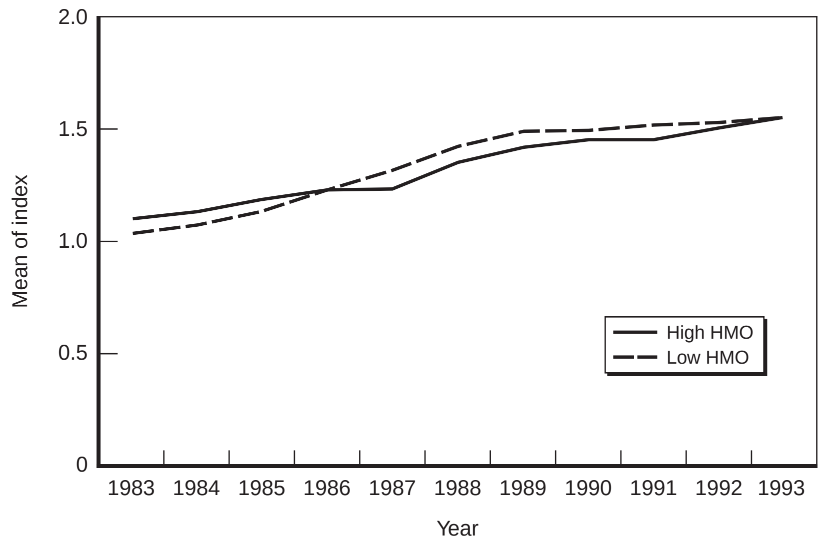


SOURCE: Our calculations based on American Hospital Association data.

Figure 11—Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics, Basic Technology Index 91

cities with smaller shares of government-owned and higher shares of for-profit hospitals had lower mean Saidin indices.

The results presented in this section suggest that managed care has not slowed the growth of technology, at least in recent years. High market share areas may have had higher index values in the early 1980s, but by the later 1980s and through the early 1990s high market share areas had lower index values. The differences in the early 1980s were not statistically significant. It is possible that the drop in technology availability in high-HMO cities in the early 1980s occurred because HMOs chose to expand in cities where technology had already diffused rapidly and thus there was greater opportunity for cost control. Results



SOURCE: Our calculations based on American Hospital Association data.

Figure 12—Effect of HMOs on Diffusing Technology, Controlling for Hospital and Market Characteristics, Rising Technology Index 83

for both Index 87 and Index 91 indicated that index values increased as rapidly in high market share areas as in low market share areas.

Are These Findings Robust?

One issue that may complicate this analysis is hospital closure. The closure of hospitals with relatively few technologies would tend to raise the average index in a city. If there are different rates of hospital closures across areas with high- and low-HMO market shares, we could misestimate the effects of HMOs. The same concern applies to the possibility of different rates of hospital mergers between high- and low-HMO cities. In our data, the mean number of hospitals per MSA falls by about 9 percent between 1983 and 1993 in high-HMO market share areas but only about 3 percent in low-HMO market share areas. Further, the hospitals that closed in high market share areas were disproportionately low-technology hospitals; this could artificially inflate the mean index value and would cause us to understate the technology-reducing effects of HMOs. We examined whether this is a problem using two methods. First, we added a control variable for the number of hospitals in markets to the regression equations and found that this did not change our conclusions. We interpret this as evidence that differential rates of hospital closure do not have a strong influence on our findings. Second, we repeated our analyses using a balanced panel of hospitals—that is, we limited our analysis to hospitals that were observed in every year of our analysis. The results are presented in Appendix D and are very similar to those presented here. Thus, we do not believe that hospital closures affect our conclusion that HMOs did not have an effect on technology availability in U.S. cities.

We conducted numerous other analyses to confirm that our results are robust. First, we examined the mean of Guttman scales across cities. Second, we defined high-HMO markets according to HMO penetration in 1990 instead of 1993. Third, we examined whether our results were dependent on our restriction that every city is observed in every year of our analysis. Fourth, we studied whether hospital closures might bias our results. In all cases, the results were very similar to those presented in Figures 9 through 12. Details are presented in Appendix D.[2]

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[2]We examined other potential problems with our analysis. In particular, we tried controlling for the skewed distribution of the number of hospitals across markets by adding the log of the number of hospitals as an independent variable, we dropped potentially endogenous variables, such as number of physicians and admissions, and we replaced log (population) with population and population squared to see if nonlinearity in the city size is important. None of these changes affected the HMO-technology availability relationship. Details are available from the authors upon request.

5. The Interaction Between HMO Penetration and Competition Among Hospitals

Measuring Hospital Competition

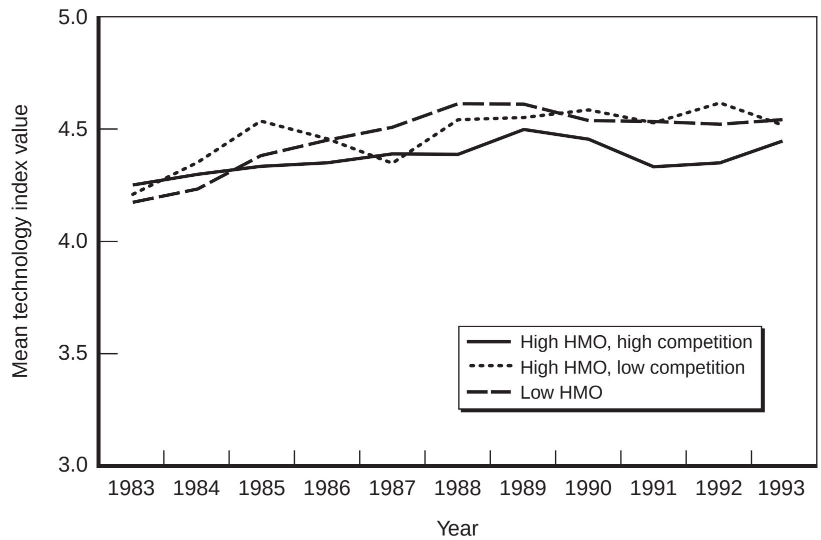
One factor that could influence the ability of managed care to affect technology availability is hospital competition. As discussed by McLaughlin (1988), HMOs might have less bargaining power in markets with a few dominant hospitals than in markets with many competing hospitals. Hospitals also might compete more aggressively for contracts with insurers in more competitive markets. This competition could take the form of either lower prices or a medical arms race.

We explored the relationship between HMO penetration and competition among hospitals by computing a Hirschman-Herfindahl index (HHI), a common measure of the degree of competition in a market (Tirole, 1990), for hospitals in each city. This index is the sum of squared market shares of hospitals in a city; it ranges from 0 to 1. An

HHI of 1 would exist in a one-hospital market. A market consisting of two equal-size hospitals would have an HHI of 0.5. As discharges become spread over a larger number of hospitals, the HHI becomes smaller. We then divided cities into two categories based on their 1993 HHI: Highly competitive cities were those with HHIs in the lowest quartile, and all others were grouped as less competitive cities. We added this variable to the models described above and interacted it with the high-HMO market share dummy variable in each year to see if the effects of HMOs vary by the degree of hospital competition. There were 32 cities with high-HMO penetration that had highly competitive hospital markets, and 33 high-HMO cities with less competitive hospital markets. We did not separate low-HMO cities into high- and low-competition groups because relatively few cities had both high levels of hospital competition and low-HMO penetration. HMOs clearly prefer to locate in more-competitive hospital markets.

The Effects of Hospital Competition and HMOs on Technology Availability

Figure 13 presents predicted values of the city average-technology indices for Index 83 for low-HMO cities, high-HMO highly competitive cities, and high-HMO less competitive cities. As in the simple high- and low-HMO analysis, the differences in technology availability depicted in this chart are not statistically significant. High-HMO cities with a high level of hospital competition appear to have had slower growth in technology availability between 1983 and 1986—after which time, the growth in technology appears similar. Overall, there is no net difference between low-HMO cities and less competitive cities with high-HMO penetration. The results presented in this figure do not suggest that

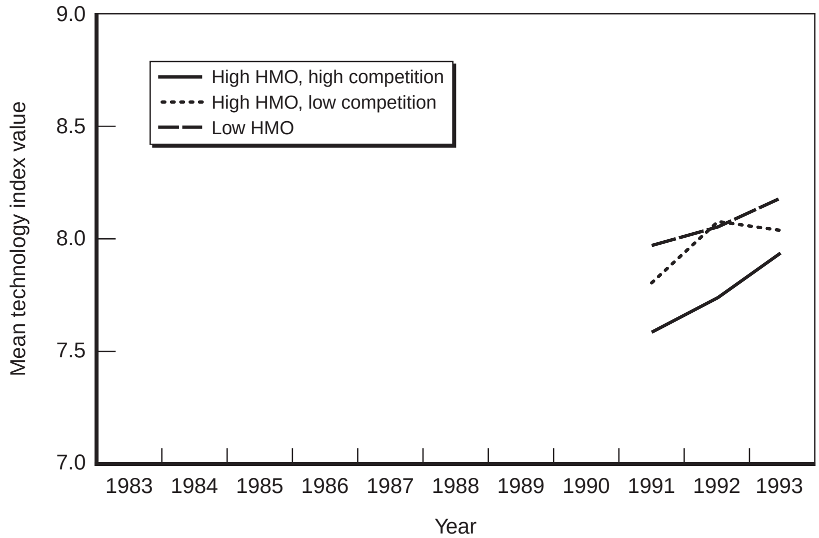


SOURCE: Our calculations based on American Hospital Association data.

Figure 13—Effect of HMOs and Hospital Competition on Technology, Controlling for Hospital and Market Characteristics, Basic Technology Index 83

HMOs have had a significant effect on technology availability in either more or less competitive hospital markets.

We conducted the same analysis for Index 87 and Index 91. The pattern of technology availability identified by Index 87 was essentially the same as that presented for Index 83. Figure 14 presents the predicted values for Index 91. In 1991, highly competitive cities with less HMO penetration had statistically significantly lower levels of technology than low-HMO and less competitive cities. By 1993, technology availability had risen in highly competitive high-HMO cities so that this difference was no longer statistically significant. This suggests that over this short period of time, there may have been more technology growth in certain high-HMO cities.

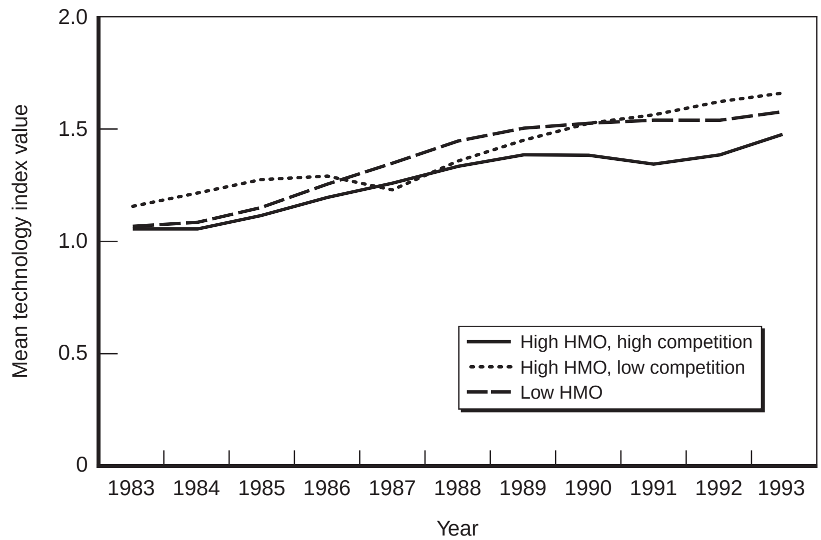


SOURCE: Our calculations based on American Hospital Association data.

Figure 14—Effect of HMOs and Hospital Competition on Technology, Controlling for Hospital and Market Characteristics, Basic Technology Index 91

The possibility that high-HMO cities with a high degree of hospital competition may have had more rapid technology growth in the early 1990s is also seen when analyzing the technology index for diffusing technologies. Figure 15 presents predicted values for this index, controlling for confounding characteristics. Between 1983 and 1991, there was slower growth in this index among highly competitive high-HMO cities. The technology indices are statistically significantly different in 1991 and 1992. However, by 1993 highly competitive high-HMO cities experienced more rapid growth in technology availability, so that the differences were not statistically significant in 1993.

Overall, it does not appear that HMOs had different effects on general technology availability in cities with high and low levels of



SOURCE: Our calculations based on American Hospital Association data.

Figure 15—Effect of HMOs and Hospital Competition on Technology, Controlling for Hospital and Market Characteristics, Rising Technology Index 83

hospital competition. However, the availability of newer technologies may have been affected in highly competitive cities. As seen with the Saidin index for diffusing technologies, there was slower growth in technology availability between 1983 and 1991 among high-HMO cities with competitive hospital markets. Between 1991 and 1993, there was more rapid growth in technology availability in these same cities as measured by Index 91 and by the diffusing Saidin index. Whether this recent change is a transitory or permanent relationship is unknown.

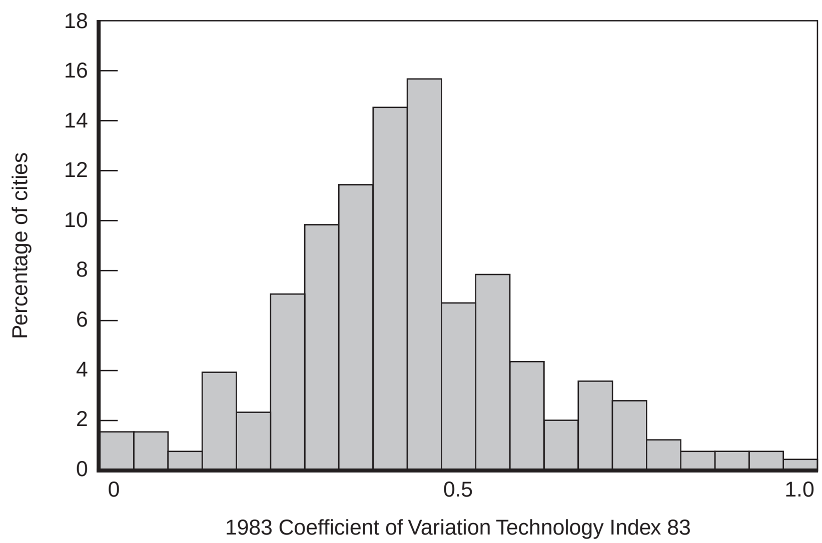
It should be noted that HMO market share and hospital competition might be closely related, since HMOs may influence the behavior of hospitals and hospital competition may influence the decisions HMOs make about entry into markets. Since these two variables are probably correlated, our regression analyses may not be able to accurately determine the separate contribution of HMOs and hospital competition.

6. Variation in Technology Availability Within Cities

It is possible that managed care changes the distribution of technologies across hospitals. By encouraging consolidation of high-tech services into fewer hospitals, managed care could, on the one hand, regionalize services by having relatively few high-level medical centers that receive referrals from other hospitals. On the other hand, if hospitals perceive the need to compete for managed care contracts through technology adoption, managed care may promote even technological development across hospitals.

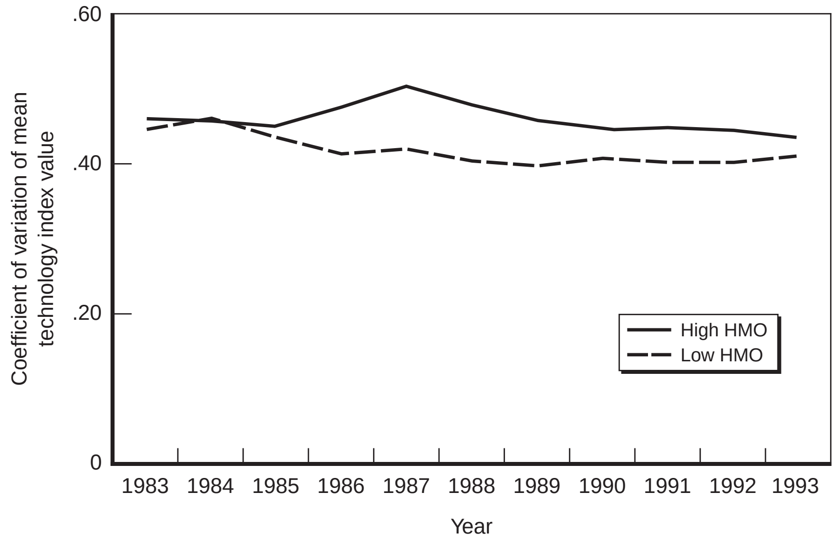
To examine whether HMO market share is associated with the dispersion of technologies across hospitals, we computed the coefficients of variation of our technology indices within 254 MSAs that had more than one hospital. The coefficient of variation is defined as the standard deviation of the technology index divided by its mean. A high coefficient of variation in a market suggests that the technology levels of hospitals in that market vary widely, with some hospitals having high index values and others having lower index values. Low coefficients of variation indicate markets in which hospitals have similar levels of technology.

Figure 16 graphs the distribution of the coefficient of variation for Index 83 across markets in 1983. The coefficients of variation range from 0.05 to about 1. The average value of the coefficient of variation is rather stable over time, as seen in Figure 17. It remains between 0.4 and 0.45 in almost every year. Between 1983 and 1985, high-HMO and low-HMO cities had almost identical coefficients of variation, indicating that there was no difference in the degree of regionalization. After 1985, however, the coefficient of variation was higher in high-HMO cities than in low-HMO cities.



SOURCE: Our calculations based on American Hospital Association data.

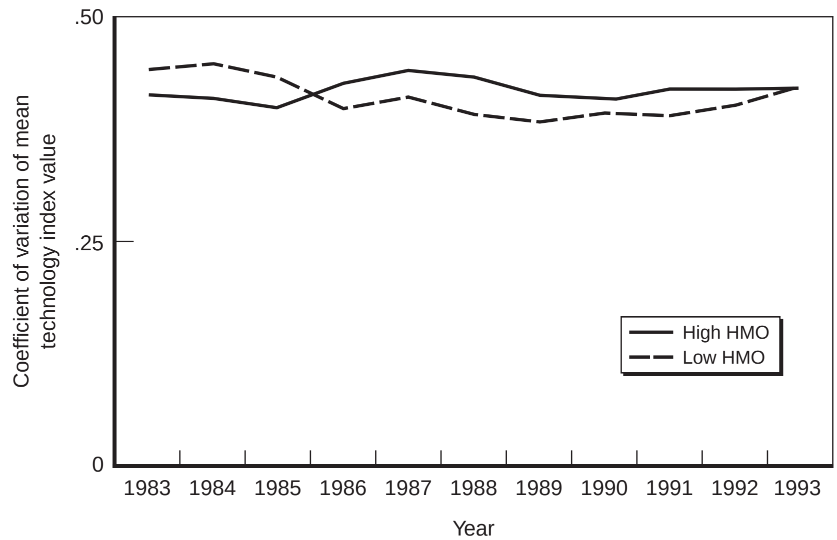
Figure 16—Distribution of 1983 Values of the Coefficient of Variation for Index 83



SOURCE: Our calculations based on American Hospital Association data.

Figure 17—Coefficient of Variation of Technology Index in High-HMO and Low-HMO Cities, 1983–1993, Basic Technology Index 83

To see whether this association between HMO market share and the coefficient of variation is statistically different from zero, we estimated regression equations analogous to those described above that explain the coefficient of variation as a function of HMO market share and other market and hospital characteristics. In general, we found no relationship between HMO market share and the dispersion of technology index values within markets. Results using Index 83 are presented graphically in Figure 18. Controlling for confounding characteristics, low market share areas had somewhat higher coefficients of variation in 1983 than high-HMO cities. Between 1986 and 1992, high market share areas had slightly higher coefficients of variation, and the coefficients were nearly



SOURCE: Our calculations based on American Hospital Association data.

Figure 18—Effect of HMOs on the Coefficient of Variation of Technology Level, Controlling for Hospital and Market Characteristics, Basic Technology Index 83

identical in 1993. There are no statistically significant differences between high- and low-HMO areas. We repeated this analysis separating highly competitive from less competitive high-HMO cities and found no differences across these groups.

It appears that managed care did not encourage regionalization of medical services, as evidenced by the lack of differences in the coefficients of variation. It is possible that managed care contributed to the regionalization of some services within particular hospitals, but regionalized different services into other hospitals.

7. Availability of Specific Technologies

Why HMOs Should Have Different Effects on Different Technologies

For the question we examined in this report—the effect of HMOs on technology availability—it is possible that the effect of managed care varies from technology to technology. When deciding whether to adopt a new technology, hospitals and other providers will compare the costs and benefits of the new technology, and adopt it if the benefits exceed the costs. An important benefit of adopting a new technology is the profit that can be generated by offering the new service. Profits depend on the cost and demand for the service, the price that can be charged, and the broader benefits that may accrue if adoption increases the standing of the hospital in the eyes of consumers or improves the hospital's bargaining position in negotiations with health plans.

Managed care can influence the profitability of adopting a new technology in a number of ways. Most important, managed care may change demand for services. Managed care organizations have a strong incentive to minimize costs, which may lead them to identify and support services that have high benefit-to-cost ratios. If they are adept at steering their patients toward cost-effective services and away from cost-ineffective services, they will change the demand for some technologies. The extent to which demand changes will vary with the cost-effectiveness of the services produced by the technology in question.

Managed care organizations also may influence technology availability through negotiation processes. Since managed care organizations typically prefer to contract with hospitals that have low costs and high quality, hospitals may prefer to adopt technologies consistent with these characteristics. Thus, variation in the costs and perceived quality of technologies may drive variation in the effect of managed care on them.

An Analysis of Four Individual Technologies

To investigate variation among some different technologies, we examined the availability of four technologies—open heart surgery, cardiac catheterization laboratories, diagnostic radioisotope units, and neonatal intensive care. These technologies vary in the degree to which they represent specific pieces of new equipment or represent reorganization and application of existing equipment. They also have different costs of adoption and operation. Finally, the time at which each was introduced varies.

We analyzed these technologies using models analogous to those used above for the technology indices. For each technology, we estimated a model that identified a time trend for high- and low-HMO market share cities, controlling for hospital and market characteristics.[1] The dependent variable was the number of hospitals that had the technology or service. Results are presented in Figures 19 through 25.

Open Heart Surgery

Open heart surgery is widely recognized by the public as an important specialized service. Open heart surgery can include the availability of several different surgical procedures, including coronary artery bypass graft, valve replacement, and surgery to correct congenital defects. The AHA survey does not specify which procedures should be included in open heart surgery; thus, it is possible that this variable is inconsistent across hospitals. Several studies have found that adverse outcomes are more prevalent when surgical volume declines (Luft et al., 1990b); this has prompted professional organizations to recommend that hospitals perform 150 to 200 procedures annually in their open heart surgery facilities (DeWeese et al., 1991; Chernew, Hayward, and Scanlon, 1996). The concentration of open heart surgery into a smaller number of hospitals could thus improve health outcomes.

In the early 1980s, high-HMO cities had a smaller number of open heart surgery units than low-HMO cities, although the difference between these groups was not statistically significant (Figure 19). This pattern persisted until 1993, when high-HMO cities had slightly more open heart surgery units on average than low-HMO cities. Again, this difference was not statistically significant. We find a different effect of

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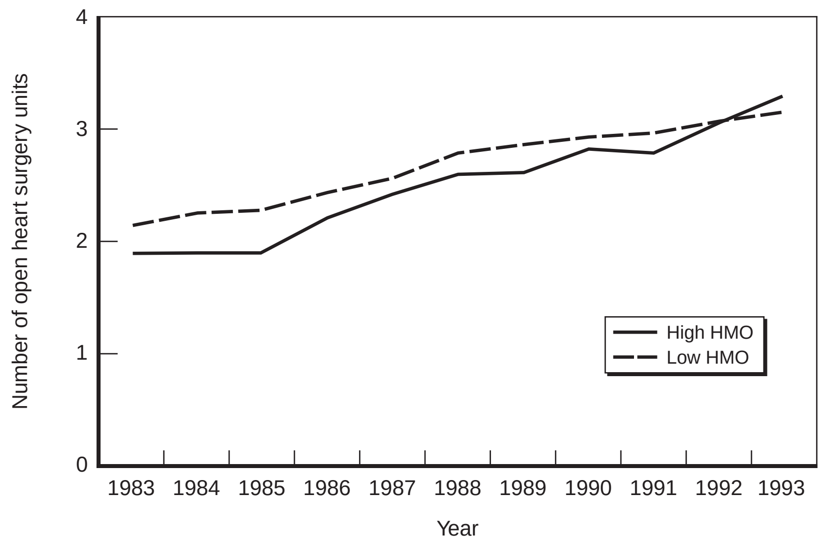
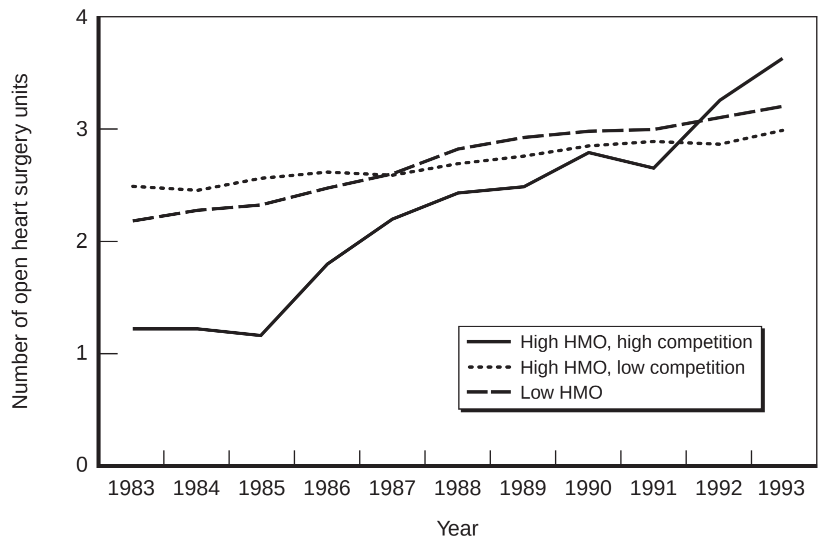
[1]Alternatively, we could have estimated an ordered probit in which the number of neonatal intensive care units in the market is the dependent variable. See Dranove, Shanley, and Simon, 1992.



SOURCE: Our calculations based on American Hospital Association data.

Figure 19—Effect of HMOs on the Number of Open Heart Surgery Units in a Market, Controlling for Hospital and Market Characteristics

HMOs, however, when we separate highly competitive high-HMO cities from less competitive cities, as seen in Figure 20. In the early and mid-1980s, high-HMO cities with more competitive hospital markets had a lower average number of open heart surgery units than other markets. This statistically significant difference disappeared over the late 1980s and early 1990s as highly competitive high-HMO cities experienced more rapid diffusion of open heart surgery than other cities. Thus, in cities with high levels of competition among hospitals, HMOs may have increased the rate of diffusion of this expensive service.



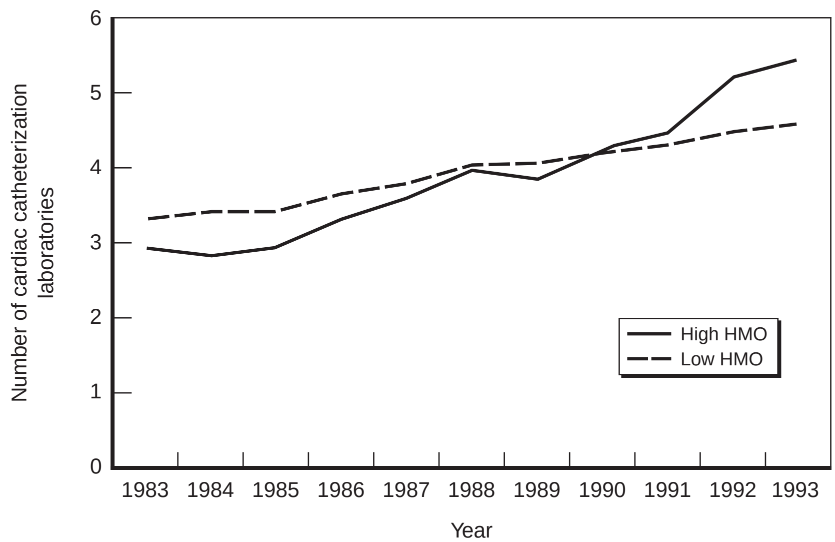
SOURCE: Our calculations based on American Hospital Association data.

Figure 20—Effect of HMOs and Hospital Competition on the Number of Open Heart Surgery Units in a Market, Controlling for Hospital and Market Characteristics

Cardiac Catheterization Laboratories

Cardiac catheterization is a widely practiced diagnostic procedure in which a small tube is threaded into coronary arteries to view their condition. Sometimes cardiac catheterization is paired with angioplasty, in which a small balloon at the end of the catheter is inflated to compress the blockage and open the artery. Thus, cardiac catheterization is often tied to the availability of open heart surgery. This technology diffused into hospitals during the 1980s and 1990s. The American College of Cardiology and the American Health Association have expressed concern that there are may be an oversupply of cardiac catheterization facilities (Pepine et al., 1991). The Inter-Society Commission on Heart Disease has recommended that facilities perform at least 300 diagnostic procedures annually to ensure high-quality care (Inter-Society Commission on Heart Disease, 1982).

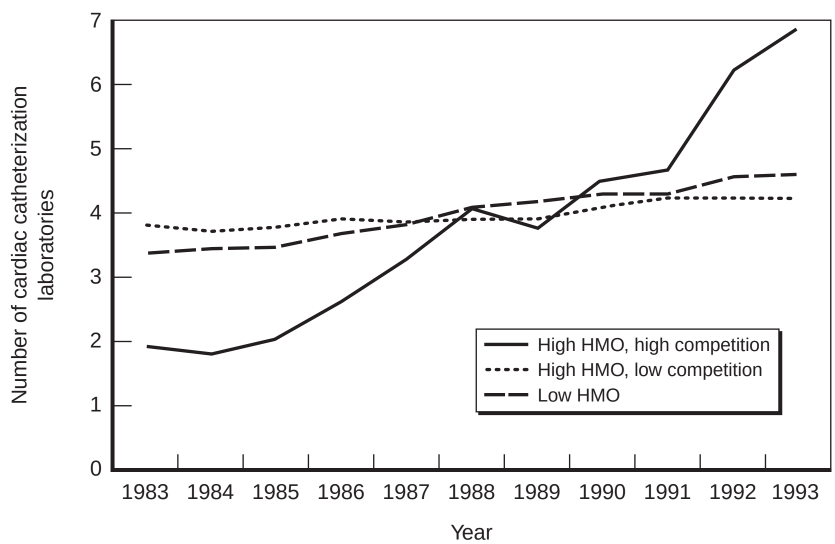
Figure 21 presents the predicted number of cardiac catheterization labs in high-HMO and low-HMO cities, controlling for market and demographic characteristics. High-HMO market share areas had fewer cardiac catheterization labs through the 1980s, but availability in high-HMO market share areas grew more rapidly. By the early 1990s, high-HMO cities had more hospitals with cardiac catheterization labs than cities with lower-HMO market shares. The difference between high and low market share areas is statistically significant in 1992 and 1993.



SOURCE: Our calculations based on American Hospital Association data.

Figure 21—Effect of HMOs on the Number of Cardiac Catheterization Labs in a Market, Controlling for Hospital and Market Characteristics

When high-HMO cities were split into categories based on the degree of competition between hospitals, we did not see a difference between less-competitive high-HMO cities and low-HMO cities (Figure 22). High-HMO cities with more hospital competition, however, experienced rapid growth in the availability of cardiac catheterization. They had a significantly lower average number of labs from 1983 to 1986 and a significantly higher number in 1992 and 1993. As with open heart surgery units, HMO penetration may have exacerbated the medical arms race for cardiac catheterization.



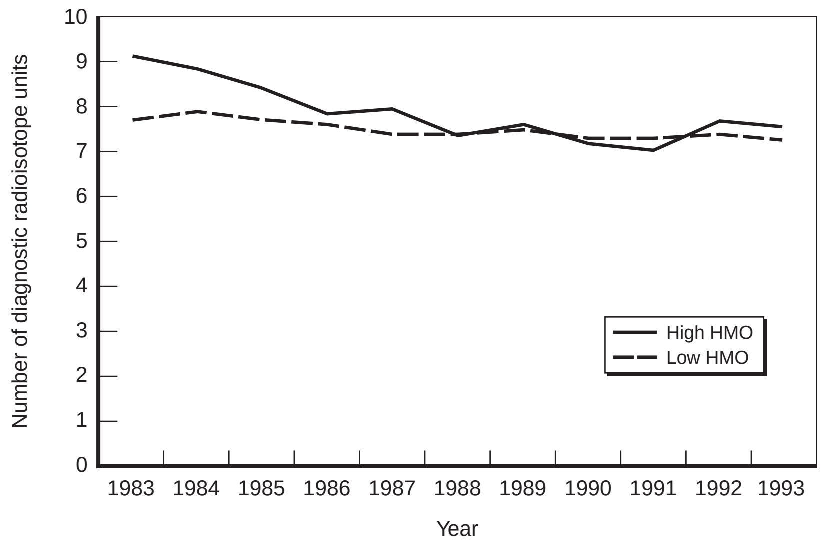
SOURCE: Our calculations based on American Hospital Association data.

Figure 22—Effect of HMOs and Hospital Competition on the Number of Cardiac Catheterization Labs in a Market, Controlling for Hospital and Market Characteristics

Diagnostic Radioisotope Units

Diagnostic radioisotope units are used to obtain information about the structure and function of organs by tracing radioactive isotopes that have been consumed by or injected into a patient. Very few hospitals offered this service in 1950; by 1980 this service had completed its diffusion into the hospital industry. Recently, this service started moving into the outpatient setting, and some hospitals are closing their diagnostic radioisotope units and referring patients to freestanding ambulatory care centers at which reimbursement rates are not as regulated by Medicare and some private health insurance plans.

As seen in Figure 23, high-HMO cities started with statistically significantly more diagnostic radioisotope units based in hospitals in the early 1980s, but the number of units contracted over time in high market share areas so that there was no difference in availability by the late 1980s. Figure 24 presents the results when we separated cities with highly competitive hospital markets from those with less competitive markets. As with open heart surgery and cardiac catheterization, the difference between high-HMO and low-HMO cities arose entirely from a difference in high-HMO cities with high levels of hospital competition. Because we do not have data about the availability of this service in outpatient facilities, we do not know if the reduction in the number of units observed in these high-HMO cities is matched by an increase in the number of outpatient units. HMO penetration could affect the decision of hospitals to relocate this type of diagnostic unit outside the hospital if reimbursement agreements make it advantageous to do so, and competition among hospitals may determine the degree of advantage.

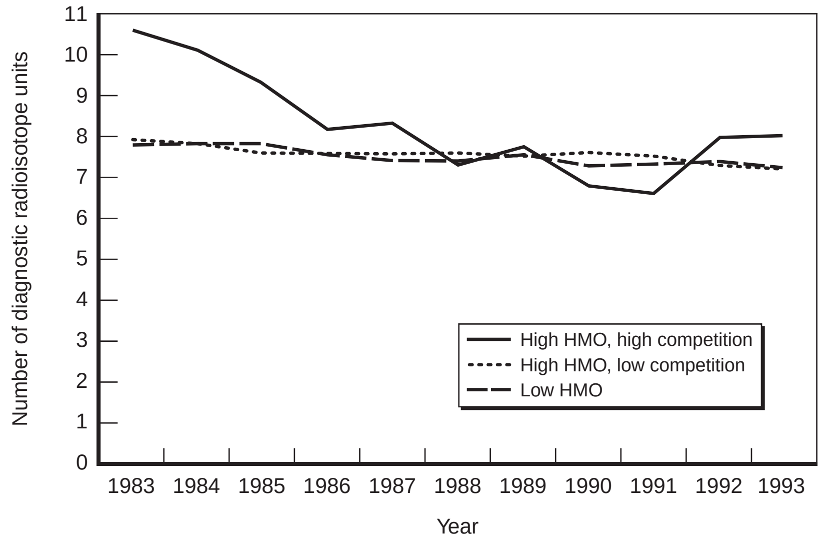


SOURCE: Our calculations based on American Hospital Association data.

Figure 23—Effect of HMOs on the Number of Diagnostic Radioisotope Units Based in Hospitals in a Market, Controlling for Hospital and Market Characteristics

Neonatal Intensive Care

Neonatal intensive care was developed in the 1960s and diffused rapidly in the 1970s and 1980s. Phibbs et al. (1993) documented that the existence of a neonatal intensive care unit (NICU) is a significant determinant of a woman's choice of hospital for delivery of her baby, particularly for high-risk, privately insured women. Thus, the potential exists for hospitals to attract patients by opening NICUs. Increased penetration of managed care may be changing the incentives of hospitals to operate NICUs. Low-volume NICUs are known to have higher mortality rates than high-volume NICUs (Phibbs et al., 1996).



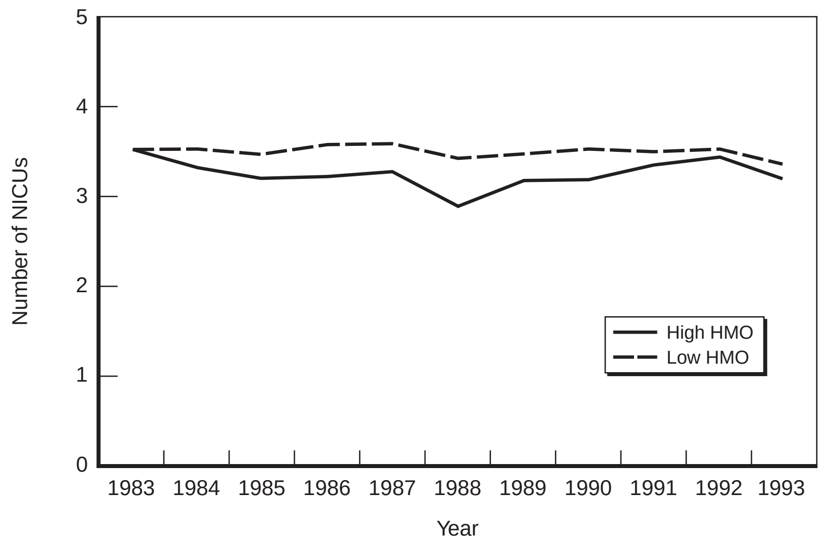
SOURCE: Our calculations based on American Hospital Association data.

Figure 24—Effect of HMOs and Hospital Competition on the Number of Diagnostic Radioisotope Units Based in Hospitals in a Market, Controlling for Hospital and Market Characteristics

The results of our regression analysis are displayed graphically in Figure 25. Availability of NICUs fluctuated over time, and there were no statistically significant differences between high and low market share areas.

What We Have Learned from Individual Technologies

We do not intend for these brief analyses of individual technologies to be the final word on the diffusion of open heart surgery, cardiac catheterization, neonatal intensive care, or diagnostic radioisotope technology; more careful studies are clearly possible and have been undertaken in some cases (e.g., Cutler and McClellan, 1996). Rather, we hope these results will help inform the use of technology index data.



SOURCE: Our calculations based on American Hospital Association data.

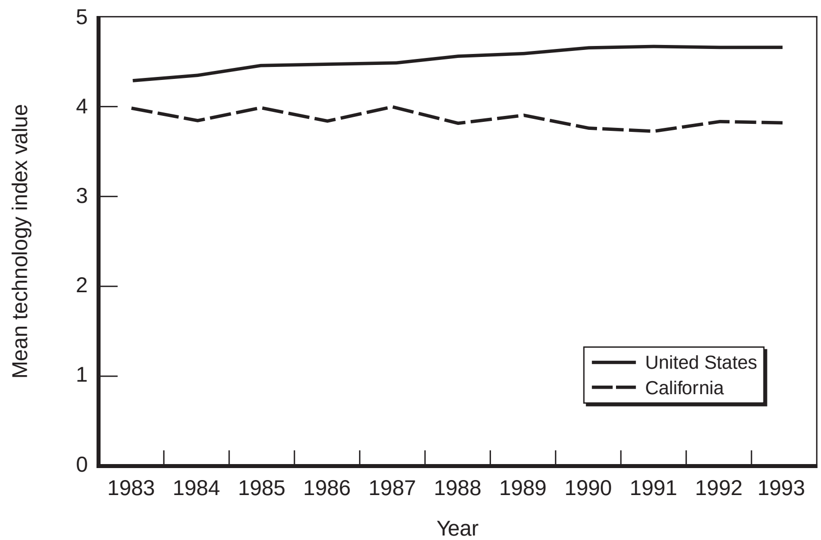
Figure 25—Effect of HMOs on the Number of NICUs in a Market, Controlling for Hospital and Market Characteristics

Our results illustrate a couple of important lessons. First, while the findings from the indices suggest that HMO activity had little or no effect on technology advancement overall, there is evidence that some technologies were affected by HMO activity. Second, while the indices did not respond to hospital competition, there may be important relationships between HMO activity and hospital competition for some individual technologies. These lessons are indicative of the fact that index data have advantages and disadvantages. They can nicely summarize aggregate movements, but they may miss effects that are apparent in individual cases.

8. What Has Happened to Technology Availability in California?

The 261 cities analyzed in this study included 20 California cities. Fourteen of these cities were in the national “high-HMO” category, and eight were in the “high-competition” group. Any effects of managed care and hospital competition on the availability of technology should be felt particularly strongly in California. Although we could not repeat our regression analysis for California because of the small sample size, we compared average technology availability in California to that in the United States to learn how managed care might be affecting the state’s hospitals.

There are clear differences in the availability of technology between California and the United States from 1983 to 1993. The Saidin index based on 1983 technologies and weights shows that California’s cities have, on average, a lower level of technology availability than cities in the United States (Figure 26). In addition, average technology availability

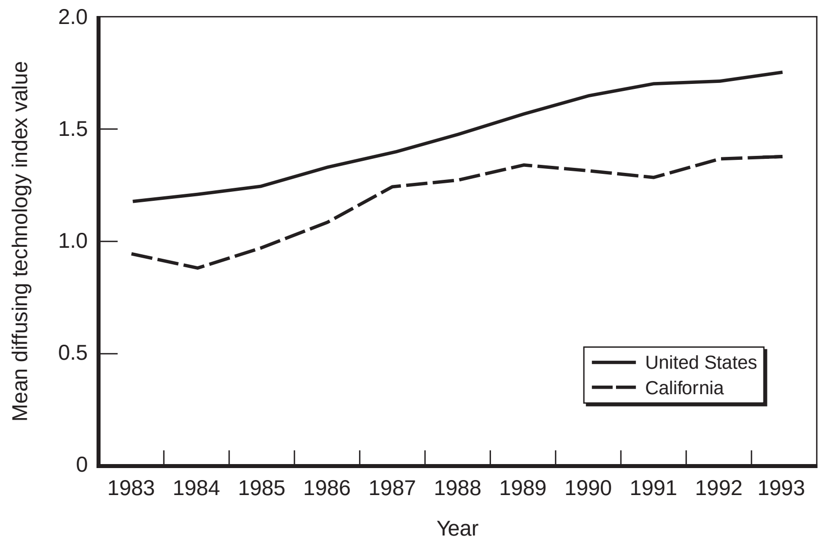


SOURCE: Our calculations based on American Hospital Association data.

Figure 26—Mean Level of Technology in Cities in California and the United States, 1983–1993, Basic Technology Index 83

appears stable in California cities, while availability is rising in the United States over this time period. These differences are not statistically significant and are consistent with the suggestion of Figures 5 and 9 that HMOs are not dampening the diffusion of technologies. As seen in Figure 27, this pattern also appears when we considered technologies that were diffusing from 1983 to 1993.

Figures 28 through 31 present the average percentage of hospitals in U.S. and California cities with the technologies and services analyzed in Chapter 7. Figure 28 shows that a smaller share of California hospitals had open heart surgery units in 1983, but that the average percentage of open heart surgery units grew at a faster rate in California cities than in U.S. cities. This is consistent with the regression analysis presented in

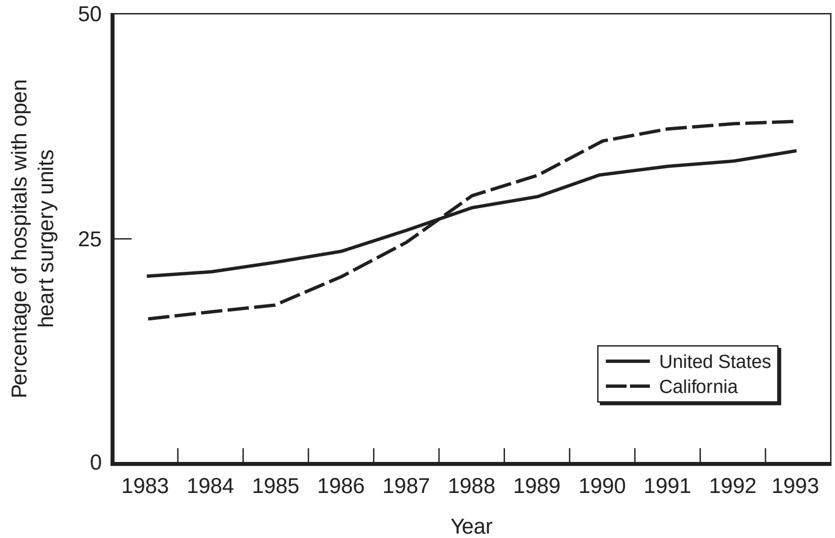


SOURCE: Our calculations based on American Hospital Association data.

Figure 27—Mean Level of Diffusing Technology in Cities in California and the United States, 1983–1993, Diffusing Technology Index 83

Figures 19 and 20: High-HMO cities, of which California has a disproportionate share, experienced more rapid diffusion of open heart surgery than low-HMO cities in the 1980s and early 1990s.

California's experience with cardiac catheterization differs from that found in our national regression analysis, as seen in Figure 29. The regression analysis revealed that highly competitive high-HMO cities had more rapid diffusion of cardiac catheterization than other cities (Figures 21 and 22). In contrast, cardiac catheterization expanded nearly identically in California and U.S. cities. Whatever factors have led to more rapid diffusion of cardiac catheterization in cities with competitive hospital markets do not appear to exist in California's cities.

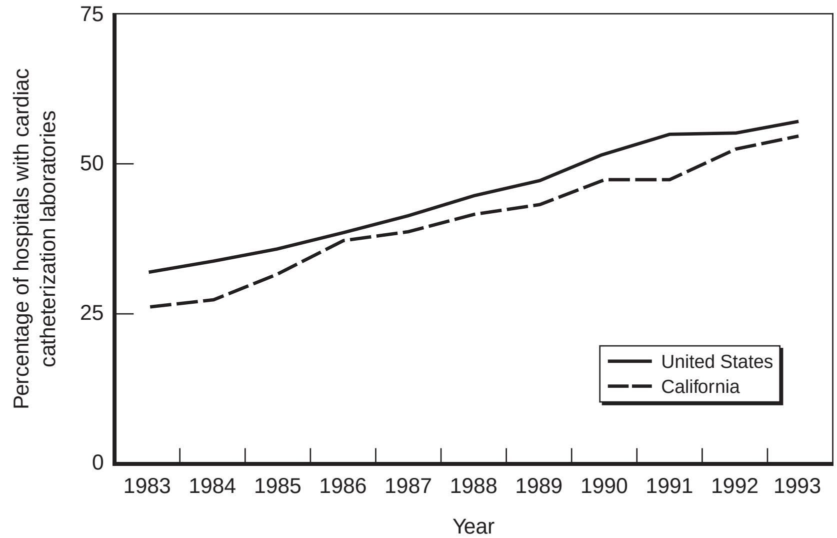


SOURCE: Our calculations based on American Hospital Association data.

Figure 28—Average Percentage of Hospitals with Open Heart Surgery, Cities in California and the United States, 1983–1993

Diagnostic radioisotope facilities were less common in California from 1983 to 1993 than in the United States (Figure 30). California cities also experienced a slightly more rapid decline in the availability of this service than did U.S. cities. The prevalence of this service dropped from about 79 percent to approximately 71 percent of hospitals in California between 1983 and 1993 and from 84 to 79 percent of U.S. hospitals over the same period. Again, we cannot determine how much of this decline was caused by the movement of diagnostic radioisotope units to outpatient facilities.

Neonatal intensive care was becoming more prevalent between 1983 and 1987, with a slight drop in the percentage of hospitals operating NICUs between 1989 and 1993 (Figure 31). Growth in the share of

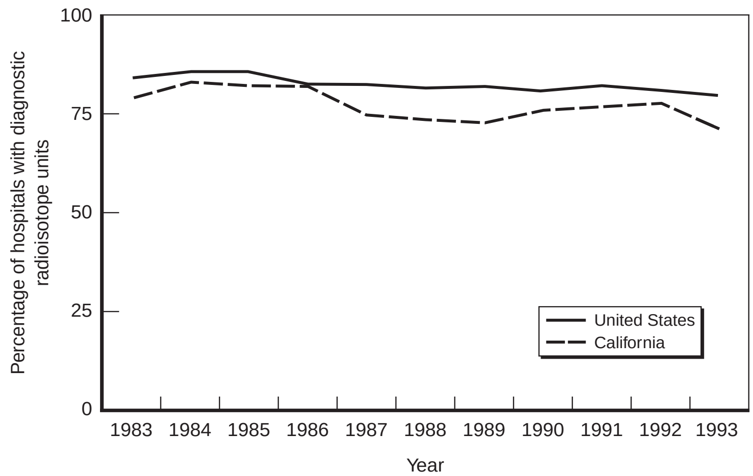


SOURCE: Our calculations based on American Hospital Association data.

Figure 29—Average Percentage of Hospitals with Cardiac Catheterization Laboratories, Cities in California and the United States, 1983–1993

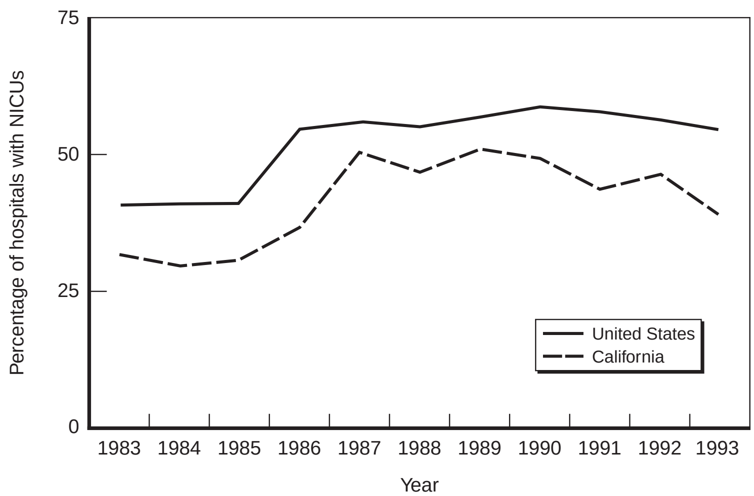
NICU was similar for California and the United States. This is consistent with the national analysis, controlling for confounding characteristics; HMO penetration does not appear to have had an effect on the availability of neonatal intensive care.

In general, our comparison of California and U.S. cities demonstrates that our national findings apply to California. Managed care is not having a clear effect on the availability of technology either nationally or in California. In fact, managed care may be speeding the diffusion of certain technologies and services (such as open heart surgery and cardiac catheterization) while it reduces the availability of others. These effects are observed particularly in California because managed care has become dominant in many cities in the state.



SOURCE: Our calculations based on American Hospital Association data.

Figure 30—Average Percentage of Hospitals with Diagnostic Radioisotope Units, Cities in California and the United States, 1983–1993



SOURCE: Our calculations based on American Hospital Association data.

Figure 31—Average Percentage of Hospitals with Neonatal Intensive Care Units, Cities in California and the United States, 1983–1993

9. Conclusions and Policy Implications

Results of This Study

This study found little evidence that managed care has slowed the growth of overall medical technology availability in recent years. Cities with high penetration of managed care did not have slower technology growth rates than cities with low penetration of managed care in the late 1980s and early 1990s, even when new technologies were incorporated into the indices. Whether we looked at aggregate indices for all technologies or focused our analysis on currently diffusing technologies, we found that HMO penetration was associated with slower growth in technology availability only between 1983 and 1986, and that this association is not statistically significant.

These conclusions hold even when we varied our statistical specifications. Most significant, using additional data to account for variation in competition among hospitals did not change the overall effect of HMOs on technology availability. Our results also did not change when we defined high-HMO cities based on HMO penetration in 1990 (rather than 1993), when we controlled for patient days instead of admissions, or when we used a Guttman scale rather than a Saidin index to measure technology availability.

Managed care did not affect the distribution of technology within cities, either. We examined the possibility that managed care has led to the regionalization of services, so that one or more large hospitals offer sophisticated technologies while smaller hospitals do not offer these services and instead refer patients to the major hospitals as necessary. If this were happening, the average level of technology availability in a city could remain constant while the variation of hospitals' technology indices would increase. We did not find any association between the variation of technology availability within cities and the prevalence of managed care; thus, we concluded that managed care is not systematically changing patterns of technology availability in hospitals in U.S. cities.

While these findings do not provide reason to believe that managed care slowed the overall growth in new technology availability in the late 1980s and early 1990s, managed care may have had important effects on individual technologies. In the four example technologies we examined, managed care is associated with increases in the availability of open heart surgery and cardiac catheterization, but high-HMO cities also have experienced marked declines in the availability of diagnostic radioisotope services based in hospitals. These findings are observed more strongly in cities with a high degree of hospital competition. Managed care appears to have had no effect on the availability of neonatal intensive care services. These findings are examples of the fact that conclusions drawn from aggregate index data need not apply to each of the technologies within the index. These findings also suggest that managed care may be achieving cost savings by limiting the use and availability of some technologies and also may be increasing costs by encouraging some hospitals to acquire technologies for competitive purposes.

Limitations to This Analysis

There are three important limitations to the analysis presented here. First, it is possible that we have not fully controlled for the possibility of reverse causality by which technology availability may influence HMOs' location decisions. Managed care organizations may prefer to locate in cities with relatively low levels and growth of technology availability because costs are lower in these cities. Thus, managed care will not affect technology availability simply because there is no need to reduce availability. If this is the case, we cannot predict what might happen as managed care diffuses into cities with excessively high technology levels. We doubt that there has been a high degree of selection into low-technology cities. Our analysis indicated that high-HMO cities in 1983 had statistically equivalent (and possibly even higher) technology levels of low-HMO cities.

The second potential limitation comes from the closure of hospitals. Differential rates of hospital closure in high and low market share areas could have caused us to understate the technology-limiting effects of managed care. Our statistical analysis did not provide reason to believe that differential closure rates are a serious problem, but it is possible that they exert some influence on our findings (see Appendix D).

Finally, we cannot examine whether there have been changes in technology availability outside hospitals. The available data are limited to hospitals and exclude freestanding ambulatory surgery centers, clinics, and laboratories. This is important for two reasons. First, these centers may have responded differently to the growth of managed care. Second, hospitals may eliminate some services (such as diagnostic radioisotope) and instead refer their patients to a freestanding center for the service. Nonetheless, we believe this analysis reflects the effect of managed care on high-cost technologies and thus health care costs in general. The basic Saidin indices do not include many technologies that can move to freestanding settings, and the "currently diffusing" index represents services and technologies almost exclusively provided by hospitals. More important, hospital-based technologies are more complex, and thus probably more expensive, than outpatient technologies, so limiting this analysis to technology availability in hospitals is appropriate to the cost-containment question.

Technology and Health Care Costs

Given the lack of evidence that managed care is changing the availability of technology, it is doubtful that managed care can reduce long-term health care cost growth. As suggested by McLaughlin (1988), it is unclear whether managed care *should* reduce quality and/or technology competition. The exact structure of competition in a market and overall demand for health care will determine whether managed care can change hospital provision of technological services. Without controlling the demand for and supply of technology, managed care can have only a limited, short-term effect on growth in the cost of health care (Schwartz, 1987; Newhouse, 1993).

We have not designed our technology index specifically to reflect high-cost technologies, but we expect that identifying new and relatively rare technologies also captures technologies with high adoption costs to at least some degree. It is also important to note that our index can provide evidence about cost savings that would result only from reducing the costs associated with the adoption and installation of new technologies. Some new technologies increase the costs of caring for patients, and others might decrease patient care costs by taking the place of even more expensive technologies. We did not measure patient care costs in our analyses.

Options for Policymakers

How might policymakers control the availability and diffusion of technology in order to control long-term cost growth? Thus far, no policy has been successful in this area. Certificate-of-need programs were widely abandoned in the 1980s, as it became apparent that they had little effect on technology adoption (Banta, Burns, and Behney, 1983; Cromwell and Kanak, 1982; Noether, 1988; Bryce and Cline, 1998). Prospective reimbursement may have had a small effect on technology diffusion, but the evidence is limited (Cromwell and Kanak, 1982; Romeo, Wagner, and Lee, 1984). And now, we find no support for the possibility that managed care will reduce technology availability.

It seems likely that an important reason for the failure of previous efforts to restrain technology growth was a lack of sufficient public and political will. Limiting the growth of technology often appears to be associated with limitations in access to care or reductions in the quality of care delivered, and the public generally has been unwilling to support policies that have even the appearance of restricting health care access or quality.

However, the public has become increasingly concerned about rising health care costs and has encouraged some efforts to restrict spending growth. This creates a dilemma. There is relatively little room to cut health care expenditures by reducing fraud and abuse or eliminating other obvious inefficiencies, despite the public's impression that significant cost savings can be achieved this way. Achieving substantial cost savings will almost certainly require reductions in the volume or intensity of services delivered, the amenities associated with health care service delivery, patient choice of providers, or other aspects of the quality of services delivered.

Making sound policy decisions with regard to technology adoption rests on the ability of the public and policymakers to reach a consensus about this dilemma. If there is sufficient public and political will to restrain costs, then adopting policies that would constrain technology growth is a course of action that could produce significant savings.

To begin to act in this arena, the public and policymakers must agree upon the importance of controlling long-term health care cost growth. It is not possible for health care costs to increase perpetually above the rate of growth of gross domestic product. However, it is possible that Californians have not yet satisfied their demand for high-cost medical care. At what point are additional expenditures on health care undesirable? The answer to this question can come only from public reflection and debate. Unfortunately, there has been relatively little informed public debate about these issues. Any discussion about increasing or improving the quality and availability of medical services should be matched by a discussion about the costs of such changes. These costs are borne by the general public, even though the costs are not known by the public because employers and the government provide most health insurance. Policymakers should strive to educate the public about the true costs of health care so the public can understand the cost-quality trade-off and relay preferences about health care to policymakers, employers, and health care providers.

If the public is willing to accept some reduction in technology availability to reduce health care cost growth, policymakers can consider a few approaches:

- Do nothing and see if the practices of the past several years will reduce technology availability in the future. Thus far, policymakers have allowed managed care to change our health care system with little regulation or guidance. This has proven to be problematic. First, our analysis provides little reason to believe that managed care will limit technology growth and thus long-term cost growth, although it is possible that managed care could be more effective in the future. Second, the growth of managed care has brought questions about technology and procedure eligibility into the legal system, which may not be the best setting for resolving these issues. Moreover, the backlash against managed care has spawned numerous piecemeal efforts to reduce the decisionmaking ability of HMOs—when these issues could be resolved in a more comprehensive manner. Finally, it is unclear whether the public wants health care cost reduction to be under the control of health care organizations, which are increasingly motivated by profit.
- In cases where the state serves as insurer, the state could consider following the approach taken by Oregon with its Medicaid insurance plan: Policymakers could develop a priority list of services based on both impartial cost-benefit analysis and public opinion and use this list to explicitly ration care, which could affect technology purchase decisions. While this policy is appealing because it forces the debate to be public, it has been met with numerous legal challenges. More important is whether the public can be comfortable with such explicit rationing of

health care. This would work only for Medi-Cal and other state-financed programs.

- Policymakers can require hospitals to consolidate services into referral centers and encourage the closure of hospitals. Some analysts have suggested that California has an excessive number of hospital beds (Enthoven and Singer, 1996); reducing this excess could be the key to maintaining slowed health care cost growth. Moreover, this could improve health outcomes because hospitals that provide a higher volume of services tend to have lower mortality rates and better overall outcomes (e.g., DeWeese et al., 1991; Chernew, Hayward, and Scanlon, 1996; Inter-Society Commission on Heart Disease, 1982; Phibbs et al., 1996). There are several mechanisms the government could use to consolidate services and limit the diffusion of technologies. First, certificate-of-need regulations could be recreated and might succeed if there is sufficient public will to support their mission. Alternatively, the state could establish minimum service volumes for particular technologies and services and refuse to license facilities that do not meet volume requirements.[1] Finally, policymakers could provide financial incentives to hospitals to close low-volume units, establish referral centers, and consolidate operations. These financial incentives could come in the form of tax credits or additional reimbursements to hospitals that consolidate and close units. This would be a difficult policy to design but it could be very successful if its economic incentives match policy goals. However, this policy is risky because it is possible that a reduction in the number of services in a region could result in monopolies being held by hospitals providing specific

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[1]This type of policy could have the negative consequence of encouraging hospitals to perform an unnecessarily high number of procedures in order to maintain a high volume of patients.

> technologies. Monopolies could lead to increased costs and reduced availability of services. Thus, a consolidation or certificate-of-need policy should be approached with caution.

The current pattern of managed care does not seem likely to result in future reductions in the availability of technology. Thus, it appears that controlling long-term health care cost growth will require a change in behavior by managed care insurers or new public cost-containment policies.

Appendix A

Corrections and Adjustments Made to the Data Sets

Nonresponse in the American Hospital Association Survey Data

The main data source for the analysis presented in this report was the American Hospital Association's *Annual Survey of Hospitals*. This survey is conducted every year, and data may be purchased from the AHA. We limited our analysis to short-term general hospitals and children's hospitals because other types of hospitals, such as psychiatric facilities, typically do not purchase and utilize the technologies studied in this project.

In each year, some hospitals do not respond to various questions in the AHA survey. In 1983, the AHA data file listed 7,120 hospitals, of which 6,098 (86 percent) were general and children's hospitals. 5,631 hospitals (92 percent) provided information in response to most of the survey questions. In 1993, 5,436 of 6,667 hospitals (82 percent) were general or children's hospitals; 4,958 (91 percent) responded to most survey questions.

The hospitals that do not respond to most questions in the AHA survey are somewhat different from those that respond. Table A.1 summarizes the differences in 1983 and 1993 for those survey questions to which every hospital responded or the AHA imputed the relevant data. In general, the nonrespondent hospitals are smaller, are less likely to be associated with medical education programs, and are more likely to be owned by for-profit organizations. Our sample probably has a higher level of availability of technology than exists across all U.S. hospitals because the AHA respondents are larger than average.

Table A.1

Characteristics of Hospitals That Do and Do Not Respond to Most Questions in the AHA Survey

	1983		1993	
Hospital Characteristics	Responded	Did Not Respond	Responded	Did Not Respond
Number of beds	134	199	130	182
Number of admissions	274	5,818	3,089	5,320
Number of adjusted admissions	3,300	6,704	4,222	7,381
Percentage with residency program	4.4%	18.7%	9.9%	19.4%
Percentage government owned	41.0%	29.1%	24.6%	26.8%
Percentage not-for-profit owned	22.8%	52.9%	31.6%	53.2%
Percentage for-profit owned	35.2%	12.7%	38.3%	15.3%
Percentage federal owned	0.7%	2.8%	4.2%	2.2%
Percentage rural	45.4%	42.5%	31.6%	38.7%

Imputing the Number of NICUs

In each survey year, a significant number of hospitals do not report whether their NICU was intermediate level (level II) or the most advanced level (level III). For example, in 1983, only 3,486 hospitals (57 percent) reported the level of NICU care they provided. If a year with missing data was preceded and followed by years with the same level of NICU, we assumed that the NICU level of the missing year was the same as before and after. If the preceding and subsequent years had different levels of NICUs, we did not interpolate the missing data. Table A.2 presents the percentage of hospitals with NICUs in each state. There is a wide range of variation in the pattern of NICU availability and in changes in NICU diffusion over time. NICU availability is not obviously related to differences in degree of urbanization or region of the United States.

Comparing the AHA Survey to California's OSHPD Data

Hospitals respond to the AHA survey voluntarily, and the quality of the data will depend on how accurately they respond to survey questions. California requires that all nonfederal hospitals in the state complete an annual report on the services they provide, staffing levels, patient care statistics, and financial data. These data are collected by the Office of Statewide Health Planning and Development (OSHPD), which audits the data for consistency and makes it available to the public. We matched California hospitals that reported to OSHPD with those that reported to the AHA in 1990 and compared their reports of technology availability to see if there are systematic differences that would compromise the validity of our analysis.

We were able to match 331 hospitals in the AHA and OSHPD surveys in 1990. At least 80 percent of hospitals reported the same information about technology availability in both surveys. We were able

Table A.2
Percentage of Hospitals with a Neonatal Intensive Care Unit

	Level II (Intermediate) NICU			Level III (Most Advanced) NICU		
State	1983	1988	1993	1983	1988	1993
Alabama	13.3	20.6	14.0	9.2	5.2	5.6
Alaska	21.7	25.0	16.0	4.3	0.0	0.0
Arizona	18.3	19.7	17.8	8.5	7.9	4.1
Arkansas	16.0	28.0	17.5	6.7	2.7	5.0
California	17.9	18.9	16.9	10.0	8.8	8.4
Colorado	19.0	20.9	16.9	8.3	7.7	10.1
Connecticut	33.3	20.5	21.3	9.5	13.6	10.6
DC	36.4	36.4	27.3	54.5	54.5	54.5
Delaware	12.5	25.0	30.0	12.5	12.5	0.0
Florida	15.5	22.1	17.0	5.9	6.3	8.0
Georgia	19.1	29.9	30.5	5.9	7.5	9.2
Hawaii	11.1	11.1	5.9	33.3	5.6	11.8
Idaho	20.0	16.2	13.5	2.9	2.7	2.7
Illinois	36.3	35.5	28.4	6.3	6.1	7.6
Indiana	23.3	26.4	19.4	5.3	4.0	4.5
Iowa	17.1	13.3	11.1	3.1	3.1	1.7
Kansas	12.3	16.8	17.0	3.3	3.5	6.0
Kentucky	21.1	32.9	30.1	1.1	3.9	2.4
Louisiana	11.1	16.4	16.8	8.5	11.2	8.8
Maine	11.9	30.0	13.3	7.1	5.0	4.4
Maryland	25.0	33.3	32.1	14.6	11.1	11.3
Massachusetts	31.5	26.0	16.1	11.0	4.2	2.5
Michigan	13.9	18.2	17.3	10.8	8.5	8.1
Minnesota	15.1	17.0	13.6	5.0	4.3	5.4
Mississippi	44.7	38.3	35.1	12.8	10.6	7.0
Missouri	28.7	24.2	24.0	5.1	4.7	7.2
Montana	7.0	6.1	19.0	0.0	2.0	2.4
Nebraska	11.4	12.7	15.1	7.1	7.0	2.7
Nevada	12.0	13.0	3.7	4.0	8.7	3.7
New Hampshire	27.0	21.9	30.6	5.4	3.1	2.8
New Jersey	30.3	34.8	27.8	9.0	10.9	15.5
New Mexico	21.3	32.1	12.7	6.6	1.8	1.8
New York	21.8	17.5	13.8	15.6	13.6	11.5
North Carolina	14.7	19.0	15.7	2.6	6.9	7.4
North Dakota	6.0	8.5	10.2	10.0	8.5	8.2
Ohio	17.2	18.8	21.6	4.7	5.9	6.4
Oklahoma	18.6	23.6	19.6	5.2	5.7	3.6
Oregon	24.2	21.9	18.3	7.6	4.1	7.0
Pennsylvania	24.1	19.3	21.8	10.6	9.6	9.5
Rhode Island	50.0	18.2	12.5	7.1	9.1	6.3
South Carolina	53.2	54.4	40.9	6.5	8.8	6.1
South Dakota	25.5	10.4	10.0	2.1	4.2	6.0
Tennessee	17.6	20.4	16.7	9.3	7.4	10.0
Texas	12.8	17.8	21.5	6.5	6.4	6.0
Utah	24.5	21.7	15.0	6.1	8.7	10.0
Vermont	26.7	28.6	30.8	6.7	7.1	7.7
Virginia	26.7	26.8	25.5	7.8	7.2	8.5
Washington	20.8	31.1	17.9	10.4	4.9	6.3
West Virginia	22.6	19.6	13.7	4.8	7.1	5.9
Wyoming	14.3	13.0	19.2	3.6	0.0	0.0

to compare reported technology availability for 10 technologies included in our computation of the Saidin index. Hospital reports of the availability of open heart surgery and cardiac catheterization were very consistent across surveys, with over 96 percent of hospitals providing the same information for each of these technologies. Hemodialysis was the least consistently reported technology; only 73 percent of hospitals reported the same availability in both surveys. Table A.3 presents the percentages of hospitals with matching data for each of the technologies we considered.

We would like to see more consistent responses between these surveys. We are unable to determine which is more accurate, although we suspect the OSHPD data are better. We did not find any indication of one survey having consistently underreported or overreported technology availability relative to the other. Thus, we use the AHA data as reported and consider our data to be subject to random measurement error.

Table A.3

Percentage of Hospitals with Matching Data in the AHA and OSHPD Surveys, 1990

Type of Service	Percentage Matching
Cardiac Catheterization Lab	96.1
CT Scanner	80.7
Diagnostic Radioisotope	77.3
Hemodialysis	72.8
Megavoltage Radiation Therapy	91.8
NMR/MRI	74.6
Open Heart Surgery	97.0
Therapeutic Radioisotope	80.1
X-Ray Radiation Therapy	82.8
Neonatal ICU	78.4

Appendix B
Technology Measurement

Aggregate Technology Indices

Few researchers have attempted to measure aggregate levels of hospital technology, even though technology affects the cost of patient treatment, the type of care provided, and the demand for other inputs. Researchers rely almost exclusively on size of a hospital—usually measured as number of beds—as a proxy for the quantity and type of services available in a hospital, or measure the “case mix” of patients to capture differences in intensity of care and services available (Tatchell, 1983). In this report, we study a new aggregate technology index, which Spetz (1995) calls the Saidin index, and we consider one previously used technology scale—the Guttman scale.

Some researchers have created indices for the measurement of technology or have sought to group hospitals according to the services available. Berry (1973) classified hospitals into categories defined by the type of services provided: basic services, quality-enhancing services (e.g., pathology laboratory services, postoperative recovery units, pharmacies), complex services (e.g., physical therapy, intensive care), community services (e.g., occupational therapy, family planning), and special services (e.g., chaplaincy, tests unrelated to those routinely provided). Berry argued that hospitals evolve through these categories in the sequence above. Although this method of distinguishing among hospital services is crude, it captures a fair amount of variation in hospital costs. Feldstein (1967) and Cohen (1967) have proposed more complex measures of hospital services. Their approaches focused on classifying hospitals by multiple diagnostic-therapeutic categories. These groupings can be difficult to create, and many data sources do not provide all the necessary data for their development.

The Saidin Index

The index used in this report, the Saidin index, is a weighted sum of indicators for various technologies and services, with each weight being the percentage of hospitals that do not possess the technology or service. Technologies that are rare—whether they are rare because they are new, expensive, or difficult to implement—receive higher weights in this measure. Technologies that are common, such as operating rooms, receive low weights. This weighting scheme corresponds with most people's idea of what defines "high technology": that which is rarely found, whether it is rare due to newness, expense, or difficulty of operation. When a technology becomes common, it is not perceived as being of a high level.

More specifically, to create an index for hospital i in year t, we begin with a list of technologies available in that year, which we index by k = 1, . . . , K. For each technology, we assign a weight $a_{k,t}$, where

$$a_{k,t} = 1 - \left(\frac{1}{N_t}\right)\sum_{i=1}^{N_t} \tau_{i,k,t}.$$

N_t is the total number of hospitals in the United States and $\tau_{i,k,t}$ takes the value 1 if hospital i has technology k in year t and 0 otherwise. We then use these weights to compute the index $s_{i,t}$ for hospital i in year t:

$$s_{i,t} = \sum_{k=1}^{K} (a_{k,t} \; \tau_{i,k,t}).$$

That is, the index for each hospital is the sum of the percentage of hospitals in the United States that do not have that technology over all of the technologies the hospital has.

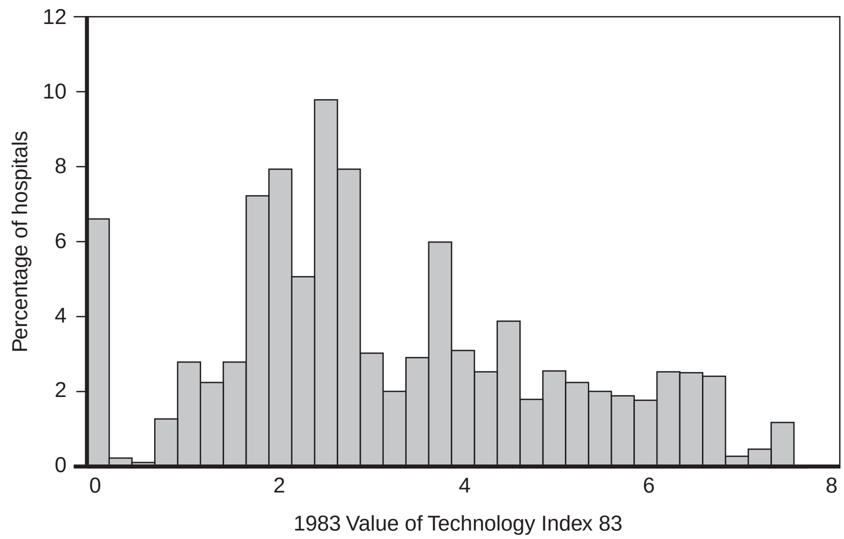
Two characteristics of this index deserve discussion. First, the index rewards technologies based on how uncommon they are. From the standpoint of identifying high-technology services, high-cost services, or even new services, this may be insufficient. But, as a starting point, relative rarity is a factor that is frequently incorporated into the definition of health care technologies—items that are rare, either because they are expensive, new, or difficult to implement, are more likely to be considered high tech. As a practical matter, identifying whether technologies are more or less common is one of the few methods that can be implemented purely from the data. The second characteristic is that both the number and relative rarity of the technologies are entered into the calculation of the index, so the index will not distinguish hospitals that have a small number of rare technologies from hospitals that have many common technologies. There are very few hospitals that have adopted one or two uncommon technologies but have *not* adopted a wide range of common technologies, which alleviates this problem in practice.

To be useful for analyses, the index should have two properties. First, it should accurately reflect the degree of technology advancement across hospitals at a single point in time. That is, in any given year, hospitals with higher values of the index should be "more advanced." While it is not completely clear what "more advanced" means, we believe this index does reflect advancement as it is commonly conceptualized. Adding technologies will increase the index value. Adding technologies that are relatively rare will increase the index value more than by adding technologies that are common. In general, hospitals that have more, rarer technologies will have higher index values than hospitals with fewer, more-common technologies.

The second property needed for the index to be valid is the ability to identify changes in technology over time. That is, the index should increase over time with increases in the degree of technology advancement. If a hospital has a higher index value this year than last year, we would like to conclude that the hospital became more advanced. In this regard, the most straightforward implementation of this index can be problematic. Difficulties could arise if we were to identify a new list of technologies and compute a new set of weights measuring the relative rarity of the listed technologies each year, and then compute the index values for each hospital for each year. Because hospitals rarely shut down services, the relative rarity of the technologies, expressed in the weights, could be expected to decline from year to year as more hospitals adopt new technologies over time. The index values would thus tend to fall over time even if hospitals did not change their technology set from one year to the next. A related problem is that the set of technologies under consideration changes from year to year, as new technologies are introduced to medicine and to the surveys. The surveys we used to create the indices are updated periodically to add new technologies. When the set of technologies changes, discontinuities can be introduced into the time series of index values.

To address this problem, we defined indices using a set of technologies and weights that are defined in a base year and held fixed for subsequent years. We then computed index values for each hospital using this fixed set of technologies and weights. For example, we defined a list of technologies available in 1983, determined their relative rarity in 1983, and then computed index values for hospitals for all years using the 1983 list and the 1983 weights. This method preserves that ability of the index to function as a useful measure over time. With the weights fixed, increases in the index signify the addition of new technologies. It is important to note, though, that this is valid for only a limited period of time. The fixed technology list and weights eventually produce a poor indicator of the current state of the world and thus need to be updated.

Weights for the Saidin indices were computed from three years of AHA data to update the indices for the increasing availability of certain technologies. Table 1 in Chapter 3 presents the technologies and weights used for the Saidin indices for 1983, 1987, and 1991. The Saidin index ranges from 0 to 7.6. Figure B.1 presents the distribution of Index 83 for 1983 for all hospitals in the United States. Over 6 percent of hospitals had none of the technologies on the list and thus had an index value of 0. Most hospitals had index values in the range of 2 to 4. The means, standard deviations, and percentiles of the Saidin indices for each



SOURCE: Our calculations based on American Hospital Association data.

Figure B.1—Distribution of 1983 Values of Saidin Index 83 Across All U.S. Hospitals

year of data are presented in Table B.1. As expected, the average technology level increases over time for all three indices. There is a discontinuity in the values of Index 87 in 1987 because prior to 1987 three of the technologies included in Index 87 were not surveyed by the AHA. An even larger discontinuity is observed in 1991 for Index 91 because six new technologies were added to Index 91 that may not have been available in previous years.[1]

Another way we can focus our analysis on technologies that are relatively new is to create a Saidin index with technologies that are rare or

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[1]Some of the technologies added to Index 91 were added to the AHA survey in 1990; thus, the average value of Index 91 is 4.63 in 1989 and 5.83 in 1990. Similarly, several technologies were added to the survey in 1986.

Table B.1

Summary Statistics of Saidin Indices Based on 1983, 1987, and 1991 Weights, All Hospitals in the AHA Survey, 1983–1993

				Percentile				
	Mean	Std. Dev.	Skewness	10%	25%	50%	75%	90%
Index 83								
1983	3.28	1.84	0.35	1.11	2.10	2.94	4.53	6.13
1984	3.36	1.88	0.21	1.06	2.10	2.94	4.67	6.23
1985	3.47	1.89	0.12	1.11	2.20	3.39	4.72	6.28
1986	3.52	1.87	0.11	1.21	2.20	3.46	4.73	6.28
1987	3.53	1.89	0.13	1.26	2.20	3.53	4.76	6.28
1988	3.60	1.89	0.13	1.42	2.20	3.53	4.88	6.40
1989	3.65	1.91	0.07	1.33	2.20	3.65	4.93	6.47
1990	3.67	1.87	–0.01	1.42	2.25	3.65	4.93	6.41
1991	3.68	1.89	–0.07	1.21	2.32	3.66	4.99	6.41
1992	3.27	1.90	–0.10	1.18	2.39	3.77	5.03	6.46
1993	3.72	1.95	–0.17	0.84	2.51	3.79	5.07	6.47
Index 87								
1983	3.80	2.52	0.60	0.85	1.91	3.48	5.27	7.57
1984	3.98	2.69	0.60	0.63	2.13	3.50	5.61	8.20
1985	4.11	2.75	0.60	0.63	2.26	3.66	5.76	8.36
1986	4.42	2.90	0.60	0.93	2.32	3.96	6.17	8.78
1987	4.44	2.98	0.60	0.89	2.29	3.96	6.18	8.92
1988	4.49	3.00	0.61	1.03	2.28	3.96	6.19	9.04
1989	4.54	3.03	0.58	0.85	2.31	4.01	6.38	9.26
1990	4.60	3.02	0.52	0.88	2.33	4.05	6.60	9.30
1991	4.63	3.05	0.48	0.68	2.37	4.17	6.71	9.36
1992	4.76	3.10	0.44	0.85	2.42	4.37	6.91	9.51
1993	4.79	3.16	0.38	0.26	2.38	4.37	7.01	9.59
Index 91								
1983	3.77	2.54	0.77	0.80	2.02	3.31	5.14	7.92
1984	3.86	2.62	0.74	0.65	2.04	3.31	5.17	7.93
1985	3.97	2.68	0.76	0.72	2.39	3.49	5.29	8.13
1986	4.29	2.85	0.77	1.00	2.42	3.69	5.76	8.61
1987	4.32	2.94	0.78	0.99	2.42	3.70	5.85	9.04
1988	4.42	3.01	0.79	1.03	2.42	3.70	5.96	9.16
1989	4.63	3.30	0.84	0.80	2.42	3.72	6.47	9.94
1990	5.83	3.97	0.66	1.14	2.95	5.09	8.21	12.02
1991	5.93	4.04	0.59	0.85	2.97	5.12	8.56	12.25
1992	6.14	4.13	0.54	1.03	3.01	5.50	8.81	12.42
1993	6.24	4.25	0.48	0.46	3.02	5.52	9.11	12.69

are currently diffusing. Technologies that are becoming more common over time may be affected differently by market characteristics than technologies that are well established. The last column of Table 1 in Chapter 3 indicates which technologies were deemed appropriate for a "rising" technology index. 1983 weights were used to construct this index. Table B.2 presents the yearly means, standard deviations, and percentiles for the rising technology index. Over 25 percent of hospitals had an index value of 0, reflecting the fact that many hospitals had not yet invested in newer technologies.

Table B.2

Summary Statistics of the Rising Saidin Index Based on 1983 Weights, All Hospitals in the AHA Survey, 1983–1993

				Percentile				
	Mean	Std. Dev.	Skewness	10%	25%	50%	75%	90%
1983	0.69	1.05	1.66	0.00	0.00	0.00	0.99	2.55
1984	0.70	1.06	1.67	0.00	0.00	0.22	1.15	2.58
1985	0.74	1.08	1.67	0.00	0.00	0.22	1.15	2.58
1986	0.78	1.12	1.60	0.00	0.00	0.22	1.15	2.67
1987	0.81	1.17	1.55	0.00	0.00	0.22	1.15	2.76
1988	0.87	1.21	1.48	0.00	0.00	0.22	1.15	2.92
1989	0.91	1.23	1.40	0.00	0.00	0.22	1.33	3.01
1990	0.94	1.23	1.32	0.00	0.00	0.22	1.49	3.01
1991	0.97	1.24	1.26	0.00	0.00	0.22	1.68	3.10
1992	1.02	1.26	1.19	0.00	0.00	0.22	1.84	3.10
1993	1.05	1.27	1.14	0.00	0.00	0.22	1.84	3.10

The Guttman Scale

We compared the Saidin index to another previously used aggregate technology measure—the Guttman scale—to learn how the Saidin index compares with other possible technology measures. Edwards, Miller, and Schumacher (1972) proposed using a Guttman scale to measure technology level—the Guttman scale was originally developed by social psychologists for the measurement of attitudes. The Guttman scale for hospitals is a unidimensional measure for which a higher value represents a broader and/or more sophisticated level of services. The scale is defined by a set of technologies and services that might be provided by hospitals, with rarer technologies being assigned higher Guttman values. The scaling assumes a sequential acquisition of technologies and services, and a hospital is assigned the Guttman score of the highest-scoring technology the hospital provides. For example, if dialysis is less commonly offered by hospitals than ultrasound, we assume that a hospital providing dialysis will also provide ultrasound. Edwards, Miller, and Schumacher created this index using the American Hospital Association's 1969 Annual Survey of Hospitals.

We can test the accuracy of this underlying premise of Guttman scaling by computing the number of technologies predicted correctly by the score assigned to a hospital. Guttman (1950) suggests that this "coefficient of reproducibility" should be the primary criterion for assessing the validity of a scale, and rather arbitrarily states that a 10-percent error would be acceptable. Edwards, Miller, and Schumacher created Guttman scales for various categories of hospitals and found that the coefficients of reproducibility for these scales ranged from 0.87 to 0.92. Other tests for the unidimensionality of the scale (that the services in the scale represented measures of the same underlying variable) and cohesiveness (single items in the scale are positively correlated with the total score) demonstrated that the Guttman scale provides a satisfactory unidimensional measure of hospital services. Later work by Zaretsky (1977) found that the Guttman scale is a useful measure for distinguishing the services available at hospitals in the estimation of cost functions.

Hospital technology has changed significantly since 1969, so we re-created a Guttman scale using AHA data from 1983. The technologies included in the Guttman scale are determined by computing the correlations for each technology and the sum of all the technologies under consideration. Technologies with low item-total correlations are successively removed from the list of candidate technologies until further removals substantially change the ordering and values of the item-total correlations. The Guttman scale obtained from the 1983 AHA survey is listed in Table B.3. All the technologies used to assign Guttman scores are also part of the computation for our Saidin indices. In 1983, the coefficient of reproducibility for the new Guttman scale is 0.89.

Guttman scores were computed for every hospital for every year of the AHA data; summary statistics are presented in Table B.4. As expected, the Guttman scale rises over time as technologies diffuse through hospitals. The coefficient of reproducibility (1 minus the error)

Table B.3

Guttman Scale for the 1983 AHA Data

Rank	Technology	Percentage of Hospitals with Technology
1	Histopathology lab	61.1
2	Diagnostic radioisotope	59.4
3	Computerized tomography scanner	33.6
4	Premature nursery	24.4
5	Hemodialysis	22.5
6	Therapeutic radioisotope	21.5
7	NICU	20.3
8	Radioactive implants	20.2
9	X-Ray radiation therapy	15.8
10	Cardiac catheterization lab	15.6
11	Megavoltage radiation therapy	14.4
12	Open heart surgery	10.3

Table B.4

Summary Statistics of the Guttman Scale Based on the 1983 AHA Survey, All Hospitals in the AHA Survey, 1983–1993

	Mean	Std. Dev.	Skewness	Percentile 10%	25%	50%	75%	90%	Percent Error
1983	4.67	4.31	0.51	0	1	3	8	12	11.0
1984	4.76	4.31	0.48	0	1	3	8	12	10.6
1985	4.87	4.29	0.45	0	1	4	9	12	10.5
1986	4.92	4.35	0.45	0	1	3	10	12	12.8
1987	4.87	4.43	0.46	0	0	3	10	12	12.3
1988	5.01	4.45	0.43	0	1	3	10	12	12.9
1989	5.10	4.47	0.40	0	1	3	10	12	13.2
1990	5.30	4.49	0.34	0	2	3	10	12	13.9
1991	5.37	4.49	0.32	0	2	3	10	12	14.3
1992	5.54	4.51	0.26	0	2	3	11	12	15.0
1993	5.59	4.54	0.24	0	2	3	11	12	15.3

drops over time as the scale created using 1983 data becomes less appropriate for subsequent years.

Comparing the Indices

There are several reasons to question the validity of the Guttman score as an aggregate measure of technology. First, the popular press has purported that many hospitals sought to specialize during the 1980s; this may be evident in the lower accuracy of the Guttman scales computed in the late 1980s as compared with those of the earlier years. Second, the distribution of the Saidin indices is less skewed than that of the Guttman scale. As seen in Table B.1, the Saidin index based on 1983 weights has a skewness ranging from –0.17 to 0.35. The Guttman scale's skewness ranges from 0.24 to 0.51—substantially higher than that of the Saidin index and not centered around 0 (Table B.4). Third, the distribution of the Saidin index more closely resembles a normal distribution than does that of the Guttman scale. In 1983, the mean of the Saidin index is 3.28 and the median is 2.94. The middle 50 percent of hospitals have index values ranging from 2.10 to 4.53. In contrast, the Guttman scale's mean is 4.67, its median is 3, and the middle 50 percent of hospitals has scores ranging from 1 to 8. This higher degree of variation in the Guttman scale suggests that the scale does not distinguish hospitals at the high and low ends of the technology availability spectrum well.

The correlations between the Saidin index and the Guttman scale are presented in Table B.5; they range from 0.874 to 0.890. This suggests that both indices measure essentially the same element—the availability of technology within hospitals. Because our Saidin indices have a less skewed, more normal distribution, our main analysis uses this type of index. We repeated our analysis using the Guttman scale as our aggregate technology measure; the results are presented in Appendix D.

Table B.5

Correlations Between the Guttman Scale and the Saidin Index 83

Year	Correlation
1983	0.874
1984	0.879
1985	0.882
1986	0.882
1987	0.890
1988	0.888
1989	0.882
1990	0.878
1991	0.875
1992	0.877
1993	0.881

Appendix C
Complete Regression Results

Table C.1 presents regression coefficients for equations predicting the technology index for high- and low-HMO cities as a function of hospital and market characteristics, corresponding to Figures 9, 10, 11, and 12.

Table C.2 presents regression coefficients for equations predicting the technology index for high-competition high-HMO cities, low-competition high-HMO cities, and low-HMO cities as a function of hospital and market characteristics, corresponding to Figures 13, 14, and 15.

Table C.3 presents regression coefficients for equations predicting the coefficient of variation of the technology index within cities for high- and low-HMO cities as a function of hospital and market characteristics, corresponding to Figure 18.

Table C.4 presents regression coefficients for equations predicting the availability of individual technologies in high- and low-HMO cities

Table C.1

Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics

	Index 83 (Fig. 9)		Index 87 (Fig. 10)		Index 91 (Fig. 11)		Rising Index (Fig. 12)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
Community characteristics								
Log (population)	**–0.159**	0.021	**–0.200**	0.033	**–0.234**	0.038	**–0.035**	0.015
Log (population/square mile)	0.038	0.021	–0.051	0.031	**–0.082**	0.036	**–0.094**	0.014
Income per capita/100	–0.001	0.001	**–0.002**	0.001	**–0.002**	0.001	**–0.001**	0.0004
% over age 65	0.006	0.004	–0.008	0.006	–0.008	0.006	**–0.015**	0.002
Log (physicians per capita)	**0.209**	0.035	**0.497**	0.052	**0.584**	0.061	**0.360**	0.023
Hospital characteristics								
Average adj. admissions/100	**0.012**	0.0004	**0.020**	0.001	**0.023**	0.001	**0.008**	0.0003
CV of adj. admissions	**–0.969**	0.048	**–1.490**	0.072	**–1.628**	0.084	**–0.495**	0.032
# with residency programs	**0.034**	0.014	**0.065**	0.022	**0.071**	0.025	**0.035**	0.010
# with medical schools	–0.024	0.014	–0.038	0.021	–0.041	0.024	**–0.021**	0.009
# with COTH membership	0.019	0.013	–0.005	0.019	–0.006	0.022	**–0.018**	0.009
% in health system	0.039	0.039	**0.162**	0.058	**0.221**	0.068	**0.166**	0.026
% government owned	**–0.356**	0.065	**–0.596**	0.098	**–0.635**	0.115	**–0.174**	0.044
% for-profit owned	–0.034	0.067	**0.298**	0.102	**0.262**	0.119	**0.196**	0.046
Log (distance between neighbors)	**0.057**	0.026	0.061	0.039	0.021	0.046	**–0.003**	0.017
1984 low HMO	0.050	0.057	**0.267**	0.087	0.111	0.101	0.030	0.039
1985 low HMO	**0.198**	0.058	**0.488**	0.088	**0.315**	0.103	**0.089**	0.039
1986 low HMO	**0.280**	0.059	**0.953**	0.089	**0.796**	0.104	**0.182**	0.040
1987 low HMO	**0.331**	0.060	**1.082**	0.090	**0.954**	0.105	**0.283**	0.040
1988 low HMO	**0.427**	0.061	**1.191**	0.093	**1.146**	0.108	**0.379**	0.041
1989 low HMO	**0.444**	0.063	**1.235**	0.096	**1.479**	0.111	**0.442**	0.043
1990 low HMO	**0.367**	0.065	**1.171**	0.099	**2.952**	0.116	**0.455**	0.044
1991 low HMO	**0.364**	0.067	**1.178**	0.101	**3.081**	0.118	**0.476**	0.045

Table C.1 (continued)

	Index 83 (Fig. 9)		Index 87 (Fig. 10)		Index 91 (Fig. 11)		Rising Index (Fig. 12)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
1992 low HMO	**0.350**	0.069	**1.204**	0.105	**3.172**	0.122	**0.479**	0.047
1993 low HMO	**0.355**	0.072	**1.239**	0.110	**3.294**	0.128	**0.518**	0.049
1983 high HMO	0.064	0.082	0.148	0.124	0.181	0.145	0.061	0.055
1984 high HMO	0.119	0.082	0.182	0.124	0.223	0.145	0.059	0.055
1985 high HMO	0.079	0.082	0.137	0.124	0.168	0.145	0.058	0.055
1986 high HMO	–0.026	0.082	–0.078	0.124	–0.014	0.145	0.011	0.055
1987 high HMO	–0.115	0.082	–0.236	0.124	–0.157	0.145	–0.083	0.056
1988 high HMO	–0.115	0.082	–0.229	0.124	–0.193	0.145	–0.081	0.056
1989 high HMO	–0.072	0.082	**–0.247**	0.124	–0.161	0.145	–0.073	0.056
1990 high HMO	0.007	0.082	–0.107	0.124	–0.081	0.145	–0.039	0.056
1991 high HMO	–0.076	0.082	–0.193	0.124	–0.268	0.145	–0.062	0.056
1992 high HMO	–0.023	0.082	–0.101	0.125	–0.131	0.145	–0.016	0.056
1993 high HMO	–0.036	0.082	–0.137	0.125	–0.175	0.145	–0.004	0.056
Intercept	**5.160**	0.190	**6.647**	0.288	**6.801**	0.336	**1.932**	0.129

NOTES: Statistically significant coefficients are in bold type. CV is coefficient of variation. COTH membership is membership in the Council of Teaching Hospitals.

Table C.2

Effect of HMOs and Hospital Competition on Technology, Controlling for Hospital and Market Characteristics

	Index 83 (Fig. 13)		Index 87		Index 91 (Fig. 14)		Rising Index (Fig .15)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
Community characteristics								
Log (population)	**–0.145**	0.022	**–0.178**	0.034	**–0.215**	0.040	–0.019	0.015
Log (population/square mile)	0.033	0.021	–0.059	0.031	**–0.089**	0.037	**–0.100**	0.014
Income per capita/100	–0.001	0.001	**–0.002**	0.001	**–0.002**	0.001	**–0.001**	0.0004
% over age 65	**0.007**	0.004	–0.006	0.006	–0.006	0.007	**–0.014**	0.002
Log (physicians per capita)	**0.215**	0.035	**0.507**	0.053	**0.593**	0.061	**0.369**	0.023
Hospital characteristics								
Average adj. admissions/100	**0.012**	0.0004	**0.020**	0.001	**0.023**	0.001	**0.008**	0.0003
CV of adj. admissions	**–0.989**	0.048	**–1.521**	0.073	**–1.655**	0.086	**–0.518**	0.033
# with residency programs	**0.034**	0.014	**0.067**	0.022	**0.071**	0.025	**0.035**	0.010
# with medical schools	–0.023	0.014	–0.037	0.021	–0.040	0.024	**–0.020**	0.009
# with COTH membership	0.018	0.013	–0.006	0.019	–0.006	0.022	**–0.019**	0.009
% in health system	0.038	0.039	**0.160**	0.058	**0.218**	0.068	**0.164**	0.026
% government owned	**–0.350**	0.065	**–0.587**	0.098	**–0.627**	0.115	**–0.167**	0.044
% for-profit owned	–0.019	0.068	**0.320**	0.102	**0.282**	0.119	**0.213**	0.046
Log (distance between neighbors)	**0.057**	0.026	0.060	0.039	0.020	0.046	–0.004	0.017
1984 low HMO	0.050	0.057	**0.267**	0.087	**0.111**	0.101	0.030	0.039
1985 low HMO	**0.198**	0.058	**0.487**	0.088	**0.314**	0.103	**0.089**	0.039
1986 low HMO	**0.279**	0.059	**0.952**	0.089	**0.795**	0.104	**0.182**	0.040
1987 low HMO	**0.330**	0.060	**1.081**	0.090	**0.953**	0.105	**0.283**	0.040
1988 low HMO	**0.426**	0.061	**1.190**	0.093	**1.144**	0.108	**0.378**	0.041
1989 low HMO	**0.442**	0.063	**1.233**	0.096	**1.477**	0.112	**0.441**	0.043
1990 low HMO	**0.366**	0.065	**1.169**	0.099	**2.951**	0.116	**0.455**	0.044
1991 low HMO	**0.363**	0.067	**1.176**	0.101	**3.080**	0.118	**0.476**	0.045

Table C.2 (continued)

	Index 83 (Fig. 13)		Index 87		Index 91 (Fig. 14)		Rising Index (Fig. 15)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
1992 low HMO	**0.348**	0.069	**1.203**	0.105	**3.171**	0.123	**0.479**	0.047
1993 low HMO	**0.353**	0.072	**1.237**	0.110	**3.293**	0.128	**0.518**	0.049
1983 high HMO high comp.	0.061	0.111	0.157	0.168	0.164	0.196	–0.012	0.075
1984 high HMO high comp.	0.067	0.111	0.057	0.168	0.122	0.196	–0.036	0.075
1985 high HMO high comp.	–0.037	0.111	–0.055	0.168	0.017	0.196	–0.037	0.075
1986 high HMO high comp.	–0.104	0.111	–0.198	0.168	–0.117	0.196	–0.060	0.075
1987 high HMO high comp.	–0.116	0.111	–0.241	0.168	–0.148	0.196	–0.088	0.075
1988 high HMO high comp.	–0.207	0.111	**–0.323**	0.168	–0.291	0.196	–0.107	0.075
1989 high HMO high comp.	–0.110	0.111	–0.286	0.168	–0.225	0.196	–0.116	0.075
1990 high HMO high comp.	–0.076	0.111	–0.211	0.168	–0.205	0.196	–0.132	0.075
1991 high HMO high comp.	–0.194	0.111	**–0.378**	0.168	**–0.390**	0.196	**–0.185**	0.075
1992 high HMO high comp.	–0.169	0.111	–0.304	0.168	–0.328	0.196	**–0.150**	0.075
1993 high HMO high comp.	–0.090	0.112	–0.243	0.169	–0.246	0.197	–0.120	0.075
1983 high HMO low comp.	0.041	0.107	0.100	0.162	0.163	0.189	0.103	0.072
1984 high HMO low comp.	0.143	0.107	0.264	0.162	0.287	0.189	0.123	0.072
1985 high HMO low comp.	0.167	0.107	0.286	0.162	0.281	0.189	0.122	0.072
1986 high HMO low comp.	0.025	0.107	0.002	0.162	0.054	0.189	0.051	0.072
1987 high HMO low comp.	–0.138	0.107	–0.267	0.162	–0.198	0.189	–0.106	0.072
1988 high HMO low comp.	–0.049	0.107	–0.174	0.162	–0.131	0.189	–0.083	0.072
1989 high HMO low comp.	–0.059	0.107	–0.244	0.162	–0.131	0.189	–0.057	0.072
1990 high HMO low comp.	0.063	0.107	–0.041	0.162	0.006	0.189	0.025	0.072
1991 high HMO low comp.	0.014	0.107	–0.049	0.162	–0.181	0.189	0.031	0.072
1992 high HMO low comp.	0.093	0.107	0.061	0.162	0.027	0.189	0.088	0.072
1993 high HMO low comp.	–0.009	0.107	–0.069	0.162	–0.139	0.189	0.082	0.072
Intercept	**5.067**	0.194	**6.510**	0.294	**6.679**	0.343	**1.830**	0.131

NOTES: Statistically significant coefficients are in bold type. Comp is competition. CV is coefficient of variation.

Table C.3

Effect of HMOs and Hospital Competition on the Coefficient of Variation of Technology Level, Controlling for Hospital and Market Characteristics

	CV Index 83—Fig. 18		CV of Index 83	
	Coef.	S. E.	Coef.	S. E.
Community characteristics				
Log (population)	**0.022**	0.007	**0.022**	0.007
Log (population/square mile)	**–0.018**	0.006	**–0.018**	0.006
Income per capita/100	–0.0003	0.0002	–0.0003	0.0002
% over age 65	0.001	0.001	0.001	0.001
Log (physicians per capita)	**0.068**	0.011	**0.068**	0.011
Hospital characteristics				
Average adj. admissions/100	**–0.001**	0.0001	**–0.001**	0.0001
CV of adj. admissions	**0.275**	0.015	**0.276**	0.015
# with residency programs	0.002	0.004	0.002	0.004
# with medical schools	0.003	0.004	0.004	0.004
# with COTH membership	**–0.017**	0.004	**–0.017**	0.004
% in health system	**0.029**	0.012	**0.029**	0.012
% government owned	**0.066**	0.020	**0.065**	0.020
% for-profit owned	0.039	0.021	0.038	0.021
Log (distance between neighbors)	–0.010	0.008	–0.010	0.008
1984 low HMO	0.005	0.017	0.005	0.018
1985 low HMO	–0.011	0.018	**–0.011**	0.018
1986 low HMO	**–0.039**	0.018	**–0.039**	0.018
1987 low HMO	**–0.036**	0.018	**–0.036**	0.018
1988 low HMO	**–0.049**	0.019	**–0.049**	0.019
1989 low HMO	**–0.058**	0.019	**–0.058**	0.019
1990 low HMO	**–0.051**	0.020	**–0.050**	0.020
1991 low HMO	**–0.055**	0.020	**–0.055**	0.020
1992 low HMO	**–0.042**	0.021	**–0.042**	0.021
1993 low HMO	–0.024	0.022	–0.024	0.022
1983 high HMO	–0.029	0.025		
1984 high HMO	–0.039	0.025		
1985 high HMO	–0.031	0.025		
1986 high HMO	0.022	0.025		
1987 high HMO	0.029	0.025		
1988 high HMO	0.039	0.025		
1989 high HMO	0.031	0.025		
1990 high HMO	0.018	0.025		
1991 high HMO	0.032	0.025		
1992 high HMO	0.019	0.025		
1993 high HMO	–0.001	0.025		

Table C.3 (continued)

	CV Index 83—Fig. 18		CV of Index 83	
	Coef.	S. E.	Coef.	S. E.
1983 high HMO high comp.			0.048	0.033
1984 high HMO high comp.			–0.046	0.034
1985 high HMO high comp.			–0.009	0.033
1986 high HMO high comp.			0.034	0.033
1987 high HMO high comp.			0.023	0.033
1988 high HMO high comp.			0.048	0.033
1989 high HMO high comp.			0.033	0.033
1990 high HMO high comp.			0.006	0.033
1991 high HMO high comp.			0.040	0.033
1992 high HMO high comp.			0.038	0.034
1993 high HMO high comp.			–0.005	0.034
1983 high HMO low comp.			–0.009	0.033
1984 high HMO low comp.			–0.030	0.033
1985 high HMO low comp.			–0.051	0.033
1986 high HMO low comp.			0.011	0.033
1987 high HMO low comp.			0.036	0.033
1988 high HMO low comp.			0.031	0.033
1989 high HMO low comp.			0.030	0.033
1990 high HMO low comp.			0.030	0.033
1991 high HMO low comp.			0.026	0.033
1992 high HMO low comp.			0.001	0.033
1993 high HMO low comp.			0.005	0.033
Intercept	**0.379**	0.057	**0.382**	0.059

NOTES: Statistically significant coefficients are in bold type. CV is coefficient of variation. Comp. is competition. COTH membership is membership in the Council of Teaching Hospitals.

as a function of hospital and market characteristics, corresponding to Figures 19, 21, 23, and 25.

Table C.5 presents regression coefficients for equations predicting the availability of individual technologies in high-competition high-HMO cities, low-competition high-HMO cities, and low-HMO cities as a function of hospital and market characteristics, corresponding to Figures 20, 22, and 24.

Table C.4

Effect of HMOs on Individual Technologies, Controlling for Hospital and Market Characteristics

	Open Heart Surgery (Fig. 19)		Cardiac Catheterization (Fig. 21)		Diagnos. Radioisotope (Fig. 23)		NICU (Fig. 25)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
Community characteristics								
Log (population)	**0.514**	0.133	–0.050	0.167	**–0.634**	0.230	**–0.295**	0.148
Log (population/square mile)	–0.009	0.069	**0.183**	0.087	**0.525**	0.119	0.054	0.077
Income per capita/100	–0.002	0.002	**0.006**	0.002	0.006	0.003	**0.009**	0.002
% over age 65	**–0.058**	0.012	**–0.045**	0.015	**0.103**	0.021	**–0.076**	0.014
Log (physicians per capita)	**0.321**	0.128	**–0.658**	0.160	**–2.837**	0.220	**–1.685**	0.141
Hospital characteristics								
Log (number of hospitals)	**0.595**	0.151	**1.636**	0.189	**3.897**	0.260	**1.196**	0.167
Average adj. admissions/100	0.002	0.002	**0.008**	0.002	0.002	0.003	**0.005**	0.002
CV of adj. admissions	0.148	0.160	–0.295	0.201	–0.413	0.276	0.155	0.177
# with residency programs	**0.776**	0.048	**0.992**	0.060	**1.517**	0.083	**0.782**	0.053
# with medical schools	**–0.206**	0.046	**–0.242**	0.057	**–0.280**	0.078	0.060	0.050
# with COTH membership	**–0.097**	0.043	**0.222**	0.054	**0.970**	0.074	**0.282**	0.047
% in health system	0.180	0.129	0.292	0.162	0.294	0.223	**0.434**	0.143
% government owned	–0.375	0.219	–0.257	0.275	–0.599	0.377	0.070	0.243
% for-profit owned	**3.466**	0.226	**4.042**	0.283	**5.661**	0.389	**2.514**	0.250
Log (distance between neighbors)	0.090	0.087	**0.496**	0.109	**0.840**	0.149	**0.595**	0.096
1984 low HMO	0.094	0.192	0.104	0.242	0.059	0.332	–0.007	0.213
1985 low HMO	0.119	0.195	0.099	0.245	–0.007	0.336	–0.020	0.216
1986 low HMO	0.295	0.198	0.332	0.248	–0.123	0.341	0.066	0.219
1987 low HMO	**0.412**	0.200	0.455	0.251	–0.360	0.345	0.065	0.222

Table C.4 (continued)

	Open Heart Surgery (Fig. 19)		Cardiac Catheterization (Fig. 21)		Diagnos. Radioisotope (Fig. 23)		NICU (Fig. 25)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
1988 low HMO	**0.624**	0.206	**0.701**	0.258	–0.346	0.355	–0.086	0.228
1989 low HMO	**0.713**	0.212	**0.745**	0.266	–0.278	0.365	–0.035	0.235
1990 low HMO	**0.783**	0.220	**0.876**	0.276	–0.443	0.379	0.010	0.244
1991 low HMO	**0.810**	0.224	**0.946**	0.281	–0.492	0.387	–0.028	0.248
1992 low HMO	**0.908**	0.233	**1.133**	0.293	–0.374	0.402	0.015	0.258
1993 low HMO	**1.000**	0.244	**1.238**	0.306	–0.490	0.421	–0.166	0.270
1983 high HMO	–0.247	0.276	–0.394	0.346	**1.383**	0.476	0.026	0.306
1984 high HMO	–0.353	0.276	–0.631	0.346	**1.020**	0.476	–0.199	0.306
1985 high HMO	–0.362	0.276	–0.486	0.346	0.625	0.475	–0.303	0.305
1986 high HMO	–0.227	0.276	–0.380	0.346	0.183	0.476	–0.337	0.306
1987 high HMO	–0.163	0.276	–0.220	0.347	0.502	0.477	–0.305	0.306
1988 high HMO	–0.203	0.276	–0.075	0.347	0.016	0.477	–0.533	0.306
1989 high HMO	–0.243	0.276	–0.243	0.347	0.101	0.476	–0.302	0.306
1990 high HMO	–0.103	0.276	0.048	0.347	–0.101	0.476	–0.361	0.306
1991 high HMO	–0.174	0.276	0.158	0.346	–0.194	0.476	–0.134	0.306
1992 high HMO	–0.004	0.276	**0.677**	0.347	0.237	0.477	–0.076	0.306
1993 high HMO	0.151	0.277	**0.890**	0.348	0.333	0.477	–0.163	0.307
Intercept	**–4.159**	0.763	**–5.522**	0.957	**–8.852**	1.315	**–4.667**	0.845

NOTES: Statistically significant coefficients are in bold type. CV is coefficient of variation. COTH membership is membership in the Council of Teaching Hospitals.

Table C.5

Effect of HMOs and Hospital Competition on Individual Technologies, Controlling for Hospital and Market Characteristics

	Open Heart Surg. (Fig. 20)		Cardiac Cathet. (Fig. 22)		Diagnos. Radio. (Fig. 24)		NICU (Fig .25)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
Community characteristics								
Log (population)	**0.536**	0.133	–0.027	0.166	**–0.662**	0.229	–0.278	0.148
Log (population/square mile)	–0.032	0.069	**0.166**	0.086	**0.,554**	0.120	**0.031**	0.077
Income per capita/100	–0.002	0.002	**0.005**	0.002	**0.007**	0.003	**0.009**	0.002
% over age 65	**–0.053**	0.012	**–0.040**	0.015	**0.094**	0.021	**–0.071**	0.014
Log (physicians per capita)	**0.344**	0.127	**–0.624**	0.159	**–2.872**	0.219	**–1.674**	0.141
Hospital characteristics								
Log (number of hospitals)	**0.641**	0.152	**1.640**	0.189	**3.822**	0.262	**1.251**	0.169
Average adj. admissions/100	0.001	0.002	**0.007**	0.002	0.003	0.003	0.005	0.002
CV of adj. admissions	0.054	0.163	–0.354	0.203	–0.274	0.281	0.065	0.181
# with residency programs	**0.796**	0.048	**1.041**	0.060	**1.510**	0.083	**0.786**	0.054
# with medical schools	**–0.229**	0.046	**–0.300**	0.057	**–0.267**	0.079	0.056	0.051
# with COTH membership	**–0.085**	0.043	**0.245**	0.053	**0.952**	0.074	**0.288**	0.047
% in health system	0.160	0.129	0.262	0.161	0.316	0.223	**0.419**	0.144
% government owned	–0.368	0.218	–0.269	0.272	–0.613	0.377	0.081	0.243
% for-profit owned	**3.519**	0.226	**4.058**	0.282	**5.592**	0.390	**2.574**	0.251
Log (distance betw. neighbors)	0.073	0.087	**0.467**	0.108	**0.861**	0.149	**0.583**	0.096
1984 low HMO	0.096	0.192	0.108	0.239	0.056	0.331	–0.006	0.213
1985 low HMO	0.122	0.194	0.107	0.242	–0.012	0.335	–0.020	0.216
1986 low HMO	0.302	0.197	0.344	0.245	–0.133	0.340	0.068	0.219
1987 low HMO	**0.419**	0.200	0.472	0.249	–0.371	0.344	0.066	0.222
1988 low HMO	**0.641**	0.205	**0.744**	0.256	–0.364	0.354	–0.083	0.228
1989 low HMO	**0.732**	0.211	**0.795**	0.263	–0.301	0.364	–0.032	0.235
1990 low HMO	**0.801**	0.219	**0.921**	0.273	–0.470	0.378	0.013	0.244
1991 low HMO	**0.825**	0.224	**0.982**	0.279	–0.520	0.386	–0.025	0.248

Table C.5 (continued)

	Open Heart Surg. (Fig. 20)		Cardiac Cathet. (Fig. 22)		Diagnos. Radio. (Fig. 24)		NICU (Fig .25)	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
1992 low HMO	**0.927**	0.233	**1.183**	0.290	–0.405	0.401	0.017	0.258
1993 low HMO	**1.024**	0.243	**1.299**	0.303	–0.528	0.420	–0.163	0.270
1983 high HMO high comp.	**–0.934**	0.372	**–1.394**	0.463	**2.797**	0.641	–0.279	0.413
1984 high HMO high comp.	**–1.036**	0.372	**–1.668**	0.463	**2.236**	0.642	–0.682	0.413
1985 high HMO high comp.	**–1.128**	0.372	**–1.447**	0.463	**1.519**	0.641	–0.721	0.413
1986 high HMO high comp.	–0.706	0.371	**–1.106**	0.463	0.548	0.641	–0.790	0.413
1987 high HMO high comp.	–0.417	0.371	–0.582	0.462	0.863	0.640	–0.517	0.412
1988 high HMO high comp.	–0.396	0.371	–0.054	0.463	–0.059	0.641	**–1.127**	0.413
1989 high HMO high comp.	–0.419	0.371	–0.337	0.462	0.276	0.640	–0.654	0.412
1990 high HMO high comp.	–0.178	0.371	0.233	0.462	–0.457	0.640	–0.631	0.412
1991 high HMO high comp.	–0.345	0.371	0.368	0.462	–0.613	0.640	–0.238	0.412
1992 high HMO high comp.	0.153	0.372	**1.688**	0.463	0.571	0.642	–0.034	0.413
1993 high HMO high comp.	0.451	0.374	**2.252**	0.465	0.747	0.645	–0.186	0.415
1983 high HMO low comp.	0.322	0.359	0.520	0.447	0.152	0.618	0.226	0.398
1984 high HMO low comp.	0.201	0.358	0.292	0.446	–0.012	0.618	0.170	0.398
1985 high HMO low comp.	0.277	0.358	0.372	0.446	–0.099	0.618	0.003	0.398
1986 high HMO low comp.	0.142	0.358	0.264	0.447	–0.036	0.618	0.007	0.398
1987 high HMO low comp.	–0.006	0.360	0.078	0.448	0.278	0.620	–0.189	0.399
1988 high HMO low comp.	–0.098	0.359	–0.132	0.448	0.207	0.620	–0.045	0.399
1989 high HMO low comp.	–0.153	0.359	–0.186	0.448	0.046	0.620	–0.046	0.399
1990 high HMO low comp.	–0.098	0.359	–0.137	0.447	0.350	0.620	–0.180	0.399
1991 high HMO low comp.	–0.086	0.359	–0.078	0.447	0.319	0.619	–0.115	0.399
1992 high HMO low comp.	–0.216	0.359	–0.291	0.447	0.014	0.619	–0.195	0.399
1993 high HMO low comp.	–0.194	0.359	–0.400	0.447	0.029	0.619	–0.220	0.399
Intercept	**–4.287**	0.764	**–5.462**	0.952	**–8.691**	1.318	**–4.843**	0.849

NOTES: Statistically significant coefficients are in bold type. CV is coefficient of variation. Comp. is competition. COTH membership is membership in the Council of Teaching Hospitals.

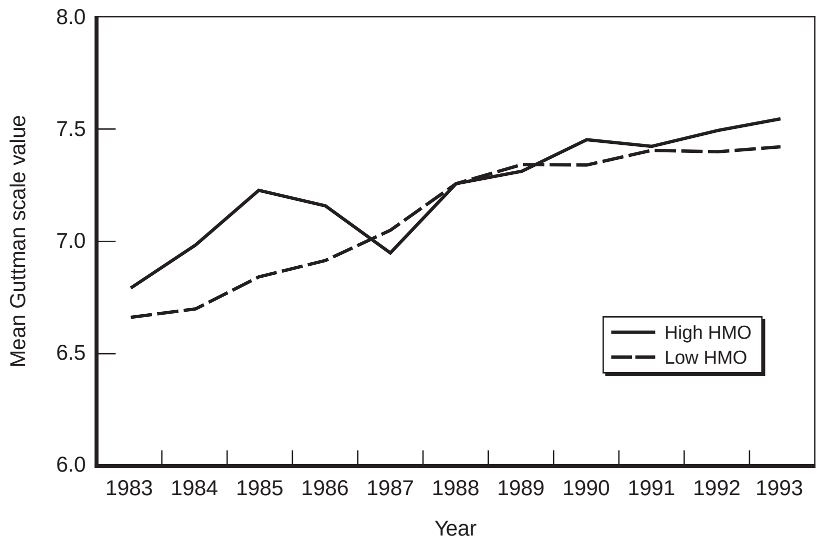
Appendix D

Robustness Checks

Using the Guttman Scale Rather Than a Saidin Index

We conducted our analyses using two measures of aggregate technology: Saidin indices, as presented in the body of this report, and the Guttman scale. The Guttman scale has been used by other researchers to control for technology availability in studies of hospital costs and patient preferences for particular hospitals (Adams et al., 1991; Zaretsky, 1977). The Guttman scale is described in detail in Appendix B.

Figure D.1 charts predicted values of the mean of the average Guttman scales in cities, controlling for hospital and market characteristics. This figure is analogous to Figure 9. As with our Saidin index, high-HMO cities had a higher average level of technology in 1983, but by 1987 low-HMO cities had a higher level. The average technology levels were similar from 1987 through 1993. In 1985, the



SOURCE: Our calculations based on American Hospital Association data.

Figure D.1—Effect of HMOs on Average Technology Levels, Controlling for Hospital and Market Characteristics, Guttman Scale

difference in the average Guttman scales is statistically significant; however, since it is not statistically significant in any other year, we cannot conclude that there is an overall difference between high- and low-HMO cities. Table D.1 presents the regression coefficients associated with Figure D.1.

Defining High-HMO Cities by 1990 Penetration Rather Than by 1993 Penetration

To measure the effect of HMO penetration on technology availability, we divided our sample of cities into two groups: cities with HMO penetration in the highest quartile, and cities with HMO penetration in the lower three quartiles. High-HMO cities are defined as

Table D.1

Robustness Checks: Effect of HMOs on Average Technology Levels, with Varying Specifications

	Index 83					
	Guttman Scale—Fig. D.1		1990 HMO Penetration—Fig. D.2		Unbalanced Panel—Fig. D.3	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
Community characteristics						
Log (population)	**–0.177**	0.046	**–0.159**	0.021	**–0.142**	0.021
Log (population/square mile)	**–0.133**	0.044	0.039	0.021	**0.041**	0.019
Income per capita/100	–0.002	0.001	–0.001	0.001	**–0.001**	0.001
% over age 65	0.005	0.008	0.006	0.004	**0.009**	0.004
Log (physicians per capita)	**0.705**	0.074	**0.208**	0.035	**0.210**	0.035
Hospital characteristics						
Average adj. admissions/100	**0.023**	0.001	**0.012**	0.0004	**0.012**	0.0004
CV of adj. admissions	**–3.222**	0.102	**–0.966**	0.048	**–0.988**	0.046
# with residency programs	**0.118**	0.031	**0.035**	0.014	**0.034**	0.014
# with medical schools	**–0.100**	0.029	–0.025	0.014	–0.021	0.014
# with COTH membership	–0.001	0.027	0.020	0.013	0.011	0.013
% in health system	**0.487**	0.083	0.038	0.038	0.030	0.038
% government owned	**–0.819**	0.140	**–0.361**	0.065	**–0.313**	0.065
% for-profit owned	**0.708**	0.145	–0.041	0.068	–0.030	0.066
Log (distance betw. neighbors)	0.054	0.056	**0.058**	0.026	0.038	0.026
1984 low HMO	0.041	0.123	0.053	0.057	0.056	0.059
1985 low HMO	0.179	0.125	**0.193**	0.058	**0.213**	0.059
1986 low HMO	**0.255**	0.127	**0.290**	0.059	**0.280**	0.060
1987 low HMO	**0.393**	0.128	**0.329**	0.060	**0.341**	0.060
1988 low HMO	**0.609**	0.132	**0.433**	0.061	**0.436**	0.062
1989 low HMO	**0.693**	0.136	**0.450**	0.063	**0.447**	0.064

Table D.1 (continued)

	Index 83					
	Guttman Scale—Fig. D.1		1990 HMO Penetration—Fig. D.2		Unbalanced Panel—Fig. D.3	
	Coef.	S. E.	Coef.	S. E.	Coef.	S. E.
1990 low HMO	**0.685**	0.141	**0.368**	0.065	**0.383**	0.066
1991 low HMO	**0.745**	0.144	**0.369**	0.067	**0.397**	0.067
1992 low HMO	**0.741**	0.149	**0.344**	0.069	**0.352**	0.069
1993 low HMO	**0.770**	0.156	**0.349**	0.072	**0.391**	0.072
1983 high HMO	0.132	0.176	0.064	0.082	0.077	0.082
1984 high HMO	0.275	0.176	0.103	0.082	0.134	0.082
1985 high HMO	**0.375**	0.176	0.097	0.082	0.052	0.082
1986 high HMO	0.249	0.176	–0.068	0.082	–0.008	0.082
1987 high HMO	–0.092	0.177	–0.107	0.082	–0.097	0.082
1988 high HMO	–0.024	0.177	–0.136	0.082	–0.108	0.082
1989 high HMO	–0.025	0.177	–0.098	0.082	–0.084	0.082
1990 high HMO	0.098	0.177	0.000	0.082	0.012	0.082
1991 high HMO	0.020	0.176	–0.099	0.082	–0.130	0.082
1992 high HMO	0.097	0.177	–0.007	0.082	–0.052	0.081
1993 high HMO	0.120	0.177	–0.018	0.082	–0.076	0.081
Intercept	**9.243**	0.409	**5.160**	0.189	**5.040**	0.187

NOTES: Statistically significant coefficients are in bold type. CV is coefficient of variation. COTH member is membership in the Council of Teaching Hospitals.

those with HMO penetration in the top quartile of all cities in 1993—at least 19.3 percent. To test the sensitivity of our findings to our classification of cities, we repeated our analysis defining high-HMO cities as those with HMO penetration in the top quartile in 1990 (rather than 1993). This corresponds to a HMO penetration of 15.6 percent in 1990.

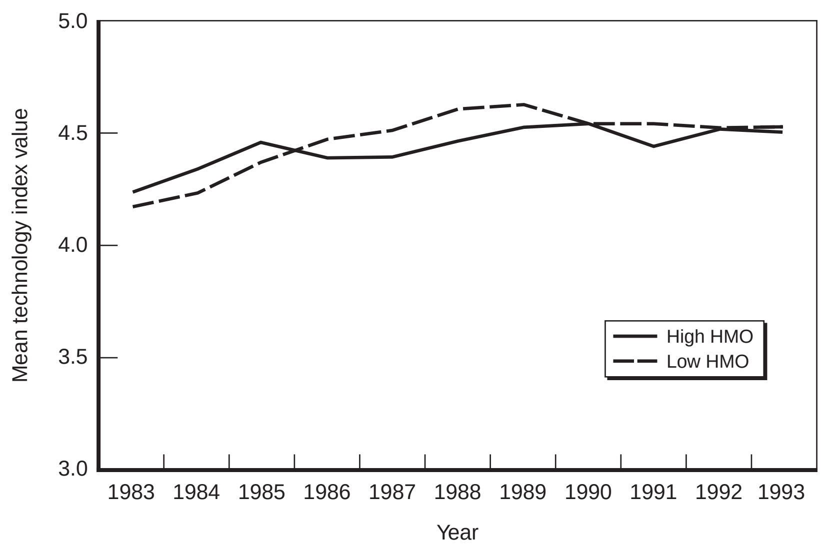
Table D.2 presents the mean HMO penetration in high-HMO and low-HMO cities under this classification. The average HMO penetration in the low-HMO group ranges from 6.1 percent in 1990 to 8.2 percent in 1993; average penetration in the high-HMO group ranges from 25.7 percent in 1990 to 29.1 percent in 1993. These figures are similar to those when the sample is divided by HMO penetration in 1990. The set of high-HMO cities in California is the same regardless of which year we use to divide our sample.

Table D.2

Mean HMO Penetration in High-HMO and Low-HMO Cities, Using 1990 Data to Determine HMO Penetration

	Low-HMO Cities		High-HMO Cities	
Year	Mean	Std. Dev.	Mean	Std. Dev
United States (195 low-HMO cities; 66 high-HMO cities)				
1990	6.1%	0.050	25.7%	0.085
1991	6.4%	0.052	25.9%	0.092
1992	7.1%	0.056	27.2%	0.094
1993	8.2%	0.063	29.1%	0.102
California (6 low-HMO cities; 14 high-HMO cities)				
1990	6.7%	0.041	33.0%	0.107
1991	7.3%	0.042	33.6%	0.105
1992	8.8%	0.043	35.8%	0.097
1993	10.3%	0.045	37.7%	0.100

Figure D.2 presents the predicted values of the Saidin indices for high- and low-HMO cities when high-HMO cities are defined by 1990 HMO penetration. As expected, the results are very similar to those presented in Figure 9. Cities with high levels of HMO penetration did not experience significantly different growth in technology availability than cities with lower HMO penetration. In 1983, high-HMO cities had a slightly higher technology level than low-HMO cities. After 1986, low-HMO cities displayed greater average technology availability. As in the analysis in the main text, the differences between high- and low-HMO cities were not statistically significant. Table D.1 presents regression coefficients corresponding to Figure D.2.



SOURCE: Our calculations based on American Hospital Association data.

Figure D.2—Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics, with High-HMO Group Defined by 1990 Penetration, Basic Technology Index 83

Conducting the Analysis with an Unbalanced Panel

In this report, we focused our analysis on cities in which at least one hospital provided technology information in each year from 1983 to 1993. 261 MSAs met this criterion. These cities tended to be larger, to have more hospitals, and to have higher-HMO market shares than the MSAs that were excluded. We repeated our analysis for all cities for which any hospital responded in any year. Table D.3 provides information about the number of cities in each year and Table D.4 presents some comparative information about the cities in this sample versus those in our balanced panel of 261 cities. The unbalanced set of cities has from 267 to 286 cities per year.

Predicted values of the average Saidin index for all hospitals in each city based on 1983 weights, computed from our regression analysis, which controls for hospital and market characteristics, are charted in Figure D.3. Table D.1 contains the regression coefficients. The pattern of technology availability in high- and low-HMO cities observed in the

Table D.3

Number of Cities in Each Year of the Unbalanced Panel

Year	Number of Cities
1983	267
1984	268
1985	272
1986	272
1987	274
1988	274
1989	274
1990	273
1991	274
1992	286
1993	286

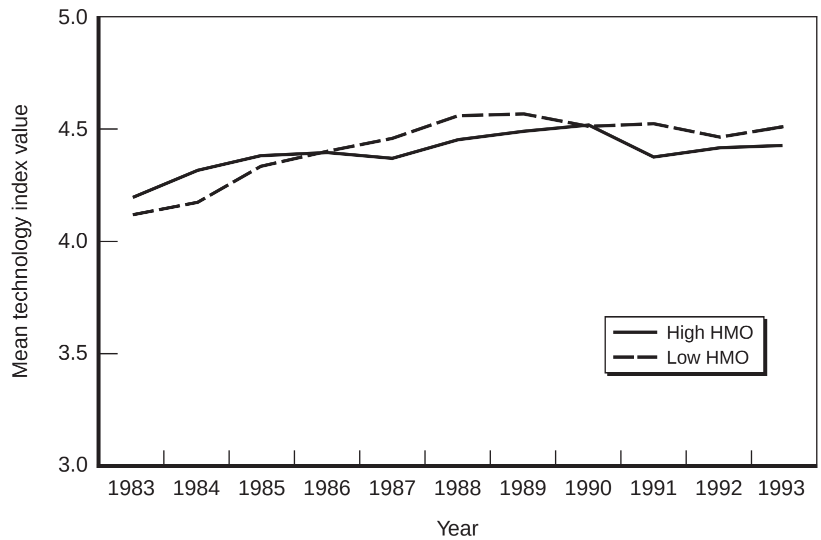
Table D.4

Summary Statistics for Cities in the Balanced and Unbalanced Panels of Cities

	Balanced Panel		Unbalanced Panel	
	1983	1993	1983	1993
Demographic characteristics				
Population (100s)	6071	6846	5979	6520
	(9626)	(10751)	(9538)	(10428)
Population (100s /square mile)	2.93	3.23	2.89	3.21
	(2.86)	(3.13)	(2.84)	(3.48)
Percentage over age 65	11.13	12.41	11.09	12.48
	(2.98)	(3.24)	(3.01)	(3.49)
Income per capita	11117	19763	11123	19682
	(1704)	(3267)	(1736)	(3242)
Physicians per capita	0.19	0.22	0.19	0.22
	(0.14)	(0.15)	(0.14)	(0.15)
Hospital characteristics				
Number of hospitals	9.66	9.07	9.52	8.67
	(13.30)	(11.54)	(13.19)	(11.20)
Miles between neighbors	8.25	8.66	8.50	9.00
	(5.64)	(5.72)	(6.36)	(6.09)
Average admissions	10635	11389	10570	11110
	(3259)	(3539)	(3271)	(3576)
CV of admissions	0.71	0.74	0.71	0.74
	(0.27)	(0.26)	(0.27)	(0.27)
Number with residency	3.15	3.02	3.08	2.08
	(4.61)	(4.31)	(4.58)	(4.18)
Number with medical school	3.02	3.01	2.95	2.78
	(4.38)	(4.59)	(4.35)	(4.46)
Number with COTH membership	1.23	1.15	1.21	1.06
	(2.45)	(2.27)	(2.43)	(2.19)
Percentage in health systems	21.5%	52.7%	20.9%	52.2%
Percentage government owned	16.9%	15.2%	17.0%	15.0%
Percentage for-profit owned	12.5%	13.4%	12.2%	14.1%

NOTES: CV is coefficient of variation. COTH membership is membership in the Council of Teaching Hospitals.

balanced panel was repeated in the unbalanced panel of cities. HMO penetration did not appear to have affected technology availability, at least since the mid-1980s.



SOURCE: Our calculations based on American Hospital Association data.

Figure D.3—Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics, Unbalanced Panel of Cities, Basic Technology Index 83

Are Hospital Closures Important?

As noted in Chapter 4, the closure of hospitals over the period we studied could render our conclusions invalid. If there were more hospital closures in high-HMO cities than in low-HMO cities and these closures were disproportionately of hospitals with low-technology levels, the average city technology level could remain high. This is misleading if those hospital closures were caused by the growth of HMOs—rather than conclude that HMOs were not affecting technology availability, we should conclude that HMOs were affecting technology availability by causing low-technology hospitals to close. This would be an interesting finding and would indicate that HMOs can control the availability of technology. The data suggest that differential hospital closure may be an important issue. In our balanced panel of cities, the mean number of hospitals per high-HMO MSA fell by about 9 percent between 1983 and 1993 but dropped only about 3 percent in low-HMO cities.

We examined whether differential hospital closure affected our conclusions using two methods. First, we added a control variable for the number of hospitals in markets to our model. As seen in Figure D.4, the pattern of technology availability is essentially the same as that measured without controlling for the number of hospitals in each city (Table D.5 presents the regression coefficients). As before, high-HMO cities had higher average technology levels in 1983; the difference is

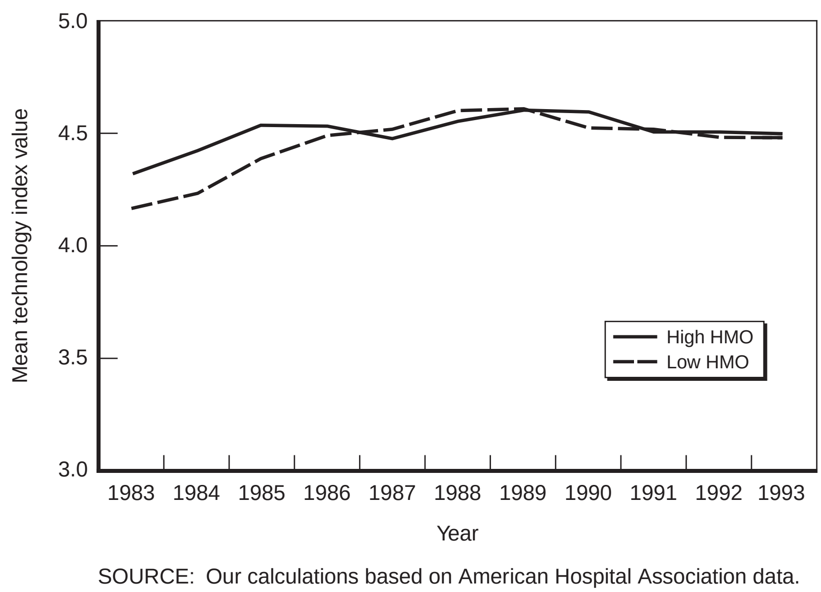


Figure D.4—Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics, Adding Number of Hospitals As Control Variable, Basic Technology Index 83

Table D.5

Tests of Whether Hospital Closures Are Important: Effect of HMOs on Average Technology Levels, with Varying Specifications

	Adding Number of Hospitals (Fig. D.4)		Balanced Panel of Hospitals (Fig. D.5)	
	Coef.	S. E.	Coef.	S. E.
Community characteristics				
Log (population)	**–0.558**	0.039	**–0.172**	0.021
Log (population/square mile)	0.034	0.020	**0.043**	0.021
Income per capita/100	0.001	0.001	**–0.002**	0.001
% over age 65	0.001	0.004	0.006	0.004
Log (physicians per capita)	0.022	0.037	**0.223**	0.035
Hospital characteristics				
Average adj. admissions/100	**0.015**	0.001	**0.012**	0.0004
CV of adj. admissions	**–1.001**	0.046	**–0.933**	0.049
# with residency programs	0.016	0.014	**0.064**	0.016
# with medical schools	–0.024	0.013	**–0.052**	0.015
# with COTH membership	**0.027**	0.012	0.025	0.014
% in health system	0.041	0.038	**0.087**	0.038
% government owned	**–0.433**	0.063	**–0.345**	0.064
% for-profit owned	–0.053	0.065	0.048	0.072
Log (distance between neighbors)	**0.057**	0.025	**0.070**	0.025
Number of hospitals	**0.537**	0.044		
1984 low HMO	0.053	0.056	0.063	0.060
1985 low HMO	**0.209**	0.057	**0.211**	0.060
1986 low HMO	**0.307**	0.057	**0.269**	0.061
1987 low HMO	**0.335**	0.058	**0.336**	0.062
1988 low HMO	**0.416**	0.060	**0.478**	0.064
1989 low HMO	**0.429**	0.061	**0.500**	0.066
1990 low HMO	**0.339**	0.064	**0.410**	0.068
1991 low HMO	**0.333**	0.065	**0.404**	0.069
1992 low HMO	**0.294**	0.068	**0.398**	0.072
1993 low HMO	**0.294**	0.071	**0.395**	0.075
1983 high HMO	0.138	0.080	0.067	0.085
1984 high HMO	**0.179**	0.080	0.129	0.085
1985 high HMO	0.132	0.080	0.103	0.085
1986 high HMO	0.030	0.080	0.077	0.086
1987 high HMO	–0.041	0.080	–0.023	0.086
1988 high HMO	–0.044	0.080	–0.035	0.086
1989 high HMO	–0.014	0.080	–0.044	0.086
1990 high HMO	0.067	0.080	0.041	0.086
1991 high HMO	–0.014	0.080	–0.069	0.086
1992 high HMO	0.033	0.080	–0.031	0.086
1993 high HMO	0.016	0.080	–0.018	0.086
Intercept	**6.652**	0.221	**5.270**	0.194

NOTES: Statistically significant coefficients are in bold type. CV is coefficient of variation. COTH membership is membership in the Council of Teaching Hospitals.

statistically significant in 1984. By 1987, the levels of high- and low-HMO cities were essentially identical. If HMOs had an effect on technology availability, that effect was limited to the early 1980s. We interpret this as evidence that differential rates of hospital closure do not have a strong influence on our findings.

For our second test of the importance of hospital closures, we repeated our regression analyses using a balanced panel of hospitals—that is, we limited our analysis to hospitals that were observed in every year of our analysis. 3,164 hospitals were observed for at least one year between 1983 and 1993 in the original analysis presented in this report. Over 60 percent of these hospitals reported data for all 11 years, and over 70 percent provided information for at least 10 years. Just over 10 percent of hospitals were observed for only one or two years.

The hospitals that reported data for fewer years had different characteristics than those that reported for most years between 1983 and 1993, as seen in Table D.6. Hospitals that provided data for fewer years tended to be smaller and to have lower average technology levels than other hospitals. Thus, hospitals that did not report data in every year and, thus, which may have closed had lower technology levels. This could bias our conclusions. The hospitals that reported data for fewer years were also more likely to be owned by for-profit corporations. They were in larger cities that had a larger number of hospitals. There was no consistent difference in average HMO penetration in the cities in which good-respondent and poor-respondent hospitals were located.

We created a balanced panel of hospitals and then derived a balanced panel of cities with which to repeat our regression analysis. 257 cities were in this new balanced panel, representing 2,165 hospitals. Figure D.5 graphs the predicted values of the city average technology indices for

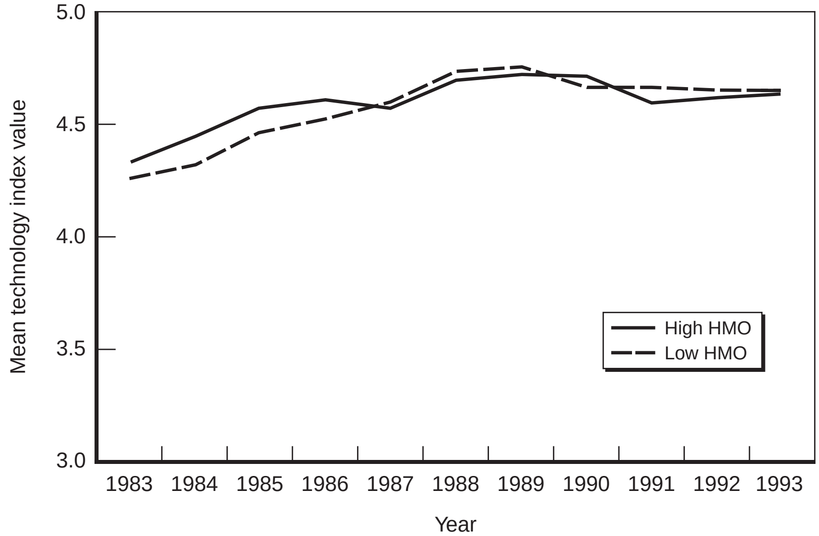
Table D.6

Summary Statistics for Hospitals, by the Number of Years Each Hospital Is Observed

	Observed 1–5 Years		Observed 6–9 Years		Observed 10–11 Years	
	1983	1993	1983	1993	1983	1993
Number of hospitals in category	230	257	224	137	2219	2208
Hospital's characteristics						
Adjusted admissions	5911	9082	6866	10348	11464	12193
	(7297)	(8392)	(6161)	(10319)	(8461)	(9467)
Average technology level	2.95	3.80	3.40	4.08	4.31	4.54
(Index 83)	(2.03)	(1.90)	(1.82)	(1.99)	(1.82)	(1.95)
% for-profit owned	30.0%	15.2%	28.6%	26.3%	14.1%	16.0%
% government owned	59.1%	65.8%	54.5%	59.1%	61.3%	61.9%
City's characteristics						
Number of hospitals in	34.06	24.82	32.37	26.49	27.05	23.74
city	(33.43)	(24.55)	(33.74)	(20.38)	(31.03)	(24.22)
Population in city (100s)	22686	21046	21624	21150	18214	20334
	(23346)	(22657)	(22836)	(19344)	(21603)	(23789)
% in high-HMO cities	46.1%	36.6%	48.7%	36.5%	42.4%	42.4%

NOTE: Standard errors are in parentheses.

the balanced panel of hospitals, controlling for the hospital and market characteristics, and Table D.5 presents the regression coefficients. The results were again nearly identical to those presented in Figure 9. Between 1983 and 1986, high-HMO cities had a higher average technology level, but the difference was not statistically significant. After 1987, average technology availability was similar between high- and low-HMO cities. Thus, we do not believe that hospital closures affect our conclusion that HMOs did not have an effect on technology availability in U.S. cities.



SOURCE: Our calculations based on American Hospital Association data.

Figure D.5—Effect of HMOs on Technology, Controlling for Hospital and Market Characteristics, Balanced Panel of Hospitals, Basic Technology Index 83

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