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MANAGED CARE AND THE GROWTH OF MEDICAL EXPENDITURES

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ABSTRACT

We use data across states to examine the relation between HMO enrollment and medical spending. We find that increased managed care enrollment significantly reduces hospital cost growth. While some of this effect is offset by increased spending on physicians, we generally find a significant reduction in total spending as well. In analyzing the sources of hospital cost reductions, we find preliminary evidence that managed care has reduced the diffusion of medical technologies. States with high managed care enrollment were technology leaders in the early 1980s; by the early 1990s those states were only average in their acquisition of new technologies. This finding suggests managed care may have a significant effect on the long-run growth of medical spending.

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Over the past few years, health insurance costs have made a dramatic turnaround. After decades of double-digit increases, health insurance cost growth has essentially ground to a halt. Most observers point to managed care as the leading culprit. "The growing dominance of managed care has helped control health care cost increases", the *New York Times* editorialized. "What this demonstrates is that in the private sector, managed care and competition are lowering the rate of cost increases in health care," Representative Nancy Johnson stated.

But the evidence on this point is far from compelling. Some surveys find that managed care premiums are not much lower than traditional indemnity premiums (Krueger and Levy, 1996), so the savings from enrollment shifts to managed care alone may not be that great. Further, managed care enrollment in many parts of the country is still very low. Finally, the growth of public health programs has slowed as well--with both Medicare and Medicaid growing more slowly over the past few years than over the previous decade. Medicare has little managed care enrollment, and while some have pointed to the growth of managed care as responsible for less rapid cost growth in Medicaid, initial analysis indicates this was not the primary factor (Holahan and Liska 1997).[1]

And even if managed care is the answer, it is not clear whether this reduced rate of cost growth can continue. Continued excess capacity in the health system bodes well for future managed care cost reductions. Hospital occupancy rates, for example, which were 78 percent in 1980 were 66 percent in 1995, even with a 12 percent reduction in hospitals beds. In the presence of excess capacity, managed care insurers find it easier to bargain among providers and

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[1] For example, growth in spending for the elderly and the blind (who are generally not enrolled in managed care) fell more than spending for children and adults.

achieve overall lower rates. But there is some concern that the increasing consolidation of the medical care sector may reduce the ability of managed care insurers to bargain among providers.

More fundamentally, however, managed care may not be addressing the right problem. Managed care insurers may lower the rates paid for particular services, and may even chip away at the margins of medical care -- for example, in reduced hospitals stays. But the fundamental drivers of medical costs in the next several decades will be aging and the expanding technological capability of medicine. The latter factor in particular accounts for the bulk of the growth of medical costs historically, and it is not clear that managed care has done, or can do, much about this. Managed care may save money, but how much and for how long?

In this paper, we examine the two issues of whether managed care has affected the growth of medical costs, and if so whether that effect will continue or slow down. We take advantage of the dramatic variation in the medical insurance environment across states. Managed care is the dominant (if not the only) source of medical insurance in some states; in California, for example, close to 80 percent of the population is enrolled in managed care. In other states, such as Alaska or Wyoming, managed care is virtually non-existent. This variation in managed care penetration provides a natural laboratory in which to examine the source of cost savings.

We conclude that managed care has reduced the growth of medical costs. States with high managed care enrollment have significantly lower cost growth than states with lower managed care enrollment. Hospital spending growth is most affected by managed care. Some of the reduced hospital spending growth is offset by increased spending on physicians, but we typically find a net reduction in total spending growth. Perhaps more importantly, we find

suggestive evidence that managed care may be reducing the diffusion of new medical technologies. States with high managed care enrollment were technology "leaders" in the early 1980s, but were only average in their use of technology in the early 1990s. This suggests that managed care may have a significant effect on the long-run growth of medical costs.

I. The Growth of Aggregate Medical Spending

We begin with an analysis of recent changes in national health expenditures to examine whether there is any plausibility to the relation between increased competition and reduced medical spending growth. Figure 1 shows the growth of real, per capita national health expenditures for various time periods from 1960 through 1995. Throughout the paper, dollar amounts in real terms are adjusted using the GDP deflator for personal consumption expenditures.

Between 1960 and 1990, medical expenditures grew about 5 percent per year in real, per capita terms. The growth rate varied by decade. In the 1960s, growth was rapid as Medicare and Medicaid were created and insurance coverage for the privately insured became for generous. In the 1970s, the medical sector consolidated and growth rates ebbed. The 1980s were marked by the first serious efforts at cost containment, including prospective payment for hospitals in the public sector and some of the private sector. But overall cost growth continued relatively unabated.

In the 1990s, however, and particularly since 1992, the growth of medical costs has slowed dramatically. In 1992, medical spending grew 4.8 percent. In 1993 growth was 3.1

percent; in 1994 it was 1.5 percent; and in 1995 it was 2.1 percent. This reduction in growth is particularly surprising given that the ongoing economic expansion of the post-1992 period (as we show below, the elasticity of medical spending with respect to income is about 1). Growth rates this low are thus extremely unusual historically.

To gain more insight into why medical expenditure increases have been so low, Figure 2 shows the growth of medical spending by service from 1990 to 1995. Acute care spending (hospitals, physicians, and prescription drugs) have grown most slowly — each about 2.5 percent per year. Together, these services account for about two-thirds of medical costs. Other professional services, long-term care services, and other spending have slowed by much less.

II. The Managed Care Explanation

A common depiction in newspapers and professional journals is that the reduction in spending growth is a result of increased enrollment in managed care. Changes in the insurance environment have been enormous over the past several years. In 1980, about 5 percent of the privately insured population was in managed care.[2] By 1987, managed care accounted for about one-quarter of the privately insured population (Gabel et al., 1987); today over three-quarters of the privately insured population is enrolled in managed care (Jensen et al., 1997).

Of course, many types of health insurance plans fall under the rubric of "managed care".

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[2] Even with the managed care that was available, there was not much competition with indemnity insurers. Employers often subsidized indemnity policies heavily so that the incentives for HMOs to limit spending were blunted.

A fee-for-service plan with some utilization review, for example, may call itself a managed care plan. Still, the change in plan enrollments has been impressive. Enrollment in the most restrictive form of managed care -- Health Maintenance Organizations [HMOs] -- rose from 16 percent of insured workers in 1987 to 48 percent in 1995 (including point-of-service plans).[3] Enrollment in Preferred Provider Organizations [PPOs], the next most restrictive form of managed care, rose from 11 percent in 1987 to 25 percent in 1995.

Managed care can reduce medical cost growth through three mechanisms. First, managed care might negotiate *price reductions*. Since much of the earnings for a physician are a return on past investment, managed care can often induce physicians to accept lower fees than they would otherwise have charged. The same is true for prescription drugs, some hospital services, and some medical durables. The result of these discounts will be a reduction in medical costs.[4] These savings will be "one-time" savings: as prices fall medical spending growth will slow, but after the return to past investment has been squeezed out medical costs will resume their increase.

Managed care might also save money through *one-time quantity reductions*. For example, managed care insurers are very careful about monitoring the number of days that their

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[3] The distinction between HMOs and other forms of managed care has become less clear over time. In general, however, HMOs require participants to receive care from particular providers and primary care physicians are typically paid on a salary or capitated basis. Preferred Provider Organizations pay their providers on a discounted fee-for-service basis, but may also monitor physician behavior to exclude physicians who do not keep utilization down. In both types of plans, cost sharing to use a provider in the insurer's network is lower than cost sharing for providers outside the network.

[4] Note that there may be long-term effects of these price reductions on the supply of new physicians or medical equipment, but we ignore that issue in this paper.

enrollees are in the hospital. If stays can be reduced by a day, costs will fall.[5] Again, however, these savings are likely to be one-time savings. Lengths of stay can fall only so much; when they cease falling medical costs will continue to increase.

Finally, managed care might save money by reducing the *rate of technology expansion* -- the intensity with which a typical patient is treated or the rate at which new technologies are adopted. We separate this factor from the first two because of its importance in the long-run growth of medical spending. Much research shows that the dominant source of increasing medical costs over time is the development of new medical technologies and the application of existing technologies to new patients (Aaron, 1991; Newhouse, 1992; Cutler and McClellan, 1996). If managed care reduces the expansion of technologies, it could have a long-term effect on the growth of medical costs.

Quantity changes resulting from managed care — either one-time savings or reductions in the rate of technology diffusion — may either improve or reduce welfare. To the extent that managed care reduces the resources needed to provide a given level of medical services, that would be an efficiency savings to society. If managed care changes the amount of services provided, however, welfare may either rise or fall, depending on whether the services that are no longer provided were worth more or less than their cost. In this paper, we look only at the effects of managed care on overall resource utilization, without drawing strong conclusions about the value of those changes.

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[5] Again, there may be long-term effects of this change on the number of hospitals, the structure of the hospital industry, etc., but for our purposes we ignore these effects.

Testing the Managed Care Effect

One piece of evidence suggesting that managed care is responsible for the reduction in national medical expenditures in the past few years is that managed care premiums are lower than premiums in traditional indemnity policies. A recent Foster Higgins report, for example, found that in 1995, costs for HMOs were either flat or declining, while costs for traditional insurance continued to rise. Hay-Huggins reports that HMO premiums are significantly lower than premiums for fee-for-service insurance, although other surveys show smaller differences (Krueger and Levy, 1997). Wholey, Feldman, and Christianson (1995) examine the impact of HMO concentration on changes in HMO premiums, and find that more HMO competition leads to lower HMO premiums.

But this evidence is not conclusive. The fact that managed care pays less than indemnity insurers does not mean that *total* medical spending is lower. It could be that providers just reduce their costs to managed care insurers and raise them to indemnity insurers, to offset the managed care discount. This type of substitution is broadly believed to occur when Medicare and Medicaid cut spending. Or it could be that managed care reduces spending for covered services but spending for uncovered services might rise. On the other hand, if competition induces changes in practice styles so that HMOs have a moderating effect on both HMO and traditional indemnity premiums,[6] then comparing HMO to fee-for-service premiums may understate the impact of managed care on health expenditures.

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[6]For example, Wickizer and Feldman (1995) found that premiums for fee-for-service insurance were lower in areas with higher HMO enrollment. Baker (1996) found that Medicare fee-for-service payments were lower in areas with more managed care.

We estimate the system-wide savings from managed care by looking at overall medical spending growth in states where managed care is more prevalent compared to states where managed care is less prevalent. If managed care reduces medical spending growth, this should be apparent through such a comparison.

Figure 3 shows a first pass at this comparison. We show per capita spending relative to the national average in California and Minnesota -- two states in the vanguard of the managed care revolution -- between 1980 and 1993. In both states, spending growth was much lower than the national average. In California, for example, per capita medical spending was 17 percent above the national average in 1980; by 1993 spending was equal to the national average. In Minnesota, medical spending fell from 9 percent above the national average to 4 percent above the national average.

Melnick and Zwanziger (1995) and Zwanziger and Melnick (1996) compare the experience of California with the rest of the nation in more detail. They show that over the 1980s, spending on all acute care services rose less rapidly in California than in the nation as a whole, as did full-time equivalent hospital employees per patient and the average length of a hospital stay.

To examine this issue more systematically, we use data on state medical spending between 1980 and 1993, from the Health Care Financing Administration.[7] Unfortunately, no more recent data on cross-state spending are available; thus, we cannot examine the effects of managed care in the period where the national changes in spending were the greatest. We

[7] See Levit et al. (1995) for a description of the data.

measure HMO enrollment as the average value, from 1980 to 1993, of HMO enrollment per capita (HMO enrollment data are from Interstudy).

Table 1 shows summary statistics for the data. The average state had spending growth of 4.6 percent in real per capita terms between 1980 and 1993, with hospital spending growing less rapidly than physician spending. HMO enrollment averaged 11.2 percent, but ranged from 0 to 28 percent. HMO enrollment includes both "pure" enrollment (closed panel HMOs) as well as "open" enrollment (plans with a Point-of-Service Option). While there are many other forms of managed care beyond HMOs, consistent data on non-HMO managed care are not available over time. We also suspect that HMO enrollment is correlated with managed care enrollment more generally. The highest HMO enrollment states are California, Minnesota, Hawaii, Oregon, and Massachusetts. The lowest HMO enrollment states are small rural states such as Alaska, Mississippi, and Wyoming, with no HMO enrollment or a very small amount.

Figure 4 shows the national analogue of Figure 3. We graph the change in real per capita medical expenditures for each state against average HMO enrollment. There is a clear negative relation between the two, consistent with the managed care explanation. States with high HMO enrollment had less rapid spending growth. The correlation between cost growth and HMO enrollment, shown in the bottom of Table 1, is -.6. And a simple regression equation gives a large magnitude: each 10 percentage point increase in HMO enrollment reduces cost growth by .6 percentage points annually.[8]

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[8] All of our correlations and regressions weight the observations by population. Without such weighting, HMOs would not have as large or significant an effect on expenditures (both because states like Alaska, Nevada, and Hawaii are outliers, but have very small population, and because weighting the regressions places more weight on California).

Before being convinced by Figure 4, however, there is a question about why managed care enrollment is so high in some states and so low in others. In particular, both managed care enrollment and subsequent spending growth may respond to a third factor -- the initial level of medical spending in the state. In states where costs are high, it will be easier for managed care to enroll new members than in states where costs are low. But this relationship is problematic if states with high medical costs naturally have less rapid growth of medical costs in the future, perhaps because other states catch up to their more advanced medical practices. Indeed, as Figure 3 showed, the effect of the slowdown in medical expenditures in California was just enough to bring California spending back to the national average from the extremely high levels observed in the early 1980s.

Figures 5 and 6 suggest this is a more general phenomenon. Figure 5 shows the relation between per capita medical spending in 1980 and average HMO enrollment between 1980 and 1993. Initial spending and managed care enrollment are positively related; the correlation between them, shown in Table 1, is .73. Figure 6 shows that initial medical spending is also associated with reductions in the growth of future medical spending. Again, the correlation is large (-.53).

The important question, then, is whether managed care enrollment really reduces the growth rate of medical spending, or whether it instead proxies for states with high initial spending, which will naturally have less rapid growth rates over time. In the next section, we address this issue.

III. Explaining State Cost Growth

To estimate the effect of managed care on the growth of state medical costs, we consider the regression analogue to Figure 4:

$$\Delta Spending_s = \beta_1 HMO\,Enrollment_s + X_s\beta + \epsilon_s, \quad (1)$$

where s denotes states and the dependent variable is the annualized growth rate of real, per capita medical spending in the state from 1980 to 1993. β_1 is the effect of HMO enrollment on annual cost growth.

We examine the impact of managed care on a number of components of spending--total medical spending, spending on hospitals, spending on physicians, and spending on prescription drugs. We also examine the impact of managed care separately on Medicare and non-Medicare expenditures. Ideally, we would like to measure the impact of managed care on the per capita spending of privately-insured individuals, but those data are not available. Non-Medicare expenditures are a decent proxy, but in addition to the health expenditures of privately-insured individuals, non-Medicare expenditures include out-of-pocket expenditures of the elderly and the uninsured, and expenditures paid by Medicaid or other government programs.

It is not clear whether the level or the change in HMO enrollment should be related to the growth of spending. In theory, the level of managed care could affect both the level of spending, through one-time efficiency gains or reimbursement cuts (so the change in HMO enrollment would be related to the change in spending), or the growth rate of spending, by changing the speed at which technology is adopted (so the level of HMO enrollment would explain changes in

spending). In practice, however, it is likely that the "one-time" effects of high HMO enrollment occur over a number of years, so that the level of managed care enrollment in a state is likely to affect the growth rate of spending regardless of whether HMOs affect technology adoption or not. Further, the change in HMO enrollment might only affect spending with a lag. For these reasons, we have decided to use the average level of HMO enrollment over the period in our regressions. As can be seen in Figure 7, however, the change in HMO enrollment is closely correlated with the level of HMO enrollment in 1980; in general, our results hold equally well when we use the change in HMO enrollment instead of the level.[9]

The other right hand-side variables included in the regression are the change in per capita income, since it is well known that people with higher incomes spend more on health care (Newhouse et al., 1993), and demographic controls (the change in fraction of the population 18 or younger and the change in fraction of the population 65 or older.)

Table 2 presents regression results for total health spending over the 1980-1993 period. The first four columns are without controlling for initial spending; the second four columns include controls for initial spending. In general, the coefficients on the control variables are as we would expect. Income growth is positively related to spending growth; the elasticity is about 1. An increasing share of older people is associated with increased medical spending while an increasing share of younger people has no effect on spending growth.

The first row shows the effect of HMO enrollment on cost growth. When not controlling for initial spending levels, HMOs have a negative and significant effect on total health spending.

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[9] The level of HMO enrollment is sufficiently highly correlated with its growth rate that the standard errors increase substantially when we include both in the regression simultaneously.

Every 10 percentage point increase in HMO enrollment reduces the growth of health expenditures by .3 percentage points per year.[10] The effect works only through hospital spending -- increased HMO enrollment is actually associated with increased spending on physicians and prescription drugs.

Consistent with our figures above, controlling for initial spending reduces the impact of HMOs on cost growth. Initial spending has a strong and negative effect on subsequent spending growth; each 10 percent increase in spending in 1980 is associated with cost growth between 1980 and 1993 that is .2 percentage points below average. Whatever the source of this convergence, it is worthwhile noting that this is not a new phenomenon. As reported in Table 3, growth of medical expenditures across states exhibited the same pattern from 1966-1980. Controlling for this phenomenon is important, and affects our estimates of the impact of managed care on health costs. Turning back to Table 2, when we control for initial spending, the coefficient of HMO enrollment on total spending is still negative (-.014) but not statistically significant. Even in this case, however, HMOs are still associated with a reduction in hospital spending; the coefficient is large (-.052) and statistically significant. But HMOs have a positive impact on physician spending that is also large and statistically significant.

Clearly, one of the major effects of managed care is to shift the site of care from the hospital to the physician's office or clinic (see Reinhardt, 1996, for a discussion of this trend). As shown in Figure 8, states with high HMO enrollment spend much less of their medical

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[10] An alternative way to see this effect is to regress the logarithm of medical spending in each year on HMO enrollment that year and the control variables for that year. If we do this, we obtain a coefficient on HMO enrollment of .688 (.214) in 1980 and .198 (.125) in 1993. The reduction in the coefficient on HMO enrollment is consistent with the regressions in Table 2.

dollars in the hospital. The share of spending on drugs is not affected by HMO coverage; most of the offset is on physicians. The large impact of HMOs on physician spending is somewhat surprising, and is worthy of further investigation.[11]

Table 4 shows regressions analogous to those in Table 2 for non-Medicare expenditures. The results are very similar -- without controlling for initial spending, HMOs reduce total and hospital spending, but increase physician and prescription drug spending. When initial spending is included, HMOs have no significant effect on total health spending, but shift spending from hospitals to physicians.

Table 5 examines the effect of managed care on Medicare expenditures per elderly person (since Medicare does not pay for prescription drug coverage, only the physician and hospital results are presented). Controlling for initial spending, the results indicate that states with high HMO enrollment (mostly of the non-Medicare population) have lower hospital spending growth, although the coefficient is not significant at a 10 percent level. HMOs have no measured effect on physicians. Since enrollment in managed care was a very small share of total Medicare enrollment in this time period, the effect of managed care on Medicare costs is not a direct effect of managed care enrollment for that group. Instead, there might be two effects at work. First, to the extent that managed care affects hospital or physician practices, it is possible that states with a high rate of HMO enrollment would also have lower Medicare expenditures. Second, HMOs

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[11] Simon and Emmons (1997) find that physicians who are paid through capitation often do not purchase reinsurance. It is possible, then, that payments to physicians increase under managed care as physicians take on increased risk. Alternatively, some of physician spending could actually be hospital spending but under systems of capitated payments the two may be hard to distinguish.

may reduce the amount of "cost-shifting" from Medicare to private insurance, which would show up as lower overall spending, and probably fewer services to the Medicare population. Further work could usefully distinguish between these effects.

There are two issues to be dealt with in our analysis to this point. First, the health care market has changed significantly in recent years (although some may argue that most of the changes have occurred in the years after 1993, for which expenditure data across states are not yet available), and it may be that HMOs have had increasing effects over time.[12] Second, these regressions ignore another major innovation in hospital financing that occurred in the 1980s--the introduction of prospective payment in Medicare. To the extent that prospective payment equalized payments across states (moving from a payment method that relied on reasonable costs to one of fixed payments per diagnosis), this would affect hospital spending as well. Since high HMO states were also high cost states, it is possible that this is negatively correlated with HMO enrollment.

To control for both of these issues, we re-estimate the regressions for the 1988-1993 period only. By 1988, prospective payment was fully phased-in and managed care was well under way. Thus, this time period might be more indicative of a true managed care effect than the 1983-88 period. Tables 6-8 present the results. The results for total spending growth, shown in Table 6, indicate that managed care is more effective at controlling costs in the later period than in the earlier period; there is a greater negative effect on hospital spending growth, and a

[12] Gabel (1997) surveys the changes in HMOs that occurred in the 1990s.

smaller positive effect on physician spending growth.[13] The overall effect is a decline of .5 percentage points per year in total health expenditures for every 10 percentage point increase in the HMO enrollment rate, which is a large effect and is significantly different from zero. As shown in Table 7, the results for private spending growth are quite similar, although the positive effect of managed care on physician spending is larger and more significant. Table 8 shows that the results for Medicare growth again suggest a managed care effect, but the coefficients are smaller and less significant over the 1988-1993 period than over the entire 1980-1993 period. This might indicate some confounding effects from the introduction of PPS in the first part of the sample.

Overall, the cross-state evidence points to managed care as an important factor in the recent decline in health costs. Over the entire 1980 to 1993 period, we find reductions in hospital spending that are nearly fully offset by increases in physician spending. When we look at the most recent period, however, we find reduction in hospital spending that are only partly offset by increased physician spending. Our results suggest that a 10 percent increase in HMO enrollment reduces the growth of hospital spending by about 0.5 percent and of overall medical costs by about 0.4 percent. These results are generally robust to a number of controls, including income, demographics, and the initial level of state spending.

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[13] Simon and Born (1996) find that the impact of managed care on physician earnings was not significant until 1993-1994.

V. Explaining the Reduction in Hospital Costs

In order to predict the longer-run effects of managed care, it is important to know not only whether managed care affects medical spending , but how it has done so. Has managed care simply extracted rents from providers--reducing payments for procedures or cutting back at the margins? Or has there been a more significant change in the medical environment? In this section, we examine changes in hospital costs to address this issue.

We start with an accounting identity: per capita spending on hospital care is the product of spending per day in the hospital times the average length of stay per admission times the number of hospital admissions per capita:

$$\left(\frac{Spending}{capita}\right) = \left(\frac{Spending}{admissions}\right)\cdot\left(\frac{Admissions}{capita}\right)$$
$$= \left(\frac{Spending}{days}\right)\cdot\left(\frac{Days}{admissions}\right)\cdot\left(\frac{Admissions}{capita}\right). \quad (2)$$

The growth of medical spending per capita can therefore be decomposed into the growth of each of these terms.

The first rows of Table 9 show regression equations for the growth of hospital spending per adjusted admission and adjusted admissions per capita.[14] Adjusted admissions are hospital admissions plus a factor to account for outpatient services provided, so that this approximates the

[14] The coefficients shown in the table are those on the average HMO enrollment, and those on initial hospital spending, but the regressions also included the change in per capita income and the change in the population shares of old and young.

total amount of hospital care provided. As the first row shows, HMOs have no significant effect on adjusted admissions per capita. The implication, shown in the second rows, is that the entire decline in hospital cost growth associated with HMOs comes from a reduction in costs per admission. Decomposing this factor into days of care and costs per day (the next rows) reveals that most of the reduction in the costs per admission comes from a reduction in the length of hospital stays. On average, a 10 percentage point increase in the fraction of the population enrolled in HMOs led to lengths of stay declining 0.5 percentage points faster per year. HMOs had a negative, but insignificant effect on the average cost per day in the hospital.

The finding that all of the cost savings are in shorter hospital stays may be somewhat misleading. Since the amount of care given to a patient likely declines with additional days in the hospital, one might have expected states that experienced a greater reduction in length of stay to see an increase in the average cost per day. When controlling for length of stay, HMO enrollment does reduce cost per day.[15]

Direct measures of hospital resource utilization also vary with managed care. On average, states with a large fraction of their population enrolled in HMOs had slower growth of hospital employees per person, and less bed growth per person.

The results for the 1988-1993 period are shown in the right columns of the Table. HMOs have a slightly larger effect on costs per admission in this period relative to the whole time period, consistent with our earlier results. Also, total days in the hospital (including an

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[15] When the change in the length of stay is included in the regression, the effect of a 10 percentage point increase in HMO enrollment is to reduce the growth of costs per day by 0.5 percentage points per year. Over the 1988-1993 period, however, the effect of HMO enrollment on costs per day is only about half this magnitude, and is statistically insignificant.

adjustment for outpatient visits) declined significantly more in states with high HMO enrollment, although the costs per inpatient day were again not significantly affected by HMOs. Length of stay for Medicare beneficiaries in this post-PPS adjustment period also declined in states with high HMO enrollment, again indicating that changes in hospital practice styles have spillover effects.

VI. Changes in Technology Adoption

We are particularly interested in the extent to which managed care has reduced the diffusion of medical technology, since that is a direct measure of its long-run impact on cost growth. We thus examine this issue in some detail, using data on the adoption of specific technologies across states. Our data on technology diffusion are from the American Hospital Association's [AHA] annual survey. The survey asks whether hospitals have acquired a variety of important, and expensive, technologies. We analyze survey responses for 1980, 1985, 1990, and 1995, to look at how managed care enrollment affects technology diffusion over time.[16]

Our ideal measure of technology diffusion is the rate at which technologies are used for patients with similar clinical conditions. The AHA does not ask about technology use, however, only whether the hospital owns the technology. We thus use as our measure of technology

[16] If a hospital does not respond to the AHA survey in some year, it will have missing data about technologies. We use data on the previous four years of responses to impute technology ownership, where possible.

diffusion the number of units of each technology per million persons in the state.[17] If all units roughly perform the same number of procedures, this will be an accurate measure of technology diffusion. If managed care consolidates technologies into some hospitals and keeps it out of other hospitals, however, we might find that managed care reduces the availability of technology when in fact it does not reduce its actual utilization. Unfortunately, there is no way to surmount this issue without detailed information on the use of particular procedures that we do not have.

Table 10 shows the range of technologies we analyze. The technologies are in five groups: cardiac technologies (catheterization lab, open heart surgery facilities, and angioplasty facilities); radiation therapy (megavoltage radiation, radioactive implants, therapeutic radioisotope, x-ray therapies, and stereotactic radiosurgery); diagnostic radiology (CT Scanner, diagnostic radioisotope, MRI, ultrasound, positron emission tomography [PET], and single photon emission computed tomography [SPECT]); transplantation services (kidney, organ [other than kidney], tissue, bone marrow); and other (extracorporeal shock wave lithotripter).

Perhaps more important than their grouping by service, however, our data are a mix of diffusing technologies and technologies that have already diffused. Catheterization labs, for example, go from 4 per million in 1980 to 7 per million by 1995; CT scanners go from 5 per million in 1980 to 20 per million in 1995. Other technologies such as radioactive implants and ultrasound machines were falling over the time period. We classify the technologies that are diffusing over our time period into one group (the diffusing sample): catheterization, open heart

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[17] An alternative measure of technology availability would be the share of hospitals with a particular technology. This will be particularly sensitive to changes in the number of hospitals, however, which our earlier results suggest managed care affects. We thus do not use this measure.

surgery, angioplasty, megavoltage radiation, stereotactic radiosurgery, CT scanners, MRIs, PET scanners, SPECT scanners, transplant services, and lithotripters. The other technologies (radioactive implants, therapeutic radioisotopes, x-ray therapy, and diagnostic radioisotopes) are classified as already diffused.

In addition to the distinction between diffusing and already diffused technologies, we also have variation within the diffusing technologies in when they were introduced. For example, angioplasty was about as diffused in 1990 as cardiac catheterization was in 1980; SPECT scanners in 1990 were about as diffused as CT scanners in 1980. Thus, we can look at how managed care has changed the diffusion of technologies in the same state of overall diffusion over time.

To examine the relation between managed care enrollment and technology adoption in 1980, we estimate models similar to our previous analysis:

$$\left(\frac{Units}{million}\right)_s = \beta_1 HMOEnrollment_s + X_s\beta + \epsilon_s. \qquad (3)$$

where s indexes states. As control variables (**X**), we include the logarithm of per capita income in the state, the percent of the population living in urban areas, and the logarithm of state population.[18] As before, all regressions are weighted by state population.

The first column of Table 11 shows estimates of equation (3). We report only the coefficient on the HMO enrollment variable. In general, the other variables are as we would

[18] We experimented with other population characteristics but found they were not significantly related to technology ownership.

expect: states with higher incomes have increased technology diffusion, and more urban areas have less technology diffusion (reflecting shorter commuting times). As population increases, so does the number of units of technology per million.

The first row of the Table shows that for all of the technologies, HMO enrollment has a positive, but not statistically significant, effect on technology diffusion. Each 10 percentage point increase in HMO enrollment raises the ownership of the average technology by 0.2 units per million people. The next two rows show that this effect is very different for the diffusing technologies relative to the already diffused technologies. Among the diffusing technologies, HMO enrollment is associated with more technology ownership. The coefficient is positive and statistically significant. Among already diffused technologies, in contrast, there is an insignificant negative effect of HMO enrollment on the ownership of technology.

The insignificant effect of HMOs on already diffused technologies suggests that HMO enrollment is not associated with long-run differences in technology availability across states. This makes sense; technologies that have been available for some time have spread more or less equally among all states. But states with high HMO enrollment in 1980 are technology "leaders" -- new technologies are more common there than in other states.

Figure 9 shows this graphically. We show the relation between HMO enrollment and cardiac catheterization units in 1980. States like California and Hawaii, leaders in managed care enrollment, also have high numbers of catheterization units. HMO enrollment is positively correlated with catheterization labs.

We want to know how the HMO coefficient changes over time. If managed care is reducing the diffusion of new technologies, the HMO coefficient should fall in the later years of

the sample. There is a problem, however, in just estimating equation (3) for different years. Our results for 1980 suggest that some states are naturally technology "leaders" and others are technology "followers". If we want to look at the effect of managed care on technology diffusion, we need to control for whether the state is a technology leader.[19] That is, we need to modify equation (3) to:

$$\left(\frac{Units}{million}\right)_s = \beta_1 HMO\,Enrollment_s + \beta_2 Technology\,Leader_s + \boldsymbol{X}_s\beta + \epsilon_s. \qquad (4)$$

Here, β_1 gives the effect of HMO enrollment on technological availability controlling for the fact that some states are naturally leaders and others are followers.

There is clearly no variable for technology "leadership". But our data suggest a nautral proxy: We take all of the diffusing technologies in 1980 and normalize the ownership variables so that they have a mean of zero and a standard deviation of 1.[20] We then add the normalized ownership measures across the different technologies. The result is a measure of the state's propensity to own high-tech medical services in 1980, which we use as a proxy for technology leadership.

The second and third columns of Table 11 show estimates of equation (4) in 1990 and

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[19] In an examination of the impact of managed care on technology adoption, Chernew, Fendrick, and Hirth (1997) examined whether a new gallbladder surgery, laparoscopic cholecystectomy, diffused more slowly within HMOS. They found little difference between HMOs and the general population in the rate of growth in utilization. However, they were not able to control for this "leader effect", which might have led to their results.

[20] That is, we form $z_s = (units/million_s - \mu) / \sigma$, where μ is the mean ownership across states and σ is the standard deviation.

1995. We report only the coefficients on HMO enrollment and the technology leadership variable, although the logarithm of per capita income, the share of the state living in urban areas, and the logarithm of state population are also included in the regression.

Increased HMO enrollment is associated with less rapid diffusion of new technologies in 1990 and 1995, and this effect is increasing over time. As the first row shows, states that were technology leaders in 1980 are more likely to adopt new technologies in the 1990s. The coefficient on the leadership variable is positive and statistically significant. Conditional on this effect, however, increased HMO enrollment significantly reduces the propensity of states to adopt new technologies. Further, the coefficient on HMO enrollment is more negative in 1995 than in 1990, suggesting that HMO enrollment is having an increasing effect on the diffusion of new technologies over time. This finding is not just a result of the fact that technologies are on average older in the 1990s than in 1980. Even for the new technologies of the late 1980s and early 1990s, such as angioplasty, PET scanners, SPECT scanners, and lithotripters, the coefficients on HMO enrollment are generally negative and often statistically significant.

Figure 10 shows one particular example graphically. We show the relation between HMO enrollment in 1990 and the number of angioplasty units per million people. Angioplasty in 1990 is roughly equivalent to cardiac catheterization in 1980; both are procedures used in the treatment of severe coronary problems. Thus, the comparison between Figures 9 and 10 implicitly reveals the effect of HMOs on similar technologies over time. As Figure 10 shows, there is essentially no relation between HMO enrollment and angioplasty units. Even though the high managed care states in 1980 are generally the high managed care states in 1990, those states are not the ones where technology is diffusing most rapidly. California, for example, is only

average in angioplasty units, and Massachusetts, another high HMO state, is below average. When we control for the fact that these states were technology leaders in 1980, our regressions in Table 11 indicate a negative and statistically significant effect of managed care on technology diffusion.

In principle, managed care might have different effects on different types of technologies. Technologies that save money might be adopted more readily in heavy managed care states, while technologies that add to costs should diffuse less rapidly. We find it difficult to analyze this in our data, however; a more systematic study of this issue would be needed to reach firm conclusions.

VII. Conclusion

The differences across states in the importance of managed care has allowed us to examine the effects of managed care on health care systems--looking not only at the insurance premiums paid by those in managed care, or the reimbursement received by providers from managed care companies, but at the total impact of managed care on health expenditures. The results are fairly encouraging.[21] The higher is HMO enrollment in a state, the lower is the growth of hospital spending. Over the entire 1980-1993 period, the reduction in hospital cost growth was almost negated by an equal increase in physician and drug spending. However, over the 1988-1993 period, the increase in physician spending was much more muted, and managed

[21] Of course, without a measure of health outcomes it is not possible to determine whether managed care is worth its cost.

care reduced the growth rate not only of hospital spending, but of spending overall.

The impact of managed care on physician spending was a surprise to us, and it warrants further investigation. The impact of managed care on hospitals was more in line with anecdotal evidence--managed care reduced hospital costs primarily by reducing the length of stay in the hospital, leading to fewer hospital employees per person as well as fewer hospital beds.

Perhaps more important than the finding that managed care reduces health spending overall is the preliminary evidence that managed care may also slow the rate of adoption of new technologies. States with high enrollment in HMOs used to be the first to adopt new technologies; now, they are only average. Since rapid adoption of new technology is believed to be one of the main factors behind the rise in health expenditures, the finding that HMOs can reduce technology adoption means that managed care may actually have a long-term moderating effect on the growth of health expenditures. That is a subject well worth further investigation.

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Figure 1: Growth Rate of National Health Expenditures

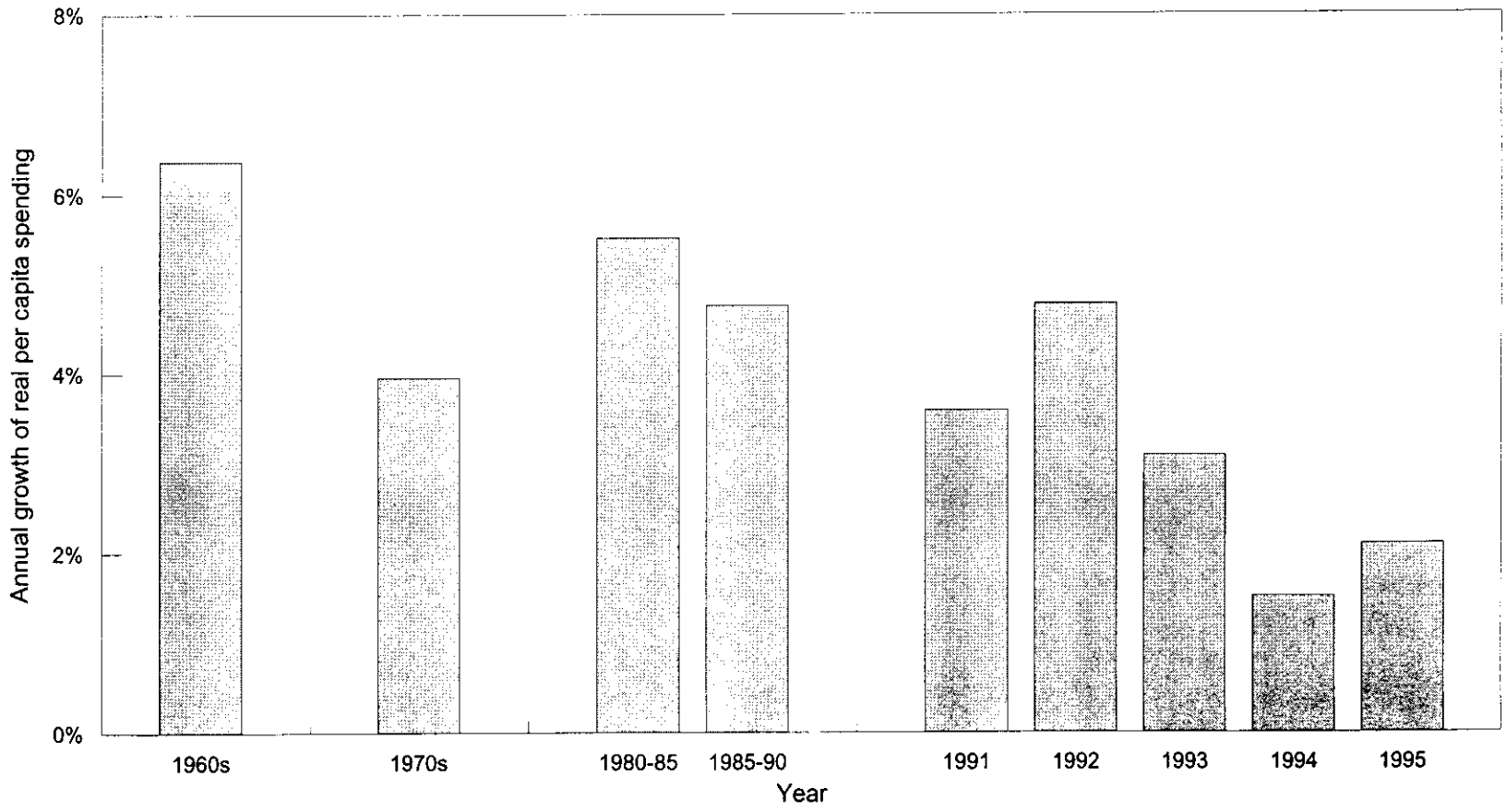

Figure 2: Growth of Medical Spending by Service
1990-1995

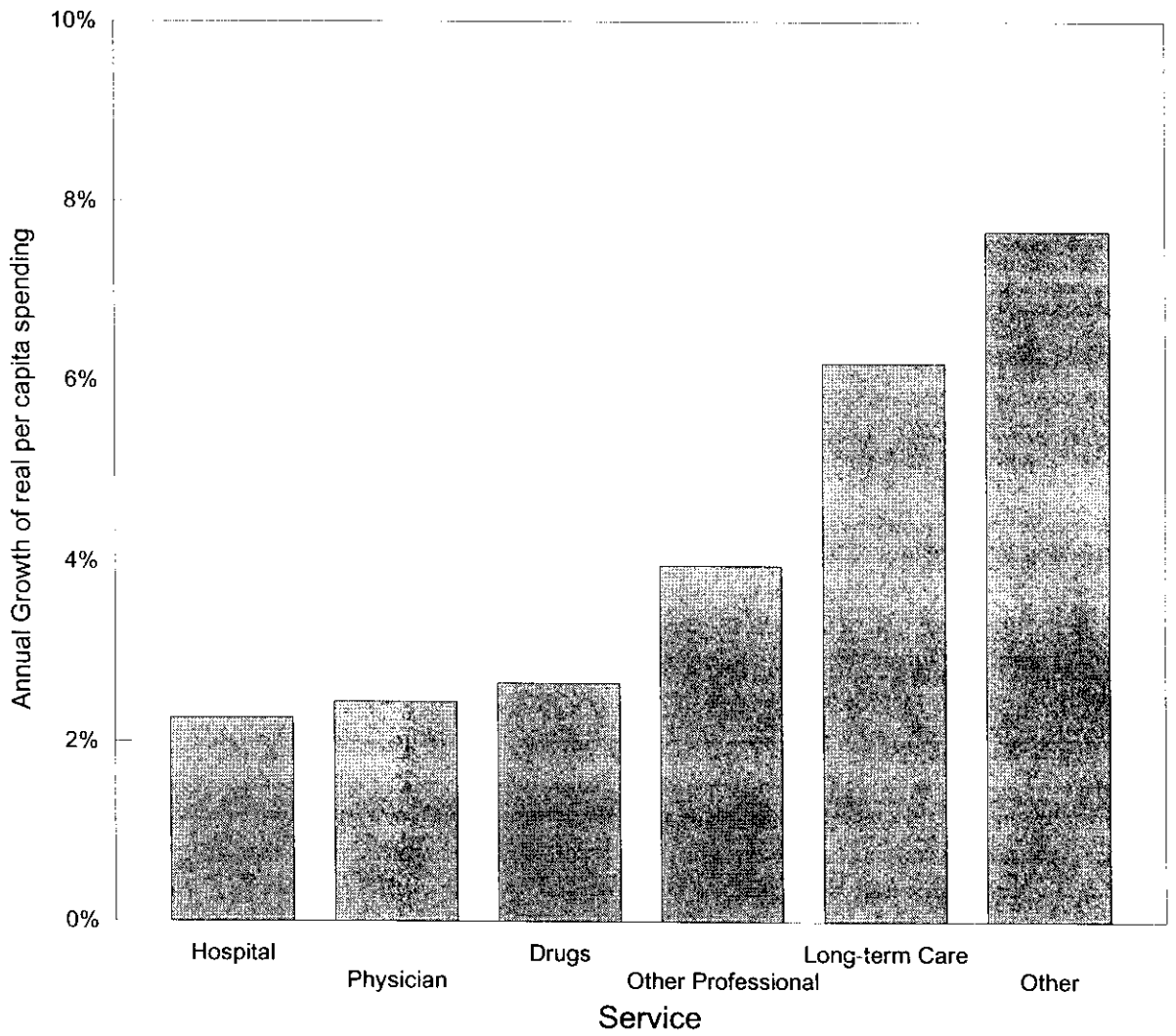

Figure 3: Relative Medical Spending in California and Minnesota

[State per capita spending / National average per capita spending]

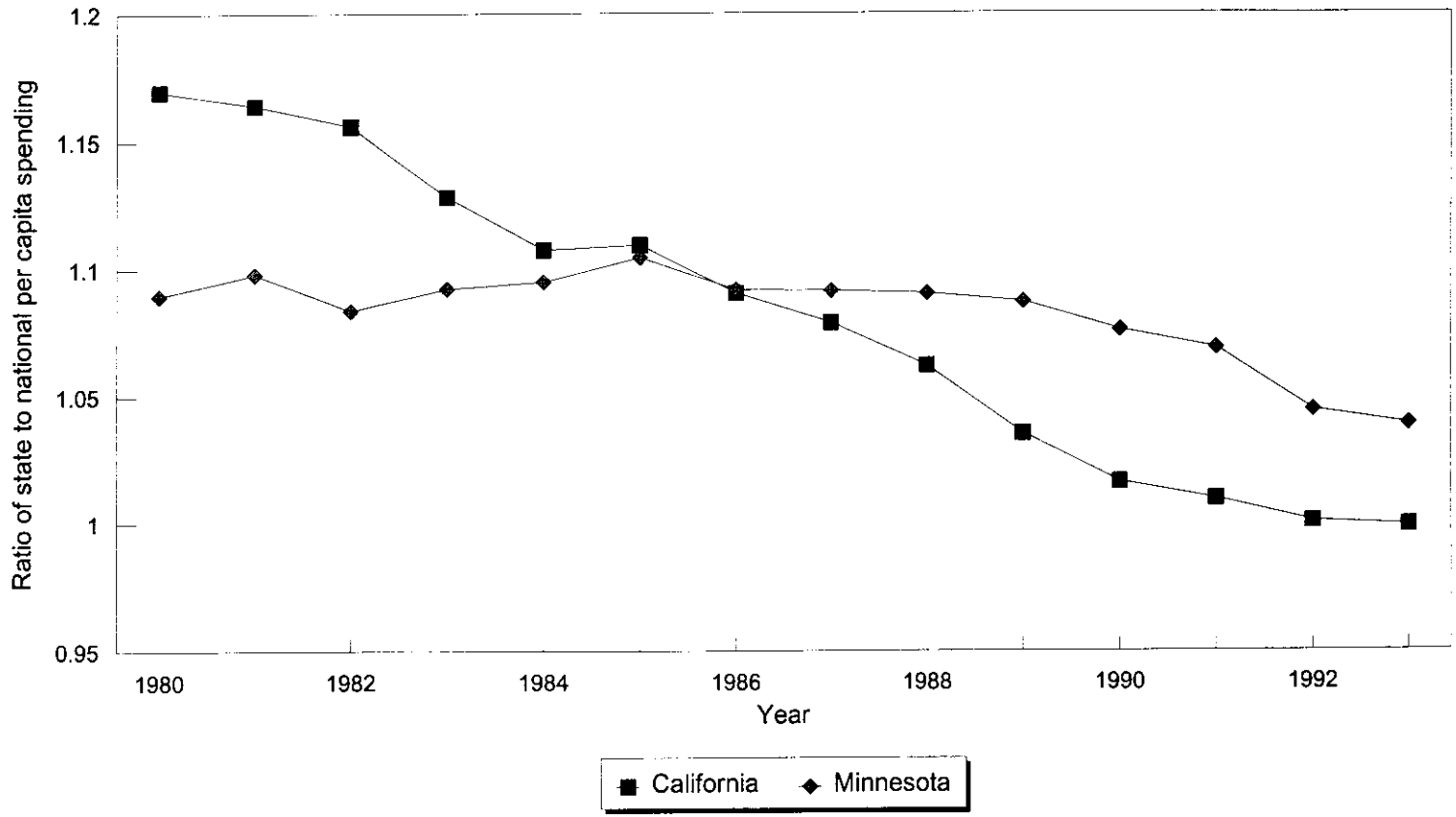

Figure 4: HMO Enrollment and the Growth of Medical Spending
1980-1993

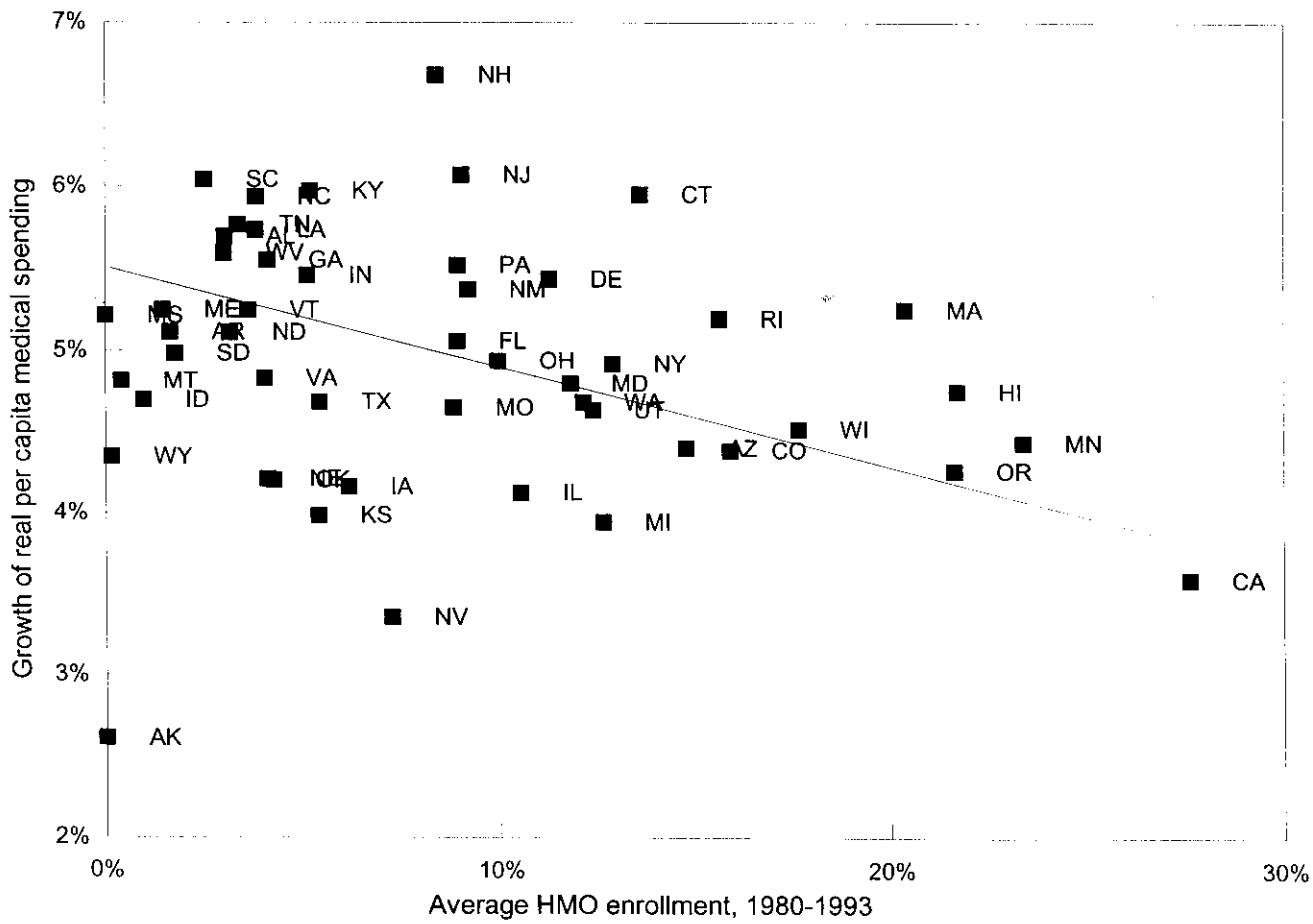

Figure 5: Initial Medical Spending and Average HMO Enrollment

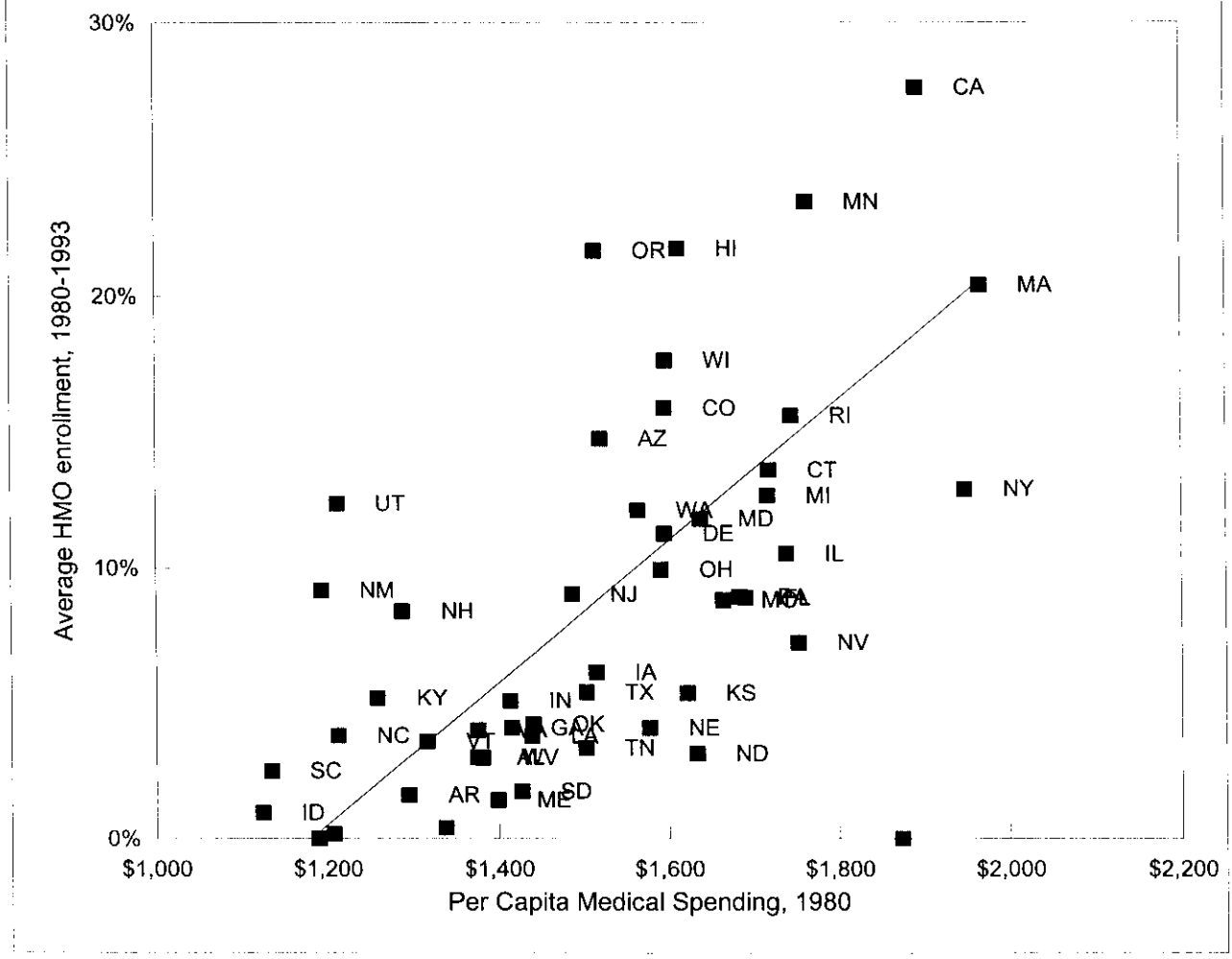

Figure 6: The Reversion of Medical Spending

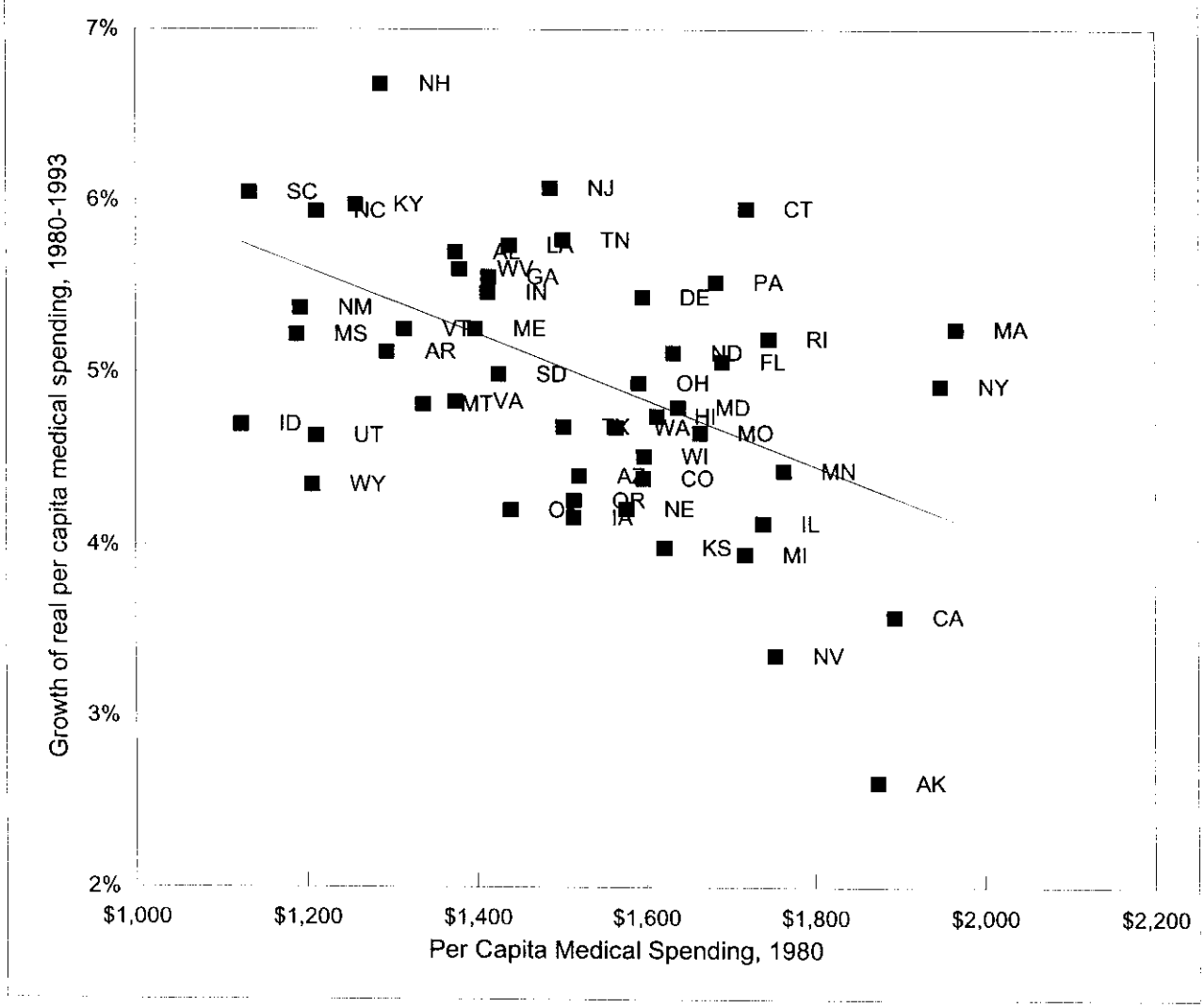

Figure 7: The Level and Growth of HMO Enrollment

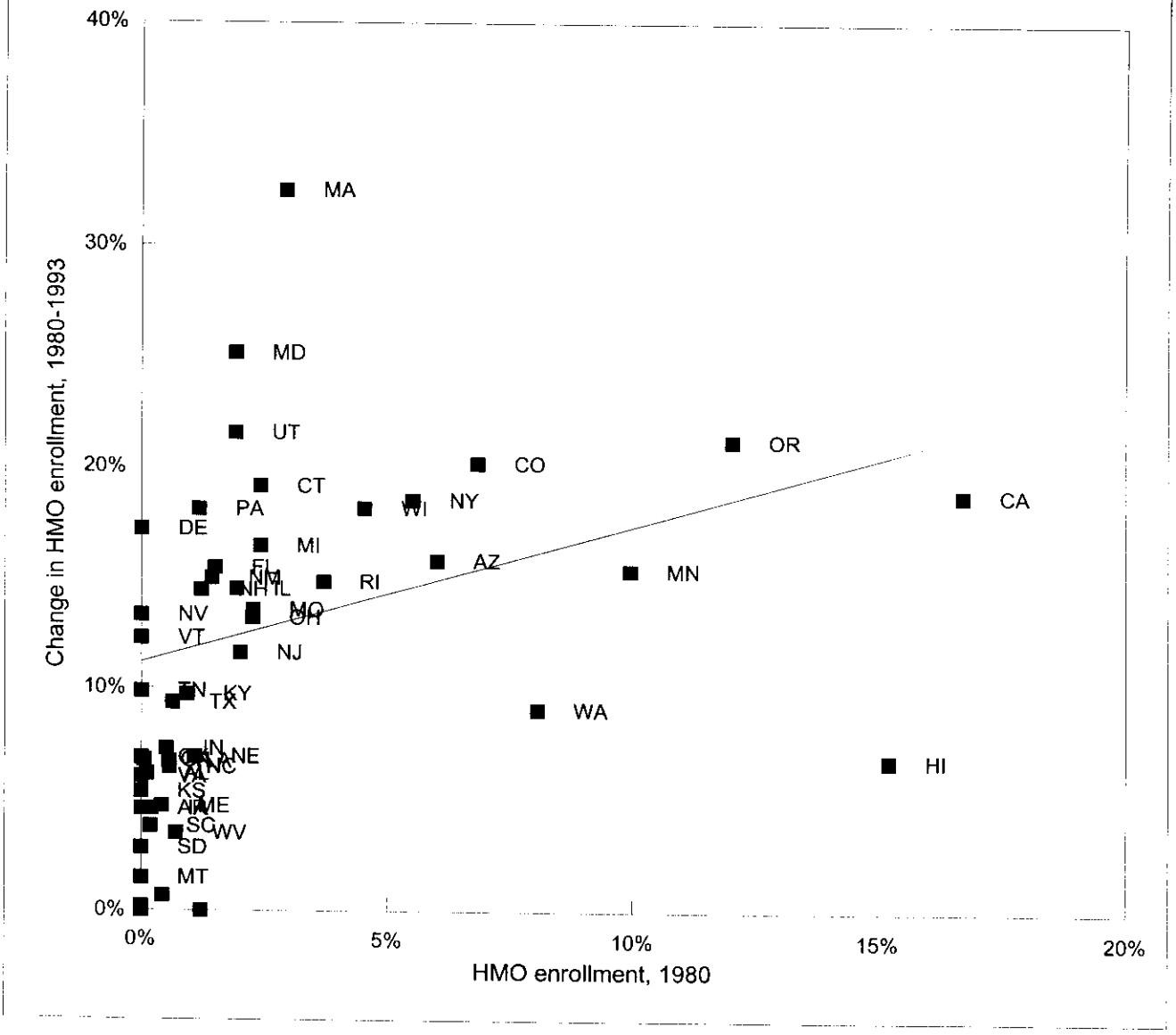

Figure 8: Managed Care and the Share of Spending on Hospitals

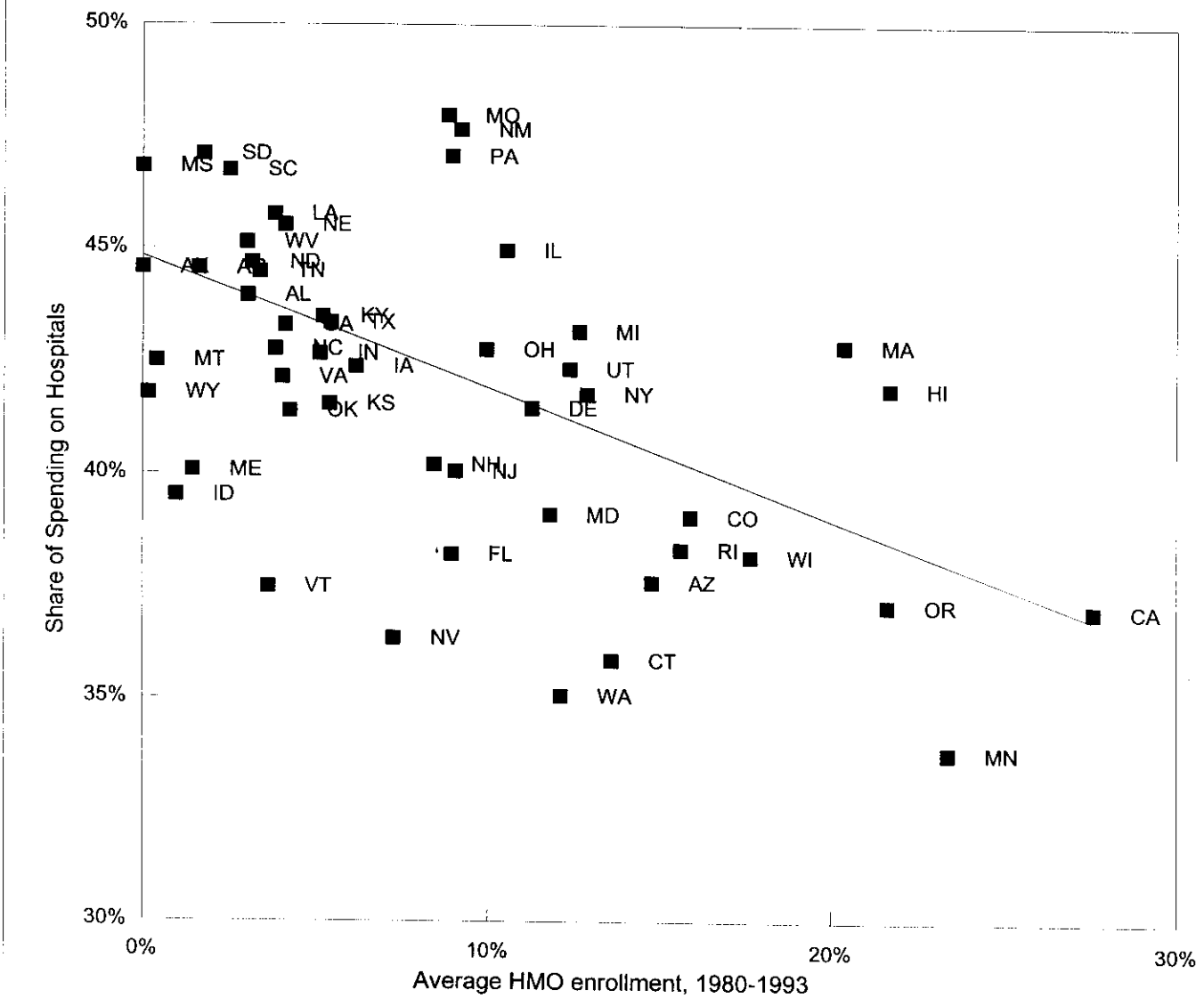

Figure 9: HMO Enrollment and the Diffusion of Cardiac Catheterization Labs, 1980

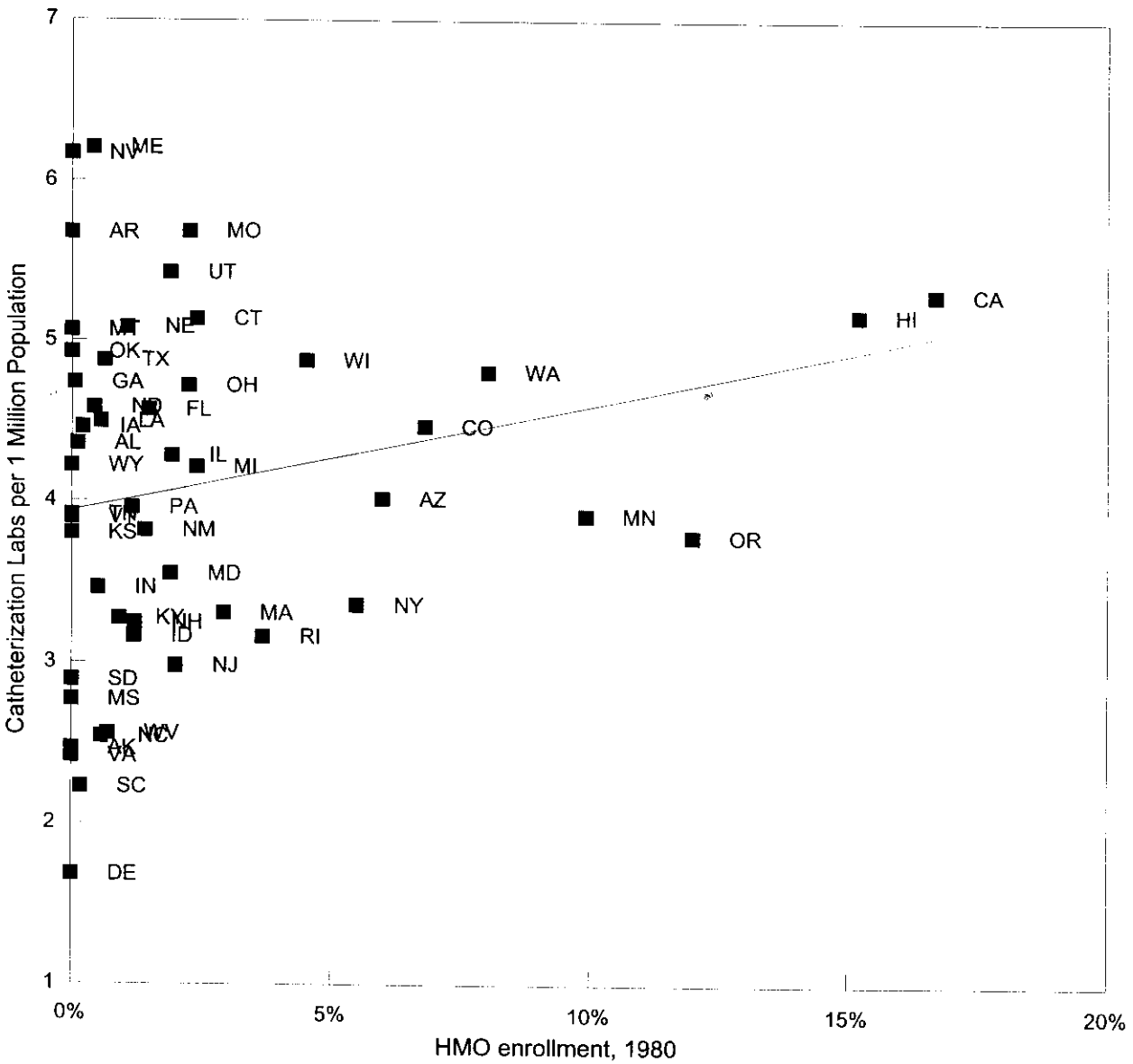

Figure 10: HMO Enrollment and the Diffusion of Angioplasty Labs, 1990

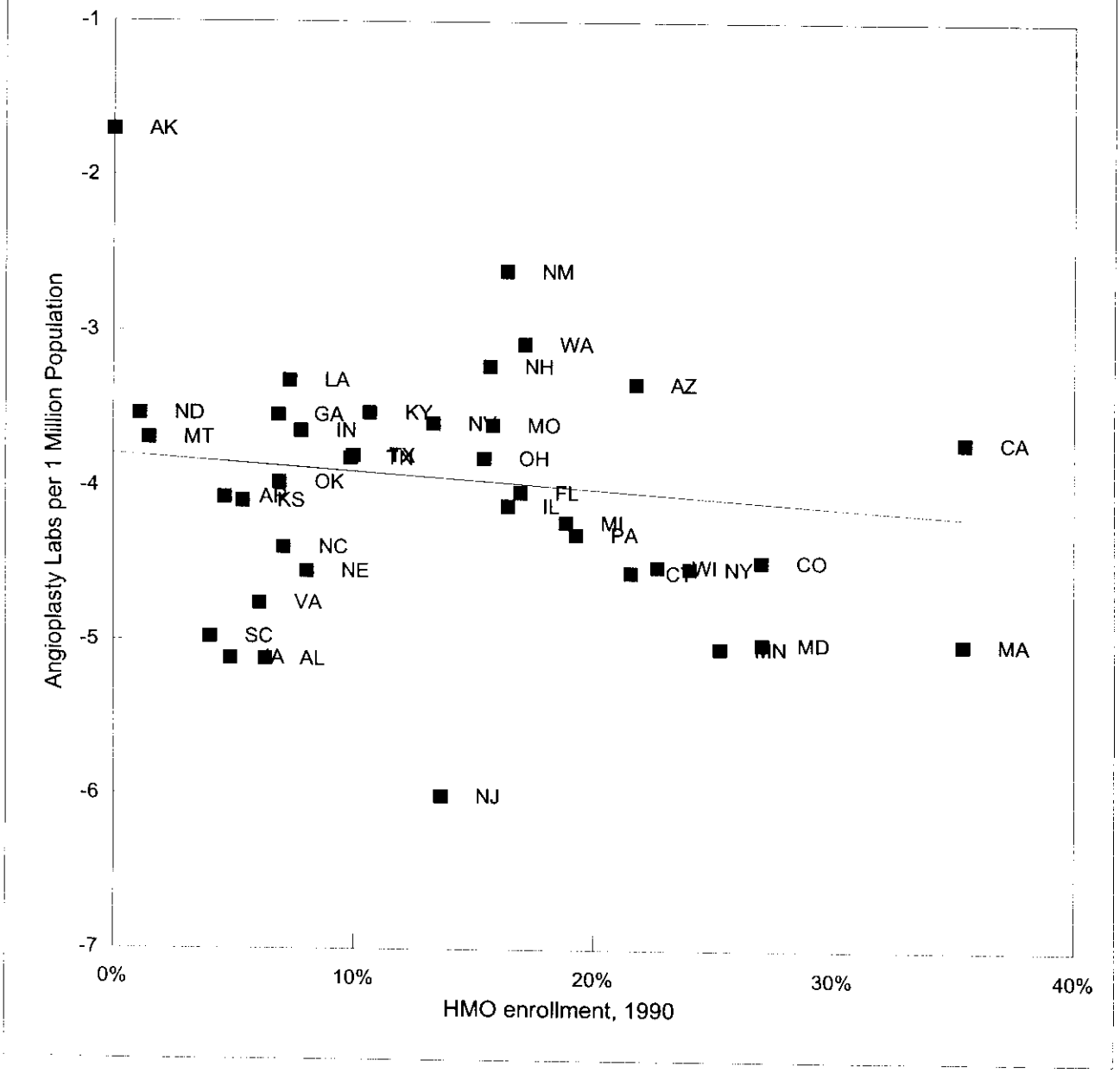

Table 1: Summary Statistics for State Data, 1980-1993

Statistic	Average HMO Enrollment	ΔMedical Spending	ΔHospital Spending	ΔPhysician Spending	ΔPersonal Income	Initial Medical Spending+
Mean	11.2%	4.6%	3.7%	4.9%	1.4%	$1,666
Standard Deviation	7.7	0.8	1.1	.9	0.6	228
Minimum	0.0	2.4	1.2	1.4	-.30	1160
Maximum	27.6	6.4	5.9	8.0	2.2	2030
			Correlations			
Avg. HMO Enrollment	1.00					
ΔMedical Spending	-.62	1.00				
ΔHospital Spending	-.73	.89	1.00			
ΔPhysician Spending	-.04	.66	.34	1.00		
ΔPersonal Income	-.42	.72	.52	.67	1.00	
Initial Medical Spending	.73	-.53	-.69	-.01	-.19	1.00

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1980 to 1993. Initial medical spending is in 1980. Medical spending and income are in real, per capita terms and growth rates are annualized. HMO enrollment is the average between 1980 and 1993. Statistics are weighted by population in 1993.

Table 2: Managed Care and Total Spending Growth, 1980-1993

	Without Initial Spending				With Initial Spending			
		Component of Spending				Component of Spending		
Independent Variable	Total	Hospital	Physician	Drug	Total	Hospital	Physician	Drug
HMO Enrollment	-.034	-.080	.042	.030	-.014	-.052	.072	.019
	(.011)	(.017)	(.016)	(.014)	(.013)	(.015)	(.017)	(.013)
ΔPersonal Income	.772	.501	1.341	.974	.897	.764	1.448	.784
	(.147)	(.221)	(.212)	(.193)	(.144)	(.194)	(1.401)	(.179)
ΔPercent Population <19	.370	.764	.282	.371	1.300	1.863	1.844	-.278
	(.991)	(1.488)	(1.428)	(1.353)	(.984)	(1.271)	(1.376)	(1.170)
ΔPercent Population >64	2.803	2.893	2.735	4.619	2.781	3.503	1.448	3.859
	(1.032)	(1.549)	(1.428)	(1.353)	(.963)	(1.306)	(1.401)	(1.222)
ln(Initial Medical Spending)	---	---	---	---	-.019	-.026	-.027	-.029
					(.007)	(.006)	(.008)	(.008)
Summary Statistics								
N	50	50	50	50	50	50	50	50
R^2	.664	.578	.518	.476	.707	.703	.605	.586

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1980 to 1993. Initial medical spending is in 1980. Medical spending and income are in real, per capita terms and growth rates are annualized. HMO enrollment is the average between 1980 to 1993. Regressions are weighted by state population in 1993.

Table 3: The Reversion of Spending, 1966-1980

		Component of Spending		
Independent Variable	Total	Hospital	Physician	Drug
HMO Enrollment	---	---	---	---
ΔPersonal Income	.213	-.161	1.173	.575
	(.163)	(.208)	(.279)	(.173)
ΔPercent Population <18	-.036	.122	-.482	.035
	(.074)	(.097)	(.129)	(.092)
ΔPercent Population >64	.309	.400	.164	.143
	(.087)	(.113)	(.148)	(.106)
ln(Initial Medical Spending)	-.018	-.021	-.006	-.042
	(.005)	(.005)	(.007)	(.007)
Summary Statistics				
N	50	50	50	50
R^2	.589	.466	.634	.623

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1966 to 1980. Initial medical spending is in 1966. Medical spending and income are in real, per capita terms and growth rates are annualized. Regressions are weighted by state population in 1980.

Table 4: Managed Care and Private Spending Growth, 1980-1993

	Without Initial Spending			With Initial Spending		
		Component of Spending			Component of Spending	
Independent Variable	Total	Hospital	Physician	Total	Hospital	Physician
HMO Enrollment	-.025	-.078	.056	-.008	-.050	.095
	(.010)	(.018)	(.018)	(.012)	(.016)	(.019)
ΔPersonal Income	.836	.476	1.589	.938	.767	1.100
	(.134)	(.234)	(.239)	(.134)	(.208)	(.247)
ΔPercent Population <19	.283	.734	.149	.961	1.638	1.165
	(.905)	(1.582)	(1.612)	(.903)	(1.344)	(1.441)
ΔPercent Population >64	3.439	3.538	1.864	3.324	3.836	.174
	(.942)	(1.647)	(1.678)	(.896)	(1.386)	(1.540)
ln(Initial Medical Spending)	---	---	---	-.015	-.027	-.034
				(.006)	(.006)	(.009)
Summary Statistics						
N	50	50	50	50	50	50
R^2	.714	.552	.530	.742	.684	.637

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1980 to 1993. Initial medical spending is in 1980. Medical spending and income are in real, per capita terms and growth rates are annualized. HMO enrollment is the average between 1980 and 1993. Regressions are weighted by state population in 1993.

Table 5: Managed Care and Medicare Spending Growth, 1980-1993

	Without Initial Spending			With Initial Spending		
		Component of Spending			Component of Spending	
Independent Variable	Total	Hospital	Physician	Total	Hospital	Physician
HMO Enrollment	-.072 (.021)	-.083 (.023)	-.010 (.018)	-.036 (.024)	-.037 (.023)	-.001 (.020)
ΔPersonal Income	.471 (.286)	.662 (.304)	-.007 (.239)	.520 (.268)	.596 (.262)	.085 (.248)
ΔPercent Population <19	.741 (1.925)	1.224 (2.050)	-1.234 (1.613)	1.953 (1.853)	1.509 (1.762)	-.070 (1.842)
ΔPercent Population >64	-3.126 (2.005)	-3.922 (2.134)	3.138 (1.679)	-2.527 (1.886)	-2.265 (1.877)	1.687 (1.705)
ln(Initial Medical Spending)	—	—	—	-.028 (.010)	-.036 (.009)	-.008 (.006)
Summary Statistics						
N	50	50	50	50	50	50
R^2	.294	.347	.108	.383	.518	.121

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1980 to 1993. Initial medical spending is in 1980. Medical spending and income are in real, per capita terms and growth rates are annualized. HMO enrollment is the average between 1980 and 1993. Regressions are weighted by state population in 1993.

Table 6: Managed Care and Total Spending Growth, 1988-1993

	Without Initial Spending				With Initial Spending			
		Component of Spending				Component of Spending		
Independent Variable	Total	Hospital	Physician	Drug	Total	Hospital	Physician	Drug
HMO Enrollment	-.050	-.058	-.010	-.010	-.050	-.058	.035	-.005
	(.018)	(.025)	(.032)	(.014)	(.019)	(.025)	(.029)	(.021)
ΔPersonal Income	.294	.664	-.327	.069	.295	.651	-.554	-.278
	(.199)	(.277)	(.354)	(.215)	(.201)	(.282)	(.302)	(.212)
ΔPercent Population <19	.717	.958	1.403	2.178	.690	1.011	3.820	1.156
	(.921)	(1.284)	(1.640)	(.997)	(.987)	(1.306)	(1.486)	(.873)
ΔPercent Population >64	3.210	4.140	1.186	-.480	3.191	4.386	-1.113	1.791
	(1.331)	(1.855)	(2.368)	(1.441)	(1.364)	(2.006)	(2.062)	(1.388)
ln(Initial Medical Spending)	---	---	---	---	.0009	-.004	-.060	-.038
					(.010)	(.012)	(.014)	(.010)
Summary Statistics								
N	50	50	50	50	50	50	50	50
R^2	.492	.521	.009	.046	.480	.511	.297	.269

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1980 to 1993. Initial medical spending is in 1980. Medical spending and income are in real, per capita terms and growth rates are annualized. HMO enrollment is the average between 1980 to 1993. Regressions are weighted by state population in 1993.

Table 7: Managed Care and Private Spending Growth, 1988-1993

	Without Initial Spending			With Initial Spending		
		Component of Spending			Component of Spending	
Independent Variable	Total	Hospital	Physician	Total	Hospital	Physician
HMO Enrollment	-.040 (.019)	-.055 (.032)	-.002 (.038)	-.039 (.021)	-.051 (.032)	.069 (.037)
ΔPersonal Income	.432 (.217)	.917 (.356)	-.248 (.428)	.430 (.220)	.842 (.356)	-.515 (.374)
ΔPercent Population <19	.752 (1.007)	1.529 (1.649)	.861 (1.984)	.825 (1.060)	1.577 (1.638)	2.496 (1.754)
ΔPercent Population >64	3.649 (1.455)	4.026 (2.381)	2.135 (2.865)	3.703 (1.486)	5.141 (2.524)	-.938 (2.578)
ln(Initial Medical Spending)	—	—	—	-.003 (.011)	-.017 (.014)	-.068 (.016)
Summary Statistics						
N	50	50	50	50	50	50
R^2	.466	.435	-.029	.454	.442	.238

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1980 to 1993. Initial medical spending is in 1980. Medical spending and income are in real, per capita terms and growth rates are annualized. HMO enrollment is the average between 1980 and 1993. Regressions are weighted by state population in 1993.

Table 8: Managed Care and Medicare Spending Growth, 1988-1993

	Without Initial Spending			With Initial Spending		
		Component of Spending			Component of Spending	
Independent Variable	Total	Hospital	Physician	Total	Hospital	Physician
HMO Enrollment	-.068	-.058	-.029	-.071	-.065	-.024
	(.029)	(.029)	(.037)	(.029)	(.030)	(.035)
ΔPersonal Income	-.311	-.028	-.384	-.270	.011	-.578
	(.323)	(.324)	(.409)	(.331)	(.326)	(.395)
ΔPercent Population <19	-.694	-1.084	2.994	-.969	-1.234	4.980
	(1.497)	(1.649)	(1.898)	(1.567)	(1.507)	(1.966)
ΔPercent Population >64	-.454	.549	-3.099	-.602	-.020	-3.802
	(2.162)	(2.167)	(2.741)	(2.189)	(2.235)	(2.611)
ln(Initial Medical Spending)	—	—	—	.010	.016	-.030
				(.016)	(.016)	(.012)
Summary Statistics						
N	50	50	50	50	50	50
R^2	.134	.205	.076	.122	.206	.172

Note: Data are for 50 states (excluding the District of Columbia). All changes are from 1980 to 1993. Initial medical spending is in 1980. Medical spending and income are in real, per capita terms and growth rates are annualized. HMO enrollment is the average between 1980 and 1993. Regressions are weighted by state population in 1993.

Table 9: HMO Enrollment and Components of Hospital Spending

Change in	1980-1993		1988-1993	
	Average HMO Enrollment	Initial Hospital Spending	Average HMO Enrollment	Initial Hospital Spending
Adjusted admissions per person	.018	.011	.019	.014
	(.013)	(.004)	(.017)	(.006)
Cost per adjusted admission	-.065	-.030	-.093	-.017
	(.016)	(.005)	(.034)	(.013)
Length of stay per admission				
All	-.053	-.006	-.080	.006
	(.021)	(.007)	(.025)	(.009)
Private	-.716	-.084	-.417	.035
	(.378)	(.125)	(.178)	(.067)
Medicare	-.551	-.123	-.283	-.012
	(.221)	(.073)	(.156)	(.058)
Costs per inpatient day	-.013	-.023	-.013	-.021
	(.022)	(.007)	(.027)	(.010)
Adjusted days per person	-.033	.003	-.061	.018
	(.022)	(.007)	(.025)	(.009)
Outpatient visits per person	-.053	.029	.026	.077
	(.038)	(.012)	(.058)	(.022)
Full-time hospital employees per person	-.060	-.006	-.056	-.006
	(.018)	(.006)	(.025)	(.010)
Hospital beds per person	-.045	.003	-.076	.019
	(.017)	(.006)	(.028)	(.010)

Note: All regressions include change in real per capita income, and changes in fraction of population younger than 20 and older than 64. Data are for 50 states and are weighted by 1993 population.

Table 10: The Diffusion of Medical Technologies

Technology	Units per 1 million people			
	1980	1985	1990	1995
Cardiac				
Catheterization	4.1	4.6	6.2	6.8
Open Heart Surgery	2.7	3.0	3.7	4.0
Angioplasty	---	---	4.6	4.7
Radiation Therapy	---	---	---	5.0
Megavoltage Radiation	3.8	4.1	4.2	---
Radioactive Implants	5.9	5.9	5.1	---
Therapeutic Radioisotope	6.8	6.1	5.6	---
X-ray Therapy	5.5	4.4	4.0	---
Stereotactic Radiosurgery	---	---	1.1	---
Diagnostic Radiology				
CT Scanner	5.2	13.3	17.7	19.7
Diagnostic Radioisotope	18.7	17.0	16.0	14.0
MRI	---	1.2	4.3	9.5
Ultrasound	---	21.4	24.6	23.3
PET Scanner	---	---	0.4	0.6
SPECT Scanner	---	---	4.2	7.2
Transplant Services	---	---	---	2.0
Kidney Transplant	0.7	0.8	0.9	---
Organ Transplant	1.0	1.1	1.1	---
Tissue Transplant	---	---	1.2	---
Bone Marrow Transplant	---	---	0.7	---
Lithotripter	---	0.2	1.4	3.1

Note: Data on ownership are from the American Hospital Association Annual Survey. The maximum number of units per million is 31.4 in 1980, 29.5 in 1985, 27.3 in 1990, and 24.5 in 1995.

Table 11: Effect of Managed Care on Technology Adoption

	1980	1990		1995	
Technology	HMO Enrollment	HMO Enrollment	Technology Leader	HMO Enrollment	Technology Leader
All	1.96	-3.93	1.03	-6.13	0.99
	(1.67)	(1.14)	(0.15)	(1.53)	(0.23)
New Technologies	6.19	-2.73	0.85	-5.40	0.89
	(1.43)	(0.91)	(0.12)	(1.37)	(0.20)
Old Technologies	-4.39	-7.28	1.54	-8.30	1.32
	(3.42)	(3.31)	(0.42)	(4.17)	(0.62)
Cardiac					
Catheterization	6.31	-7.52	1.50	-6.75	1.06
	(3.08)	(3.18)	(0.41)	(0.31)	(0.46)
Open Heart Surgery	6.13	-2.21	1.47	-3.59	1.37
	(3.34)	(1.99)	(0.25)	(1.97)	(0.29)
Angioplasty	---	-5.38	1.71	-4.32	1.24
		(2.72)	(0.35)	(2.45)	(0.36)
Radiation Therapy	---	---	---	-4.60	0.41
				(2.58)	(0.38)
Megavoltage Radiation	-1.30	-5.12	0.68	---	---
	(3.13)	(2.61)	(0.33)		
Radioactive Implants	-0.37	-5.71	1.27	---	---
	(2.73)	(2.70)	(0.34)		
Therapeutic Radioisotope	-8.14	-5.46	0.67	---	---
	(3.68)	(2.93)	(0.37)		
X-ray Therapy	-4.26	-4.47	0.87	---	---
	(4.01)	(2.67)	(0.34)		
Stereotactic Radiosurgery	---	-0.82	0.53	---	---
		(1.13)	(0.14)		

Table 11 (continued)

Technology	1980	1990		1995	
	HMO Enrollment	HMO Enrollment	1980 Technology	HMO Enrollment	1980 Technology
Diagnostic Radiology					
CT Scanner	22.18	-12.90	2.20	-12.00	2.22
	(5.67)	(5.92)	(0.75)	(5.25)	(0.78)
Diagnostic Radioisotope	-4.78	-10.14	1.57	-9.78	0.29
	(1.05)	(5.77)	(0.74)	(4.09)	(0.65)
MRI	---	-0.07	0.98	-9.15	1.78
		(2.68)	(0.34)	(3.52)	(0.52)
Ultrasound	---	-10.64	3.34	-10.53	3.25
		(8.50)	(1.08)	(7.58)	(1.13)
PET Scanner	---	-0.66	0.16	-1.48	0.26
		(0.79)	(0.10)	(0.61)	(0.09)
SPECT	---	-2.14	0.56	-7.18	-0.10
		(3.49)	(0.45)	(3.20)	(0.47)
Transplant Services	---	---	---	-1.65	-0.15
				(2.83)	(0.42)
Kidney Transplant	0.63	-1.15	0.52	---	---
	(1.20)	(0.97)	(0.12)		
Organ Transplant	3.18	2.40	0.40	---	---
	(1.93)	(2.82)	(0.36)		
Tissue Transplant	---	-2.65	0.64	---	---
		(1.45)	(0.18)		
Bone Marrow Transplant	---	0.11	0.17	---	---
		(0.82)	(0.10)		
Lithotripter	---	-0.08	0.32	-2.48	0.30
		(0.18)	(0.23)	(2.46)	(0.37)

Note: The table shows regressions of technology ownership per million population on HMO enrollment in the state and, for 1990 and 1995, the state's technology leadership in 1980. Regressions also include controls for the logarithm of per capita income, the percent of the state's population living in urban areas, and the logarithm of the state's population. Regressions are weighted by state population. The first three rows include dummy variables for the different technologies.