IESE Business School SP-SP

University of Navarra

Working Paper

WP No 554

March, 2004

IS MANAGED CARE RESTRAINING THE ADOPTION OF TECHNOLOGY BY HOSPITALS?

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Abstract

As health care costs increase, cost-control mechanisms become more widespread and it is crucial to understand their implications for the health care market. This paper examines the effect that managed care activity (based on the aim to control health care expenditure) has on the adoption of technologies by hospitals. Managed care may affect hospitals' decision to take on new technologies if it alters local market structure and physician incentives. We use a hazard rate model to investigate whether higher levels of managed care market share are associated with a decrease in medical technology adoption during the period 1982-1995. We analyze annual data on 5,390 US hospitals regarding the adoption of 13 different technologies. This is the first time that such a broad study has been implemented. After adjusting for hospital characteristics, demographics and local market characteristics, we find that managed care has a negative effect on hospitals' technology acquisition for each of the thirteen medical technologies in our study, and this effect is strongest for technologies diffusing in the 1990s, when the managed care sector was at its largest. If managed care enrollment had remained at its 1984 level, there would be 5.3, 7.3 and 4.1 percent more hospitals with diagnostic radiology, radiation therapy and cardiac technologies, respectively. We also take into account that cost-benefit analysis is one of the main dimensions considered by hospitals when deciding about the adoption of new technologies. In order to determine whether managed care affects technologies differently if they have a different cost-benefit ratio, we created a unique data set with information on the cost-benefit for each of the thirteen technologies. We find that managed care enrollment has a considerably more negative effect on the adoption of technologies with higher cost-benefit ratios. The results suggest there may be long-term reductions in medical cost growth resulting from increased managed care enrollment.

Keywords: technology adoption, managed care, cost control, cost-benefit analysis, health care, hospital

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1. Introduction

Over the past four decades persistent health care growth has kept the cost of medical expenses at the center of the policy agenda. Health care spending grew at an average annual rate of 12 percent between the 1960s and the early 1990s. However, during the 1990s –and particularly since 1992– the growth of medical costs has slowed down significantly, growing at an average annual rate of 5 percent. This decline in spending growth rates has stimulated considerable discussion about the effect that the continuing shift toward managed care has had on expenditures. Levit et al. (1998) and Zwanziger and Melnick (1996) have suggested that a large part of the expenditure growth slowdown can be attributed to growth in managed care[1]. The question of whether managed care has generated one-time savings or whether it will result in a long-term reduction in spending growth remains unanswered. For managed care to create long-term savings, it must influence the forces that drove the large spending increases observed over the past decades (Cutler and Sheiner, 1998). There is significant literature suggesting that the proliferation of new technologies is the main driving force of medical costs (Newhouse 1992, Cutler and McClellan 1996).

This paper examines the relationship between managed care activity and hospitals' technology adoption. If managed care reduces hospitals' adoption of new technologies, it could lead to a long-term reduction in health care costs. However, this reduction could also diminish the level of technological innovation in the health care market, with potentially profound implications for the quality of patient care.

The new dominance of managed care could influence hospitals' technology adoption by imposing financial pressure on providers, changing the incentives associated with purchases of new technology equipment. Managed care offers consumers oligopsony prices for insured medical services at the expense of providing limited choice. This oligopsony power decreases both product prices and quantities for hospitals. Thus, through the direct effect managed care organizations have on providers' profits, they probably induce hospitals to adopt technology less frequently.

Managed care restricts the product choice offered to consumers because it provides coverage for health care obtained through a predetermined, reduced network of providers. Even within the network, patients are required to see a primary care physician before being

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[1] In 1980 approximately 5 percent of the privately insured population was in managed care; in 1996 over 75 percent of this population had a managed care health insurance contract (Jensen et al., 1997).

We are grateful to the National Institute on Aging for research support.

referred to a specialist. Through these mechanisms, managed care may change doctors' propensity to assign patients to a particular treatment and may limit patients' access to expensive medical procedures.

However, given the managed care objective of cost containment, managed care organizations may favor hospitals that own cost-saving technologies. Hospitals might be encouraged to adopt these technologies to secure access into a managed care network or to improve their bargaining position with managed care organizations. Similarly, if reputation effects are important for managed care organizations, they may encourage hospitals to adopt high-tech procedures.

The existing studies on the effect of managed care over technology adoption have been limited to only a few technologies over short periods of time. Baker and Wheeler (1998) focus their analysis on 1994-1995 data and find evidence of a negative association between Health Maintenance Organization (HMO) penetration and availability of MRIs. Baker and Brown (1997) find that managed care penetration is associated with a decrease in the number of mammography facilities. Cutler and McClellan (1996) examine the sources of expenditure growth in heart attack treatments, specifically angioplasty. They find that the expansion of intensive cardiac surgeries explains essentially all the treatment's cost growth. They also find that insurance generosity, regulation, and market structure are the most important factors affecting technology adoption. Baker and Spetz (1998) look at more technologies, but they group all the technologies in a common index. They find evidence that high managed care areas started the early 1980s with relatively high average technology index values. However, by the late 1980s the index values for high managed care areas were similar to, or even lower than, values in other areas. In more recent years, index values for both high and low market share areas grew at similar rates. This method, however, does not allow for the identification of the effects of managed care on particular technologies, which theory suggests should be very important.

This study extends previous work in several important dimensions. We examine thirteen technologies from 1982 to1995. While some of these technologies diffused during the 1980s, when managed care was rare in the U.S. health care system, other technologies began diffusing in the 1990s, when managed care was already an important phenomenon in the health insurance sector. If managed care influences technology acquisition, we should see a larger effect on technology adoption rates in the 1990s, when the levels of managed care activity were higher. In fact, we find that managed care has a significant negative effect on hospitals' technology adoption for each of the thirteen technologies we consider, with the strongest effect for those technologies that started to diffuse during the 1990s.

In this paper we also rank the technologies according to their cost-benefit ratios (CBR). CBR were approximated using medical literature and estimations of the lifetime capital cost-reimbursement ratios. CBR is a key determinant of hospital adoption decisions. Given that managed care organizations have a strong incentive to minimize costs, they may be willing to identify and support services with low CBR. We find that managed care has a stronger retarding effect on technologies with higher CBR. This is, to our knowledge, the first time this result has been demonstrated empirically.

Our results provide evidence that managed care may be able to contribute to cost saving in the health care market by limiting the availability of technologies, especially new and less cost-effective ones. However, further research should be done to understand the effects of managed care on patient care. While these results suggest that managed care may be negatively affecting the quality of patient care by restraining the availability of

technologies, it may be the case that managed care is merely eliminating the duplication of technologies, making more efficient use of each machine or procedure. We leave this issue for further research.

The remainder of this paper is organized as follows. Section 2 describes the relationship between managed care activity and hospitals' technology acquisition decisions. Section 3 presents a description of the data used. Section 4 contains the methodology followed in our study. Section 5 presents the results and section 6 analyzes the effects of managed care on health care expenditures. Section 7 concludes.

2. Managed Care and a Hospital's Decision to Adopt New Technologies

One of the most significant changes in the health care market in the last decade has been the shift from the traditional insurance system to managed care. While traditional health insurance paid providers on a fee-for-service basis, barely controlled utilization and allowed patients unlimited access to the providers of their choice, managed care policies apply several restrictions over patients and utilization to achieve their cost-containment objective.

First, managed care payments to primary care physicians are generally capitated –physicians receive a pre-established amount per insured regardless of the number and kind of procedures performed– while hospitals and specialists also face a structure of payments that encourages lower utilization of medical care. Second, managed care restricts the product choice offered to consumers because it provides coverage for health care obtained through a predetermined group of health care providers, commonly referred to as a "network", which is selected by the plan. Given that managed care plans market themselves based on their ability to reduce costs of health care benefits, price is a critical criterion for the selection of providers into their network. Finally, even within the network, managed care requires patients to see a primary care physician before being referred to a specialist.

In this section we present a simple model of hospital behavior in which a hospital's decision to adopt a new technology responds to the incentives established by managed care and to the hospital's ownership status. The aim of the model is to provide an interpretative framework for reviewing the empirical work.

Assume that hospitals maximize a utility function $U(\pi(T_1 \ldots T_n, X), O(T_1 \ldots T_n, X))$. π are the profits earned by the hospital, O are the characteristics of the output produced by the hospital, T_t is a particular technology, where t=1…n, and X includes all other variables that may influence hospitals' profits or the characteristics of their product, such as insurance environment, hospital-specific characteristics, or government regulations. We have included the term O in the hospitals' utility function because there is extensive literature suggesting that not-for-profit hospitals, unlike other firms, do not maximize profits, but rather some utility function. Although there is debate about the components to be included in this utility function, generally profits are considered as one of its arguments (Newhouse, 1970; Ellis and McGuire, 1986; Frank and Salkever, 1991). This term O may represent quality, charity care or technology sophistication. We assumed that both hospitals' profits and hospitals' output characteristics depend on technology. Technology may affect a hospital's utility through its implications on the quality of care provided, the number of patients received, the price obtained for hospitals' services, etc. In pursuit of their goals, hospitals choose the characteristics of their product; specifically, they decide the optimum amount of each technology T_t.

We define hospitals' objective function as:

$$\text{Max} U_{T_1..T_n}(\pi(T_1..T_n, X), O(T_1..T_n, X))$$
$$\text{s.t.} \pi \geq \underline{\pi}$$

where $\underline{\pi}$ is a lower bound on hospital profits and the function U is increasing in all its arguments.

The profit function for a hospital that has a set of technologies t ε [1,n] is defined as:

$$\pi = \sum_{t=1}^{n} P_{mc,t}(Q_{mc}, T_{mc,t}, X) Q_{mc} \alpha_{mc,t}(T_{mc,t}, X) + P_{ffs,t}(Q_{ffs}, T_{ffs,t}, X) Q_{ffs} \alpha_{ffs,t}(T_{ffs,t}, X) - C(Q_{mc} \alpha_{mc,t}(T_{mc,t}, X) + Q_{ffs} \alpha_{ffs,t}(T_{ffs,t}, X), T_t, X)$$

where C is a continuous, twice differentiable cost function; $P_{mc,t}$ is the price paid to the hospital for technology T_t by managed care; $P_{ffs,t}$ is the price paid for technology T_t by traditional insurers; Q_{mc} and Q_{ffs} refer to the quantity of people enrolled in managed care and traditional insurance, respectively; and $\alpha_{mc,t}$ and $\alpha_{ffs,t}$ correspond to the proportion of people that use technology T_t with managed care and traditional insurance contracts, respectively.

Solving the hospital optimization problem with respect to technology, we obtain the following first order condition:

$$C_2 = \frac{U_2}{U_1 + \lambda} + a \qquad \textit{equation 1}$$

where

$$a = \frac{\partial P_{mc,t}}{\partial T_t} Q_{mc} \alpha_{mc,t} + \frac{\partial \alpha_{mc,t}}{\partial T_t} P_{mc,t} Q_{mc} + \frac{\partial P_{ffs,t}}{\partial T_t} Q_{ffs} \alpha_{ffs,t} + \frac{\partial \alpha_{ffs,t}}{\partial T_t} P_{ffs,t} Q_{ffs} - \frac{\partial C}{\partial \alpha_{mc,t}} \frac{\partial \alpha_{mc,t}}{\partial T_t} Q_{mc} - \frac{\partial C}{\partial \alpha_{ffs,t}} \frac{\partial \alpha_{ffs,t}}{\partial T_t} Q_{ffs}$$

$$C_2 = \frac{\partial C}{\partial T} \qquad U_1 = \frac{\partial U}{\partial \pi} \qquad U_2 = \frac{\partial U}{\partial O} \frac{\partial O}{\partial t_t}$$

and λ is the Lagrange multiplier on profits.

Assuming that C_{22} is non-negative, we can rewrite equation 1 as the following specification for hospitals' technology adoption

$$T_t = f\left(\frac{U_2}{U_1 + \lambda} + a, Q_{mc} \alpha_{mc,t} + Q_{ffs} \alpha_{ffs,t}, X\right) \qquad \textit{equation 2}$$

where f is increasing in its first argument.

Economists typically have stronger priors on the form of U in for-profit firms. In particular, setting $U(\pi(T_1 \ldots T_n, X), O(T_1 \ldots T_n, X)) = \pi(T_1 \ldots T_n, X)$ and dropping the profit constraint, yields the following first-order condition with respect to technology:

$c_2 = a$

We can rewrite it as:

$$T_t = f(a, Q_{mc}\alpha_{mc,t} + Q_{ffs}\alpha_{ffs,t}, X) \quad \textit{equation 3}$$

Equations 2 and 3 will be our main references when analyzing the impact of managed care on hospitals' technology adoption.

Looking at these two equations, we can notice that the difference between the for-profit and not-for-profit hospital first-order condition for technology is the term $U_2/(U_1 + \lambda)$. Given this difference, it is not clear if not-for-profit hospitals will adopt more or less technologies than for-profit hospitals. Each hospital will adopt a technology T_t if the change in its utility function is non-negative. For a profit maximizing hospital this means that a hospital will adopt a technology if and only if acquiring it does not reduce the hospital's profits:

$\Delta\pi_t$ $(T_1 \ldots T_n, X) \geq 0$. However, not-for-profit hospitals' utility function is increasing in both π and O. Hence, when deciding whether to adopt a new technology, not-for-profit hospitals have to consider not only its effect on their profits but also on their product characteristics. Then, the not-for-profit hospital probability of adoption can be higher, equal or smaller than the probability of adoption of a for-profit hospital. Since there is no theoretical reason to suppose that not-for-profit hospitals will adopt technology more frequently, we test for this possibility empirically.

Turning now to the implications of managed care on hospitals' technology adoption, we first need to distinguish between hospitals belonging to a managed care network and hospitals not contracting with managed care organizations. Focusing first in the hospitals already contracting with managed care networks, from analyzing equations 2 and 3, we obtain four main implications of the model.

The first effect is through the impact of managed care on the prices it pays and the quantities it demands for hospitals' products. Due to the large market shares managed care organizations have gained in the insurance market, their bargaining power with hospitals has grown, raising concerns about managed care exercising oligopsony power against hospitals and physicians. In this oligopsony setting, managed care offers consumers insured medical care at oligopsony prices with the disadvantage of having limited choice. Managed care oligopsony power means that the price and quantity of the medical care sold by hospitals will be lower than their non-managed care levels[2]. Thus, $P_{mc,t} \leq P_{ffs,t}$ and $Q_{mc,t}\alpha_{mc,t} \leq Q_{ffs,t}\alpha_{ffs,t}$ and hospitals may be induced to adopt new technologies less frequently.

Second, since hospitals have experienced substantial price reductions for medical services, they may try to increase their bargaining power to negotiate better prices with insurance companies. Hospitals may be able to do so by adopting new technologies. If a hospital has a wide array of technologies and enjoys a good reputation in the community, insurance companies may not be able to offer a plan to their consumers without offering

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[2] This statement is true unless managed care enters into take-it-or-leave-it contracts with hospitals. In this case, quantity of the medical care sold by hospitals is not necessarily reduced.

access to the hospital. If this is true, the balance of power may shift from managed care organizations to the hospital and the contracts may become more favorable for the health care provider.

Hence, for a technology T_t such that $\frac{\partial P_{mc,t}}{\partial T_t} \geq \frac{\partial P_{ffs,t}}{\partial T_t}$, managed care may encourage its adoption.

Third, managed care not only reduces hospital payments through aggressive bargaining but also makes hospitals face a structure of payments that encourages low utilization of medical care. Since managed care organizations monitor the physicians and the amount and type of care given to patients, they may change doctors' propensity to assign patients to a particular treatment, changing practice patterns towards less use of new, costly technologies. Moreover, even within the network, managed care also requires patients to see a primary care physician before getting a referral to a specialist. Primary care physicians act as "gatekeepers", limiting patients' access to expensive, high-tech medical procedures. Thus, managed care may influence hospitals' adoption of new technologies by changing the proportion of patients that use them. This implies that $\alpha_{mc,t} \leq \alpha_{ffs,t}$ in equations 2 and 3, reducing hospitals' incentives to adopt new technologies.

Finally, although managed care pays generally lower prices and restricts usage more than traditional insurers, the price reduction and practice control does not need to be the same for all technologies. Given that technologies have varying costs and benefits, and given the strong incentive of managed care organizations to minimize costs, managed care may reduce its payments less, or apply less restrictive policies, for cost-saving technologies than for expensive ones. It is then important to compare the price reductions and usage restrictions imposed by managed care for different technologies that can treat a similar prognosis. Hence, we need not only to compare the effect of the technologies on $\alpha_{mc,t}$ versus $\alpha_{ffs,t}$ and the effect of the technologies on $P_{mc,t}$ versus $P_{ffs,t}$, but also to take into account the profitability of different technologies for hospitals under the same managed care contract.

For those hospitals not contracting with managed care organizations, the incentives to adopt a new technology may still be influenced by managed care. On the one hand, as noted by Baker and Shankarkumar (1997), managed care has strong implications for the overall health care market, reducing medical care prices and affecting physicians' practice patterns for other forms of health insurance as well. If this is the case, the previous implications of managed care on hospitals' technology adoption may go beyond the managed care network, affecting all hospitals in the market.

On the other hand, hospitals may be more inclined to adopt a new technology in order to have access to a managed care network. Since a provider that is not part of a network faces the risk that its patients would be directed elsewhere to take advantage of better prices and services, access to the managed care network is especially important and even more so as the number of managed care enrollees increases. However, managed care would not contract with hospitals that do not offer a wide array of services. When dealing with providers, managed care organizations face substantial contracting costs, such as administrative costs, legal costs, or costs of monitoring the hospital. Given managed care incentives to minimize costs, it is likely that managed care organizations will prefer to contract with one hospital offering a wide selection of services rather than to deal with several small hospitals each offering different services. Thus hospitals may adopt technologies in order to secure access to managed care networks.

Summarizing, the impact of managed care on hospitals' decision to adopt new technologies is theoretically not clear and it depends on the technology and each hospital's characteristics. In section 3 we analyze how the variables included in the term X in equations 2 and 3 affect hospital technology adoption. In our empirical analysis we include thirteen different technologies that have varying costs and benefits. Through analyzing the effect of managed care on each of these technologies, we will understand better how managed care impacts hospitals' technology adoption, as well as what hospital characteristics matter most for innovation.

3. Data

Medical Technology Availability and Diffusion

Our data contain information about thirteen medical technologies from 1982 to 1995. We define the term medical technology as a set of procedures or machines owned by hospitals that are devoted to patient care. More explicitly, our information about technologies, obtained from the American Hospital Association (AHA), corresponds in some cases to specific infrastructure items held by hospitals. Examples are CT-scanners, ultrasound devices, or X-ray devices. In other cases, technology refers to hospitals' services, like open-heart surgery or therapeutic radioisotope. We have decided to incorporate these services as part of our set of technologies because frequently these types of services are good signals of the presence of other infrastructure items owned by the hospital.

The range of technologies that we analyze fall into three categories:

Diagnostic Radiology	**Radiation Therapy**	**Cardiac**
Diagnostic Radioisotope	X-Ray Therapy	Cardiac Catheterization
Ultrasound	Radioactive Implants	Open-heart Surgery
CT-Scanner	Therapeutic Radioisotope	Angioplasty
MRI	Megavoltage Radiation	
PET	Stereotactic Radiosurgery	

Appendix 1 presents information about each procedure.

The data for this study is a hospital sample drawn from the AHA database. We use information on technology adoption for an average of 5390 hospitals per year from 1982 to 1995. We have eliminated from the sample hospitals that typically do not offer the set of technologies under consideration, such as psychiatric hospitals, hospitals that are a unit of an institution, and rehabilitation hospitals. Given that hospital mergers have been an important phenomenon during the 1990s, we have also taken into account mergers during our period of analysis. Specifically, once hospitals have merged, we generate a consolidated hospital from the merging year backwards; this strategy makes all the hospitals in our panel comparable over time. The newly created hospital has the same Metropolitan Statistical Area (MSA) and

state characteristics as the hospital resulting from the merger. Regarding technology ownership, we assume that whenever one of the merging hospitals owns the technology, the newly created hospital owns it too.

Explanations for technology diffusion

Insurance environment

To account for the effect of managed care on hospitals' technology adoption we use the share of the population per MSA that is enrolled in HMOs. Data on other forms of managed care enrollment, like Preferred Provider Organizations (PPOs) or Independent Practice Associations (IPAs)[3], are not available. Data on Medicare and Medicaid managed care contracts are not available either. However, since HMOs are the most comprehensive and restrictive form of managed care, our results should be accurate in representing the effect of managed care on hospitals' technology acquisition. Furthermore, HMO enrollment and enrollment in other forms of managed care are also positively correlated.

We use two possible alternative measures of HMO enrollment at the MSA level. First, the HMO enrollment level obtained from the Area Resource File (ARF)[4]. Second, HMO enrollment growth rates obtained from Baker's (1997) estimates of HMO market share from 1990-1994[5] and Richardson's (1999) estimates for 1982[6]. Using the Baker and Richardson estimates, we computed the yearly HMO enrollment growth rate. The mean value for the first and second definition of HMO enrollment over the 1982-1995 period is 7.3% and 7.2%, respectively.

All the analysis has been done using both definitions of HMO enrollment. The results do not change when we vary the definition. The results we report in the tables use the first definition, while results using the second definition are reported in Appendix 3, Table C.

The other variables included to account for the insurance environment are the percentage of the population per MSA that is enrolled in Medicare and Medicaid, and the percentage of the population that is uninsured. These variables reflect the nature of overall insurance coverage. This data has been obtained from the CPS. We treat these variables as time varying in our econometric model. Table 1 indicates that the average hospital was in an area where over the 1982-1995 time period 12 percent of the population was uninsured, and 7

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[3] PPOs and IPAs are less restrictive forms of managed care. PPOs typically have a network of physicians. Patients pay little when they use a physician in the network and pay more when they go out of it. The IPA has a panel of doctors enrolled to provide care and they share any saving resulting from reduced hospitalization or other cost saving.

[4] One possible problem with this data is that membership information for a particular HMO is included in the county where that HMO's address is in the ARF. However, the members are often actually located in many surrounding counties. To lessen this problem we are using the data at the MSA level rather than at a county-level.

[5] Baker's estimates are constructed using data from the Group Health Association of America, which surveys all HMOs in the US each year. He constructed estimates of county-level enrollment by distributing the HMO enrollment among the counties in its service area based on county population and the distance from HMO headquarters. County-level enrollment estimates were computed by adding over all HMOs serving the county. County market shares are the ratio of county HMO enrollment to county population.

[6] Richardson (1999) used Baker's methodology to compute HMO penetration at county-level for 1982. Richardson's data was estimated by assuming that relative penetration across counties is the same as 1990 for counties within a 50-mile radius of the MSA.

percent, 13 percent and 9 percent were enrolled in HMOs, Medicare, and Medicaid respectively.

Hospital controls

The hospital controls considered are size, measured by the number of beds, and type of ownership. To control for hospital size we include eight dummy variables for number of beds. The mean hospital in the sample has 173 beds over the period 1982-1995. Hospital size might influence innovation if new technologies exhibit positive scale effects. Hence, adoption may be more profitable for larger hospitals.

Type of ownership may also affect adoption decisions. We include dummy variables for whether the hospital is not-for-profit or government. For-profit, not-for-profit and government hospitals may have different considerations when deciding on technology adoption due to their different utility functions (Baumgardner, 1991; Newhouse, 1970; Custer et. al., 1990; Frank and Salkever, 1991). For instance, not-for-profit hospitals may care more about the quality of the services while government hospitals may have more financial constraints or care less about reputation issues. Table 1 shows that about 57 percent of the hospitals are not-for-profit and about 28 percent are government.

A teaching hospital is expected to adopt technology earlier than a non-teaching one given that they perform, in principle, more research and development. Table 1 reports that teaching hospitals account for about 6 percent of the sample.

Regulation

We include an indicator for states that have government regulations that may deter technology adoption. In particular, we include an indicator for whether states have a monetary threshold requirement for equipment purchases (Certificate of Need requirement, henceforth CON). We rank the states with CON regulation into five categories by its severity, where 1 is the least severe restriction and 5 is the most. Data on CON regulation is from the AHA[7]. We expect to see less technology adoption in those states with more rigorous CON regulations. The mean hospital in the sample is in a state where the CON variable value is 1.7.

We also include an indicator variable for whether a hospital is in a state that regulates payments to the hospitals by the payers. In general, these programs reduced payments to hospitals, both per day and per case. We expect that hospitals in states with this kind of regulation will adopt fewer new medical technologies.

Market Structure

Strategic interaction among hospitals may affect technology adoption. First, if the fixed costs of technology adoption are low and use of technology is potentially high, hospitals might engage in a medical arms race to acquire new technologies (Robinson and

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[7] Certificate of Need (CON): *Back to the future?* American Hospital Association, Washington D.C., October, 1993.

Luft, 1985). Second, hospitals might invest preemptively to achieve persistent increases in market shares. Preemption is an investment strategy to exploit a first-mover advantage or can be identified with a race to appropriate a profitable investment opportunity. This preemptive strategy is particularly important as the costs of adoption rise or the volume of potential patients falls. If this is the case, rival hospitals may deter or delay investments. To capture these potential interactions, we include the share of other hospitals (measured by the number of beds) that have already adopted the technology in the area. This measure was generated using AHA data.

Demographic factors

We included the MSA population, the average family income of the MSA, and whether the hospital is in a rural area or not. All demographic data was obtained from the CPS and all the variables are time-varying.

4. Methodology

To examine the relationship between managed care activity and hospitals' technology acquisition we use a hazard rate model (Meyer, 1990; Cutler, 1995). This model provides us with a hospital's probability of adopting any given technology, after controlling for hospital and market characteristics.

Denoting the cumulative probability that a hospital h has technology j at time t as $F^j_h(t)$ and the density function at time t as $f^j_h(t)$, the hazard is the probability that a hospital acquires the technology at time t conditional on its not having acquired the technology up to that point:

$$\lambda_h^j(t) = \frac{f_h^j(t)}{1 - F_h^j(t)}$$

We specify a proportional hazard model for technology adoption of the following form: $\lambda^j_h(t) = \exp(X^j_h(t)\beta) * \lambda_0(t)$ where $X^j_h(t)$ is the time varying proportional hazard and $\lambda_0(t)$ is the baseline hazard (Cox, 1972; Kalbfleisch and Prentice, 1973). The likelihood function for the data is:

$$L = \prod_{h=1}^{N} \left[F_h^j(t_h) - F_h^j(t_h - 1)\right]^{1-c} \left[1 - F_h^j(T)\right]^{c} \qquad \textit{equation 4}$$

where $F_h^j(t_h) - F_h^j(t_h - 1)$ denotes the probability that a hospital acquires the technology during period t_h and $1 - F_h^j(T)$ represents the probability that a hospital has not acquired the technology as of the end of the sample *(T)*. We use c_h as an indicator for the hospitals that have been censored. The log of the likelihood function is maximized using standard techniques.

Before presenting the results, there are three important issues to be resolved when estimating equation 4. First, there is the possibility that managed care market share and the probabilities of technology adoption are simultaneously determined. Managed care organizations may consider current and expected technology levels when deciding whether to enter a market, as medical technologies significantly affect hospital expenditures. Second, there is the possibility that unobservable variables are correlated with both managed care market share and the probability of adoption. For instance, patients' preferences for health care, or the health status of the population may be important omitted variables.

To correct for these two problems in a linear model, an instrumental variable (IV) estimation could help to address these issues. A possible instrument for HMO enrollment is the average firm size in the corresponding MSA, as first used by Baker (1997). Since large firms are more likely to offer managed care to their employees, areas with large firms are expected to have more managed care. However, large firms in an MSA are not correlated with hospitals' technology availability. Given the difficulty of instrumenting in a hazard model, to control for omitted variables and endogeneity, we follow Cutler and McClellan (1996) and use a technique analogous to the two-stage least squares method for the hazard rate model. In the first stage we regress HMO enrollment on hospital characteristics as well as on the average values of the other MSA and state variables, including the average firm size of the MSA. We then use the predicted values in our hazard regression. First stage regressions are reported in Appendix 2, Table A.

Finally, there is one last issue to take into account. An unmeasured area effect could exist that would similarly affect all the hospitals in this given area. More precisely, hospitals would be more willing to adopt a specific technology if the demand for such a technology is high in their area. This effect could be measured as an increase in the competition that the hospital confronts. If this were the case, there would be a non-causal relationship between our measure of competition and hospitals' technology adoption (Cutler and McClellan, 1996). Ideally, an instrumental variable should be used to solve this problem. However, given the difficulty of finding a good instrument, we include 9 dummies for region and 7 dummies for MSA size to lessen the problem.

5. Results

Is the expansion of managed care affecting technology adoption?

Our first goal is to analyze if managed care has an impact on hospitals' technology adoption and if so, how substantial the effect is. As established in section 2, the impact of managed care on hospitals' technology adoption is an empirical matter. We expect the influence of managed care to be stronger in the 1990s given that managed care is a more widespread form of insurance contract. To analyze this, we distinguish between technologies diffusing in the 1980s, and technologies diffusing in the 1990s. Table 2 presents the share of hospitals that owned each technology in three years: 1982, 1990 and 1995. Through all our analyses we distinguish between diagnostic radiology, radiation therapy and cardiac technologies. In fact, we analyze each group of technologies separately to reduce the heterogeneity between technologies within each group. We consider a technology as diffused in the 1980s if fifteen percent or more of the hospitals had it in 1990. Otherwise we consider the technology as diffusing in the 1990s. This fifteen percent rule is supported by the technologies' diffusion curves in Graph 2.1: there is a different pattern of diffusion between the two groups of procedures. Using this rule, among the diagnostic radiology technologies,

diagnostic radioisotope, ultrasound and CT-scanner are treated as already diffused, while MRI and PET are considered to be diffusing in the 1990s. Similarly, for radiation therapy procedures, X-ray therapy, radioactive implants, therapeutic radioisotope and megavoltage radiation are diffused in the 1980s while stereotactic radiosurgery is diffusing in the 1990s. Finally, for the cardiac technologies, cardiac catheterization and open-heart surgery are already diffused in the 1980s while angioplasty is diffusing in the 1990s[8].

To analyze whether the effect of HMOs is significantly different for the adoption of technologies that are diffusing in the 1990s, we generate a dummy variable equal to one for the technologies diffusing during the 1990s and zero for those diffused in the 1980s. We then interact this diffusion dummy with the HMO enrollment variable (HMO enrollment*diff90). We include this diffusion variable within each group of technologies. Dummy variables for each technology are also included.

Table 3 presents the hazard rate model for each group of technologies. The regressions include the HMOenrollment*diff90 variable for those technologies diffusing in the 1990s. All the explanatory variables discussed in section 3 are included. Table 3 also presents the technique analogous to the two-stage least squares method for the hazard rate model. These regressions include average firm size in the corresponding MSA as an instrument for HMO enrollment. The results for the two specifications are consistent.

The first block of Table 3 presents the coefficient estimates for the effect of the insurance environment variables. For the three groups of technologies, the coefficient of the HMO enrollment is significantly negative. The HMO enrollment*diff90 variable is also significantly negative in each of the three cases, implying that managed care affects more strongly those technologies diffusing in the 1990s. An increase of one standard deviation in HMO enrollment above the mean reduces the probability of adopting radiation therapy procedures by 9.5 percent. The effect is lower for the adoption of cardiac and diagnostic radiology procedures, where a one standard deviation increase in HMO enrollment reduces the probability of adoption by 4 percent.

To evaluate the magnitude of these numbers, we estimate the change in the share of hospitals predicted to have the technology nowadays if the HMO enrollment had been constant at its 1984 level. The coefficient in our hazard rate model indicates that an additional 5.3 percent of hospitals would have adopted diagnostic radiology technologies, meaning that instead of 82 percent of hospitals owning these technologies by 1995, 87 percent of hospitals would have adopted them. Regarding radiation therapy technologies, there would be 34 percent, instead of 31 percent, of hospitals owning them by 1995. Finally, for cardiac technologies, there would be 4.1 percent more hospitals with these technologies, with a total of 34 percent, instead of 32 percent, of hospitals with the technologies.

The second block of Table 3 shows the effect of hospital controls over technology adoption. From section 2, there is no theoretical reason that indicates that not-for-profit hospitals should be more inclined to adopt new technologies. Testing for this empirically, we find that not-for-profit hospitals are more likely to adopt these technologies. Rural hospitals are less likely. Government hospitals have a positive impact on technology adoption. The fact that a hospital is a teaching hospital does not strongly affect the adoption probabilities for all technologies. In terms of hospital size, the number of beds dummy variables (not reported)

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[8] Angioplasty diffused extremely fast after its introduction. So, even though 17.8 percent of the hospitals had angioplasty by 1990, we are considering this technology as diffusing in the 1990s.

shows that larger hospitals are more likely to adopt the technologies. Thus, the teaching effect has probably already been picked up by the number of beds, since teaching hospitals are generally large hospitals.

States with more severe CON regulation discourage technology adoption. Given that CON regulation directly limits purchases of new equipment, it is not surprising that the CON variable has a stronger negative effect than the rate regulation variable. We were able to capture this effect because we have more detailed information about state CON restrictions.

The fourth block of the table shows that market structure is strongly related to technology adoption. In all cases, the coefficient of the share of other hospitals in the area with the technology, measured by the number of beds, has a positive effect on adoption. This might be related to hospitals engaging in a medical arms race to acquire new technologies. There could be some concerns regarding the endogeneity of this variable, so we have run also the regressions without it and the results are very robust.

Finally, the demographic variables are also good predictors of technology adoption. The average family income has a positive effect on technology adoption. The MSA population has a consistently negative effect on acquisition. This could be explained by the fact that areas with a small population usually have fewer hospitals, and these hospitals have a greater variety of technologies, whereas hospitals in areas with more hospitals may be more specialized.

Does managed care have the same effect on every technology?

We have already shown that managed care has a negative effect on hospitals' technology adoption. As managed care becomes a more widespread form of health insurance, hospitals tend to adopt fewer technologies. However, as we pointed out in section 2, managed care may affect different technologies differently, emphasizing the use of the most cost-effective ones.

When deciding whether or not to adopt a new technology, a hospital does a specific cost-benefit analysis for each technology[9]. The hospital has to analyze the cost of the technology, the expected number of patients that will use the procedure, reimbursement for the treatment, as well as the number of years the technology can be used before it becomes obsolete.

Given that the technologies have varying costs and benefits for hospitals, we expect the CBR to be an important determinant of hospitals' adoption decisions under managed care, because of their profit motive. There are several reasons to expect this to happen. Since managed care organizations have a strong incentive to minimize costs, they might be willing to identify and support services with low cost-benefit ratios. Moreover, given that managed care organizations may favor hospitals that own low-cost-high-quality technologies, hospitals might be inclined to adopt technologies that are consistent with these requirements. If they do so, hospitals may be better positioned to negotiate with the HMOs.

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[9] We are aware that the net present value method would be more appropriate than the CBR, due to the myopic problem of the CBR. However, unfortunately, the medical literature we use as a reference analyzes technology profitability based on CBR instead of net present value.

Given this situation, hospitals should be more inclined to adopt technologies that have lower CBR. To examine if this is the case, we have established a ranking of technologies according to their cost-benefit ratio, within each of the three main categories of technologies. In the ranking, 1 corresponds to the technology with the lowest CBR ratio and 5 to the technology with the highest CBR ratio.

The medical literature has provided us with clear rankings for the cost-benefit of most of our technologies[10]. For instance, regarding diagnostic radiology technologies, the consensus among specialists (Bell, 1996; Conti et al., 1994; Maroldi et al., 1996; Ripley, 1991) validates that ultrasound is the most cost-effective technology, followed by diagnostic radioisotope, CT-scanners, MRIs, and finally PET (Ripley, 1991; Bell, 1996). PET is such a costly technology that even the Institute for Clinical PET recognizes that for a PET facility to be financially viable, alternative sources of revenue such as grants, contracts or philanthropic funding are necessary (Conti et al., 1994).

A similar ranking can also be established for cardiac technologies. Open-heart surgery is considered the most profitable cardiac technology for the hospitals (BARI, 1996; Cardiology Preeminence Roundtable, 1996 and 1997). In fact, open-heart surgery costs have been declining over the last few years, while the costs for angioplasty have been increasing dramatically due to the appearance of expensive new devices, such as stents (Cardiology Preeminence Roundtable, 1996). Meanwhile the reimbursement for open-heart surgery has remained much higher. Moreover, randomized studies reveal a significantly higher incidence of heart problems following angioplasty than following bypass surgery (Cardiology Preeminence Roundtable, 1996; BARI, 1996).

Cost-benefit analyses that allow us to establish a ranking within radiation therapy technologies are scarcer. This is due basically to the fact that each technology is appropriate for the treatment of a particular kind of cancer and cannot easily be substituted for another radiation therapy technology. There is only consensus in establishing that stereotactic radiosurgery is a very costly procedure, especially if it is performed using a gamma knife (Porter et al., 1997).

Although we cannot obtain a clear ranking for radiation therapy from the literature, it is still true that a hospital will perform a cost-benefit analysis when deciding to adopt any of these technologies. In order to obtain a ranking for the radiation therapy technologies, we approximate the technology CBR by using an estimation of the lifetime capital cost-reimbursement ratio (henceforth, CRR). Given that reimbursement is an important component of a hospital's benefit and that capital cost is an important component of the total costs, this estimation should give us a good notion of the technology's overall cost-benefit ratio[11]. In order to confirm that this is a good approximation we also compute the CRR ratio for the other two groups of technologies for which we already have the literature cost-benefit rankings. To calculate the CRR for each of the thirteen technologies, we look at the lifetime cost of the equipment as well as at the hospitals' reimbursements for the procedure during its expected life span.

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[10] In the literature, the cost-benefit analysis includes all the costs, fixed and variable, the hospital faces when it adopts and uses a given technology. It also considers the reimbursement for the hospital as well as the health benefits for the patient.

[11] We are aware that the interaction between managed care and hospital decisions to acquire new technologies is very complex. Capital costs and reimbursements are not the only elements that the hospital takes into account when deciding whether or not to adopt a certain technology, but they certainly are crucial aspects to consider.

In the lifetime costs of acquiring a particular technology we have included the possible cost range, the installation costs, and the annual maintenance costs. The cost range of the equipment as well as the expected lifetime has been obtained directly from the manufacturers of the equipment, from hospitals that own the technology, as well as from the literature (Hackl et al., 1998; Bell, 1996).

We are aware of the limitations of not including the operating costs of the procedures. However, we are comparing our results to the CBR ranking, obtained from the medical literature for two out of the three groups of technologies and we obtained similar results. Moreover, we are just using the CRR ranking, not the actual CRR numbers obtained through the calculations. Thus, CRR ranking results should not change significantly when including operating costs.

To determine hospitals' reimbursement of the procedures, we have used Medicare outpatient reimbursement[12]. HMO reimbursements to hospitals are not available because they are directly negotiated between the hospitals and the HMOs and this data is fully confidential. The corresponding reimbursements have been multiplied by the life span of the procedure and for the average number of patients per hospital that receive the treatment. This information has been obtained from the Medicare CPT book and price list, from the *Agency for Health Care Policy and Research*, and from *Vital and Health Statistics* of the National Center for Health Statistics.

Table 4 presents the CRR for each technology for year 1995 as well as the corresponding CBR rankings. The CRRs have been obtained using the average expected lifetime costs and reimbursements for each technology. Notice that the rankings implied by the CRR for diagnostic radiology and cardiac technologies coincide with the rankings established by the literature based on the cost-benefit analysis. Hence we can use the CRR ranking for radiation therapy technologies as a good approximation of the cost-effectiveness ranking.

We run hazard rate model regressions for each technology containing all the explanatory variables included in the previous section. In order to make the technologies more comparable we keep the previous classification of diagnostic radiology, radiation therapy and cardiac technologies[13].

Analyzing the diagnostic radiology technologies, Table 4 shows that PET is clearly the least profitable technology, and hence it is also the one with the highest CBR ranking. It is followed by MRI, CT-scanner, diagnostic radioisotope and finally by ultrasound. Note, for instance, that the average cost of a PET is much higher than the average cost of a CT-scanner. However, the average reimbursement for a PET is only a little higher than that for a CT-scanner. This makes PET less profitable for the hospital. The same analysis could be done for all the technologies in this group.

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[12] The only cases for which we have inpatient reimbursements are open-heart surgery and angioplasty, procedures that are done only on an inpatient basis. For both cases we have considered the fraction of the corresponding DRG that goes directly to pay for the procedure rather than the hospitals' days of stay, drugs, etc.

[13] We are aware that even within each group, the technologies have specific characteristics. There are also precise requirements and considerations for the implementation of each procedure. However, we claim that with the CBR approach we are able to explain at least partially the differences in the managed care effect over the technologies within each group.

Table 5 presents the results of the hazard model for each technology (Table D in Appendix 2 reports the same regressions using the analogous two-stage least squares method). Our theory establishes that the HMO enrollment coefficient ought to be more negative the less profitable the technology. PET is the technology with the most negative coefficient for HMO enrollment and it is also the one with the highest CBR ranking. A one standard deviation increase in HMO enrollment reduces the probability of adopting a PET site by 27 percent. As expected, MRI, CT-scanner, diagnostic radioisotope and ultrasound follow. An increase of one standard deviation in HMO enrollment diminishes the probability of adoption by 4.6, 2.8, 2.4 and 1.4 percent for MRI, CT-scanners, diagnostic radioisotopes and ultrasound, respectively. The coefficients in Table 7 imply that if HMO enrollment had been constant at its 1984 level, an additional 23 percent of hospitals would have invested in acquiring PET. Thus, instead of 2.8 percent of hospitals owning the technology by 1995, 3.4 percent would have had it. Regarding ultrasound, the diagnostic radiology technology least affected by managed care, an additional 1.2 percent of the hospitals would have adopted it, implying that instead of 84.6 percent of the hospitals owning it by 1995, 85.6 percent of the hospitals would have acquired it.

This relationship between CBR and the effect of managed care on hospitals' technology adoption is also true for technologies diffusing during the same time period. For instance, both MRI and PET are diffusing during the 1990s, but PET's CBR ranking is much higher. The coefficient of HMO enrollment for PET should be more negative than that for MRI, and that is the result obtained in Table 5. The same reasoning applies to the three diagnostic radiology technologies diffusing in the 1980s.

Similar results are obtained for the radiation therapy and cardiac technologies. Stereotactic radiosurgery is the procedure with the highest CBR, followed by X-ray therapy, radioactive implants, therapeutic radioisotope and, finally, megavoltage radiation. This ranking is sustained in Table 5, where stereotactic radiosurgery is the technology with the most negative coefficient for HMO enrollment, while therapeutic radioisotope is the one with the least negative HMO enrollment coefficient. A one standard deviation increase in HMO enrollment reduces the probability of a hospital adopting stereotactic radiosurgery and therapeutic radioisotopes by 8 and 5 percent, respectively. As shown in Table 7, if HMO enrollment had been constant at its 1984 level, an additional 6.7 and 4.2 percent of hospitals would have adopted stereotactic radiosurgery and therapeutic radioisotopes, respectively.

Looking at the three cardiac technologies, we continue to obtain results supporting our CBR hypothesis. Open-heart surgery is the most cost-effective cardiac technology, followed by cardiac catheterization and angioplasty. The negative effect of HMO enrollment on the adoption of technologies is clearly stronger for angioplasty than for open-heart surgery. A one standard deviation increase in HMO enrollment reduces a hospital's probability of adopting an open-heart unit by 2.7 percent, while the probability of adopting angioplasty decreases by 6.1 percent. These coefficients mean that if HMO enrollment had been constant at its 1984 level, an additional 2.3 and 5.1 percent of hospitals would have adopted open-heart surgery and angioplasty, respectively (see Table 7).

These results show that CBR is an important aspect to consider when analyzing hospitals' technology acquisition. In general, the higher the CBR, the more negative the effect of managed care on the adoption of the corresponding technology. To prove that the CBR effect is statistically significant and it is not only that the less profitable technologies have been diffusing in the 1990s when managed care was very generalized, we run a hazard model that includes HMO enrollment*diff90 variable as well as the CBR ranking. The results are presented in Table 6. HMO enrollment has a negative effect on technology adoption and

this effect is even more negative for technologies diffusing in the 1990s. As expected, the coefficient for the CBR ranking is negative. This indicates that the probability of a hospital adopting a new technology decreases with the CBR.

The rest of the explanatory variables behave in the same way as in the previous section.

6. Effect of Managed Care on Health Care Expenditures

Over the past several decades, persistent health care growth has kept the cost of medical expenses at the center of the policy agenda. Health care spending grew at an average annual rate of 12 percent between the 1960s and the early 1990s. However, during the 1990s –and particularly since 1992– the growth of medical costs has slowed down significantly, growing at an average annual rate of 5 percent. Levit et al. (1998) and Zwanziger and Melnick (1996) have suggested that a large part of the expenditure growth slowdown can be attributed to managed care growth.

Managed care could reduce the health care cost growth through several mechanisms. For instance, managed care may reduce the rates paid for particular medical services or may affect the number of days that their customers can stay at the hospital. Although these mechanisms slow down the medical spending growth, they only generate one-time savings. For managed care to produce a long-term reduction in the growth of medical spending, it should decrease technology expansion, since more than half of the growth in medical spending can be attributed to technological change (Aaron, 1991; Newhouse, 1992). Thus, for managed care to create long-term saving, it must influence the ultimate level of technology, the force that has been driving the large spending increases observed over the past decades.

In this section we analyze whether managed care is affecting the ultimate level of technology adoption or whether it is only slowing down the technology diffusion pattern, requiring only a longer period of time to reach the non-managed care level of technology. If managed care is, in fact, effectively lowering the level of technology expansion, then we can confidently assess that managed care is having a long-term effect on health care cost growth.

Among our thirteen technologies, we select for this analysis only those technologies that by 1995 have reached their steady state level. If managed care affects the adoption rate for technologies already at their steady state level, the level of technology adoption would definitely have been higher without managed care.

To examine managed care's effects on technology adoption as well as other factors affecting hospitals' decision to innovate we use a logistic model. This model provides us with a hospital's probability of adopting after controlling for hospital and market characteristics. We estimate this logit model around the technologies' steady state level.

The technologies included in this analysis as well as the years of study considered for each of them are the following:

Technologies	Steady-State Years
Diagnostic Radiology Procedures:	
Diagnostic Radioisotope	1989-1995
Ultrasound	1990-1995
Radiation Therapy Procedures:	
X-Ray Therapy	1990-1993
Radioactive Implants	1990-1993
Cardiac Procedures:	
Cardiac Catheterization	1993-1995
Open-heart Surgery	1993-1995

We select these technologies and their steady state years based on the information presented in Graph 1.

In a given period a hospital is constrained by its own characteristics and those of the market, and faces two choices. A hospital can choose to maintain the status quo and to not innovate, or a hospital can choose to adopt a new technology. The estimated model is of the following form:

$$Prob(Y=j) = \alpha + \beta * I_i + \gamma * H_i + \varphi * R_i + \lambda * M_i + \varepsilon_i \ , j=0,1$$

where I_i represents the market-specific insurance environment –the percentage of the MSA population that is enrolled in HMO, Medicare, Medicaid or is uninsured. H_i are hospital-specific characteristics, such as number of beds, ownership status, teaching status, and hospital's location. R_i represents market-specific government regulation. Specifically, R_i shows whether a hospital is in an area where rate regulation or certificate of need regulation applies. Finally, M_i is market-specific characteristics, such as the population and the log of family income. All regressions include year, region and MSA size dummy variables. The outcome Y for each hospital is coded as either maintaining the status quo or adopting a new technology.

Table 8 shows the results of the logit rate model regressions. HMO enrollment coefficient is negative and significant for five of the six technologies analyzed. This implies that, even for technologies already in their steady state level, managed care has a negative impact on adoption decisions. Thus, managed care is affecting not only the pattern of diffusion but altering the ultimate level of innovation. The coefficients in our logit regression indicate that hospitals' adoption probabilities are lower than they would be without managed care insurance system or with a lower level of managed care enrollment. For instance, hospitals' adoption probability for radioactive implants is 7.8%. However, if the HMO enrollment had been constant at its 1984 level, the adoption probabilities would instead be 8.6%. Thus, an additional 11.1% of hospitals would have adopted the technology if HMO enrollment would stay at its 1984 level.

National health expenditure was $428.7 billion in 1985 and $993.3 billion in 1995. If we follow Aaron (1991) and Newhouse (1992) and assume that half of this expenditure was due to technological expansion, then figures in Table 9 suggest that managed care is reducing health care expenditure by $4 billion due to reductions in technology adoption[14] [15].

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[14] The $4 billions saving assumes that technology adoption is translated one to one into use.

[15] To calculate this number we estimate the weighted average of the changes in technologies' adoption probabilities.

If we calculate the changes in hospitals' adoption probabilities using the coefficients estimated with the instrumental variables methodology from Table E, savings in health expenditure due to managed care reduction in technology expansion are significantly higher at $43 billion.

7. Conclusions

Our main goal in this paper is to investigate the possible effects of managed care on technology acquisition. Since the sign of these effects is not theoretically clear and depends on the technology characteristics, we use data for thirteen different technologies between 1982 and 1995. Our results suggest that managed care negatively affects the adoption of technologies by hospitals. This result is consistent for each of the thirteen technologies we examine. Moreover, the effect is even stronger for technologies diffusing in the 1990s, when managed care was a more pervasive form of health insurance. We also examine other potential forces driving technology adoption. We find that insurance environment, regulation, and market structure are essential factors affecting technology availability.

The interaction between managed care and hospital decisions to acquire new technologies is very complex. As a first step in understanding some of the mechanisms involved, we consider that hospitals were making their decision about the adoption of technologies based on an individual cost-benefit analysis. We find that the most negative effect of managed care is for technologies with a high cost-benefit ratio.

Our results are valuable because they allow us to examine the relationship between managed care and technology adoption for thirteen different technologies, we have consistent results for all of them, and we have captured important variations among individual technologies. Further work should focus on understanding the adoption process for the hospital, looking at each technology separately and considering the aspects that may affect the hospital's decision to adopt such a technology.

The negative effect of managed care on technology adoption may have important policy implications. For instance, an important policy question is to what extent managed care may slow down health care cost growth. Our results provide evidence that managed care may be able to contribute to cost savings in the health market by limiting availability of technologies, especially the availability of new and more expensive ones. Managed care is affecting availability of health care technologies by changing the incentives associated with their acquisition.

Our results also suggest that managed care may lead to a long-term saving by significantly reducing the growth of medical expenses. However, we cannot establish the effect of managed care on technology development or in patient care. Further research should be done to understand managed care effects on these issues.

References

Aaron, Henry (1991). *Serious and Unstable Condition: Financing America's Health Care*. Washington, D.C.: The Brookings Institution.

Arrow, Kenneth (1970). "Economic welfare and the allocation of resources to invention," *Essays in the theory of Risk-Bearing*.

Baker, L. (1997). "The effect of HMOs on fee-for-service health care expenditures: evidence from Medicare," *Journal of Health Economics*, No.16.

Baker, L. and M. Brown (1997). "The effect of managed care on health care providers," NBER Working Paper 5987.

Baker, L. and J. Spetz (1999). "Managed care and medical technology growth," Working Paper Series N0.6894, NBER.

Baker, L. and S. Shankarkumar (1997). "Managed care and health care expenditures: evidence from Medicare, 1990-1994," Working Paper Series No. 6187, NBER.

Baker, L. and S. Wheeler (1998). "Managed care and technology diffusion: The case of MRI," Health Affairs, No.5.

BARI (1996). "Bypass Angioplasty Revascularization Investigation: Comparison of coronary bypass surgery with angioplasty in patients with multivessel disease," *The New England Journal of Medicine*.

Barro, J. and D. Culter (1997). "Consolidation in the medical care marketplace: A case study from Massachusetts," NBER Working Paper No.5957.

Baumgardner, James (1991). "The interaction between forms of insurance contract and types of technical change in medical care," *Rand Journal of Economics*.

Bell, R. (1996). "Economics of MRI technology," *Journal of Magnetic Resonance Imaging*.

Black, P. and J. Loeffler (1997). *Cancer of the nervous system*, Cambridge Mass: Blackwell Science.

Cardiology Preeminence Roundtable (1997). *Cardiac surgery renaissance: clinical and financial impact of minimally invasive technique*, The Advisory Board Company.

Cardiology Preeminence Roundtable (1996). *Enduring advantage: breakthrough cardiac strategy under managed care*, The Advisory Board Company.

Cardiology Preeminence Roundtable (1993). *Rapid turnaround: minimizing cardiologist downtime*, The Advisory Board Company.

Conti, P., J. Keppler and J. Halls (1994). "Positron emission tomography: A financial and operational analysis," *Perspective*.

Cox, D. (1972). "Regression Models and Life Tables," *Journal of the Royal Statistical Society,* 34.

Cromwell, J. (1984). "Treatment of capital costs in four Medicare-waivered states: Maryland, New Jersey, New York and Massachusetts," *Hospital Capital Finance Background Papers*, US Department of Health and Human Services, Wahington, D.C.

Cutler, D. (1995). "The incidence of adverse medical outcomes under prospective payment," *Econometrica*, Vol.63.

Cutler, D. and M. McClellan (1996). "The determinants of technological change in heart attack treatments," NBER Working Paper, No.5751.

Cutler, D. and L. Sheiner (1998). "Managed care and the growth of medical expenditures," *Frontiers in Health Policy Research*.

Custer, W. et al. (1990). "The production of health care services and changing hospital reimbursement: the role of hospital-medical staff relationships," *Journal of Health Economics*, No.9.

Dranove, D. (1987). "Rate-setting by DRG and hospital specialization," *Rand Journal of Economics*, No.18.

Dranove, D. and W.D. White (1998). "Medicaid-dependent hospitals and their patients: how have they fared?," *HSR*.

Ellis, R. and T. McGuire (1986). "Provider behavior under prospective reimbursement: cost sharing and supply," *Journal of Health Economics,* No.5.

Feldstein, M. (1971). "Hospital cost inflation: a study of nonprofit price dynamics," *American Economic Review*, No.61.

Frank, R. and D. Salkever (1991). "The supply of charity services by non-profit hospitals: motives and market structures," *Rand Journal of Economics*, No.22.

Gilbert R. and M. Lieberman (1987). "Investment and Coordination in Oligopolistic Industries," *Rand Journal of Economics*, 24.

Godderis, John (1980). "Insurance and incentives for innovation in medical care," S*outh Journal of Economics*.

Hackl, A. et al. (1998). "The cost of radiosurgical treatment: comparison between gamma knife and linear accelerator," *Acta Neurochirurgica*.

Hoerger, T. (1991). "Profit variability in for-profit and not-for-profit hospitals," *Journal of Health Economics*, No.10.

Jensen, G., M. Morrisey, S. Gaffney and D. Liston (1997). "The new dominance of managed Care: Insurance trends in the 1990s," *Health Affairs,* January/February, 16.

Kalbfleisch, J. and R. Prentice (1973). "Marginal Likelihoods Based on Cox's Regression and Life Model," *Biometrika*, 60.

Karshenas, M. and P. Stoneman (1993). "Rank, Stock, Order, and Epidemic Effects in the Diffusion of New Process Technologies: An Empirical Model," *Rand Journal of Economics*, 24.

Leibel, S. and T. Phillips (1998). *Textbook of radiation oncology*, Philadelphia: Saunders.

Levit, K., H. Lazenby and B. Braden (1998). "National Health Spending Trends," *Health Affairs*, 17.

Maroldi, R. et al. (1996). "Magnetic resonance and computed tomography compared in the staging of rhinosinusal neoplasms. A cost-effectiveness evaluation," *Radiologia Medica*.

Mettler, F. (1991). *Essentials of nuclear medicine imaging*, Philadelphia: Saunders.

Meyer, B. (1990). "Unemployment insurance and unemployment spells," *Econometrica*, Vol.58.

Newhouse, J. (1970). "Toward a theory of nonprofit institutions: an economic model of a hospital," *American Economic Review*, No.60.

Newhouse, J. (1992). "Medical care costs: How much welfare loss," *Journal of Economic Perspectives*.

Pauly, M. (1980). *Doctors and their workshops*, University of Chicago Press, Chicago.

Perez, C. and L. Brady (1997). *Principles and practice of radiation oncology*, Philadelphia: Lippincott-Raven.

Pope, G. (1989). "Hospital nonprice competition and Medicare reimbursement policy," *Journal of Health Economics*, No.8.

Potosky, A., Breen, N., Graubard, B. and E. Parsons (1998). "The association between health care coverage and the use of cancer screening tests in medical care," vol 36(3).

Richardson, E. (1999). "Does managed care penetration affect access to hospitals?," Harvard University, mimeo.

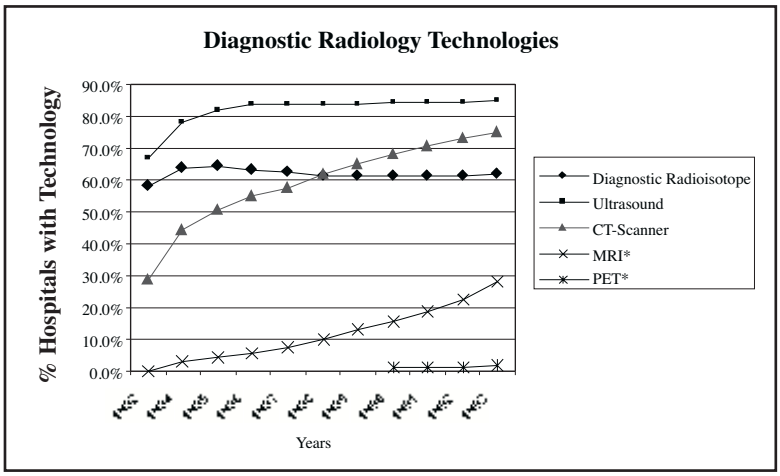
Ripley, M. (1991). " Is nuclear medicine cost-effective?," *Dimensions*, March 1991.

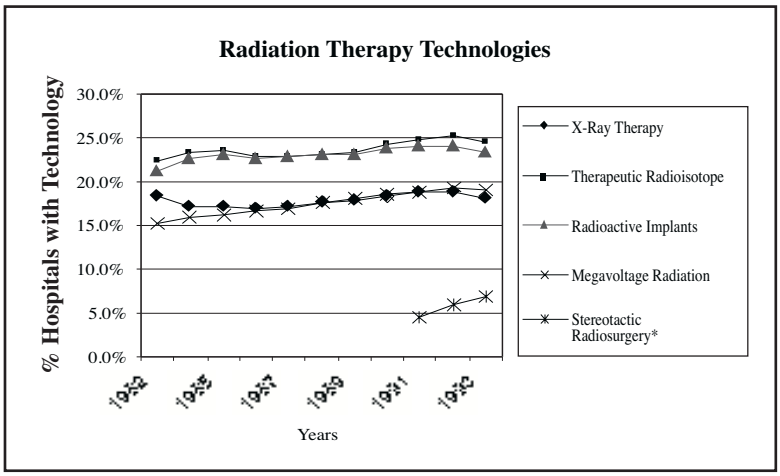
Teplensky, J, M. Pauly, J. Kimberly, A. Hillman and S. Schwartz (1995). "Hospital adoption of medical technology: An empirical test of alternative models."

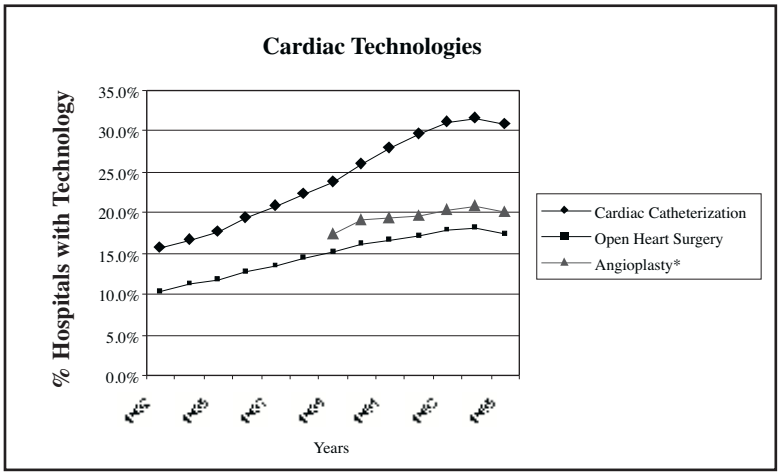
Welch, P. (1984). "HMO enrollment: A study of market forces and regulations," *Journal of Health Politics and Policy*.

Zwanziger and G. Melnick (1996). "Can Manged Care Plans Control Health Care Costs?," *Health Affairs*, 15.

Graph 1







*Technology diffusing in the 1990s

Table 1. Summary Statistics (1982-1995)

Variable	Level of Aggregation	Mean	Standard Deviation
Insurance			
HMO enrollment	MSA	7.3%	0.11
Medicare enrollment	MSA	13.3%	0.03
Medicaid enrollment	MSA	9.1%	0.04
Percent uninsured	MSA	11.5%	0.05
Hospital controls			
Not-for-profit	HOSPITAL	57.0%	0.49
Government	HOSPITAL	27.7%	0.45
Teaching	HOSPITAL	6.0%	0.24
Rural	HOSPITAL	14.6%	0.35
Number of beds	HOSPITAL	173	172.9
Regulation			
Rate Regulation	STATE	11.0%	0.31
Certificate of need (CON)	STATE	1.7	1.65
Market Structure			
Share of other hospitals with technology in the area	MSA	DOT '	DOT '
Demographics			
Log of family income	MSA	10.4	0.26
Total population	MSA	1,713,589	1,823,661

' DOT= Depends on the Technology

Sources: American Hospital Association (AHA), Area Resource File (ARF), and Current Population Survey (CPS)

Table 2. Diffusion of Medical Technologies

Technologies	Data Availability (years)	Share of Hospitals with Technology 1982	1990	1995
Diagnostic Radiology				
Diagnostic Radioisotope	1984-1995	58.4%	61.3%	60.6%
Ultrasound	1984-1995	67.1%	84.2%	84.6%
CT-Scanner	1982-1995	28.6%	68.1%	75.3%
MRI	1982-1995	3.1%	14.8%	37.2%
PET	1990-1995	-----	1.1%	2.8%
Radiation Therapy*				
X-Ray Therapy	1982-1993	18.5%	18.4%	18.2%
Radioactive Implants	1982-1993	21.2%	23.7%	23.4%
Therapeutic Radioisotope	1982-1993	22.5%	24.3%	24.4%
Megavoltage Radiation	1982-1994	15.3%	18.7%	19.0%
Stereotactic Radiosurgery	1991-1993	----	----	7.0%
Cardiac				
Cardiac Catheterization	1982-1995	15.5%	26.0%	30.8%
Open-Heart Surgery	1982-1995	16.7%	16.1%	17.4%
Angioplasty	1989-1995	----	17.9%	20.1%

*Given data availability, the information for all Radiation Therapy technologies corresponds to year 1993 instead of year 1995

Source: American Hospital Association (AHA)

Table 3. Hazard Rate Model and IV Regressions

	Diagnostic Radiology Procedures		Radiation Therapy Procedures		Cardiac Procedures	
	[1]	[2]	[1]	[2]	[1]	[2]
Variables						
Insurance						
HMO enrollment"	-0.13 **	-1.29 **	-0.59 **	-8.25 **	-0.42 **	-5.77 **
	[0.044]	[0.120]	[0.134]	[0.613]	[0.083]	[0.981]
HMO enrollment * diff90	-1.15 **	-0.99 **	-1.01 *	-1.11 **	-0.09 **	-0.39 **
	[0.329]	[0.297]	[0.102]	[0.353]	[0.032]	[0.175]
Medicare enrollment	-0.1	-0.09 *	0.87 **	1.467 **	-0.27	-0.34 **
	[0.057]	[0.055]	[0.227]	[0.150]	[0.294]	[0.151]
Medicaid enrollment	0.02	0.05	-0.03	-0.14	-0.42 *	-0.44
	[0.028]	[0.029]	[0.222]	[0.172]	[0.252]	[0.622]
Percentage uninsured	0.26 **	0.43 **	0.54 **	1.02 **	-0.43	0.27
	[0.063]	[0.077]	[0.281]	[0.349]	[0.322]	[0.652]
Hospital Controls						
Not-for-profit	0.08 **	0.06 **	0.33 **	0.30 **	0.10 **	0.13 **
	[0.009]	[0.012]	[0.025]	[0.025]	[0.022]	[0.030]
Government	0.02 **	-0.01	0.26 **	0.16 **	0.04	0.01
	[0.006]	[0.008]	[0.022]	[0.023]	[0.030]	[0.049]
Teaching	-0.02 **	-0.02 **	-0.04 **	-0.02	-0.03 **	0.03
	[0.007]	[0.007]	[0.018]	[0.013]	[0.013]	[0.029]
Rural	-0.05 **	-0.06 **	-0.71 **	-0.19 **	-0.35 **	-0.49 **
	[0.004]	[0.005]	[0.163]	[0.049]	[0.089]	[0.158]
Regulation						
Rate regulation	-0.02 **	-0.01	-0.03	-0.14 **	-0.09 **	-0.04
	[0.004]	[0.006]	[0.023]	[0.054]	[0.023]	[0.048]
CON	-0.005 **	-0.008 **	-0.02 **	-0.15 **	-0.031 **	-0.11 **
	[0.001]	[0.002]	[0.007]	[0.015]	[0.007]	[0.019]
Market Structure						
Share of other hospitals	0.81 **	0.84 **	0.69 **	0.96 **	0.59 **	0.95 **
with technology in area	[0.020]	[0.020]	[0.077]	[0.095]	[0.053]	[0.112]
Demographics						
Log of family income	0.03 **	0.11 **	-0.06	0.54 **	-0.39	0.1
	[0.014]	[0.013]	[0.099]	[0.104]	[0.178]	[0.444]
Population	-2.2*10^-8 **	-2.12*10^-8 **	-1.14*10^-8 **	3.55*10^-9	-5.5*10^-8 **	-2.89*10^-8 **
	[1.73*10^-9]	[2.18*10^-9]	[5.37*10^-9]	[5.12*10^-9]	[4.84*10^-9]	[7.77*10^-9]
N	20696	18737	15945	13756	9754	7895
Prob>chi2	0	0	0	0	0	0

[1] Hazard rate model

[2] Analogous two-stage least squares method for the hazard rate model

" We use the predicted HMO enrollment for the IV regressions.

Robust standard error values appear in brackets below the regression coefficient

All regressions include demographic and market structure variables as well as 13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.

All regressions controlled for heteroskedasticity and autocorrelation.

* Statistically significantly different from zero at the 10 percent level

** Statistically significantly different from zero at the 5 percent level

Table 4. Costs of Technologies and Medicare Reimbursements for 1995 (in dollars)

Technologies	Costs#	Reimbursements*#	Average CRR	Cost-Benefit ratio (ranking)'	HMO enrollment coefficient "
Diagnostic Radiology					
Diagnostic radioisotope	525,000-625,000	129,164-224,274	3.253	2	-0.22 [0.059]
Ultrasound	125,000-200,000	100,093-125,116	1.443	1	-0.13 [0.029]
CT-Scanner	1,145,000-1,470,000	197,368-343,421	4.835	3	-0.26 [0.065]
MRI	2,125,000-3,850,000	265,000-535,000	7.468	4	-0.43 [0.151]
PET	10,350,000-14,350,000	700,000-1,250,000	12.666	5	-2.83 [1.028]
Radiation therapy					
X-Ray therapy	540,000-900,000	400,000-1,550,000	0.738	4	-0.60 [0.122]
Therapeutic radioisotope	110,000-140,000	330,000-720,000	0.238	1	-0.47 [0.135]
Radioactive implants	356,000-486,000	360,000-3,000,000	0.251	2	-0.53 [0.148]
Megavoltage radiation	4,100,000-4,850,000	3,750,000-6,250,000	0.895	3	-0.69 [0.133]
Stereotactic radiosurgery	5,100,000-8,100,000	4,320,000-8,640,000	1.019	5	-0.76 [0.475]
Cardiac Tech.					
Cardiac catheterization	1,000,000-1,200,000	3,074,615-22,290,961	0.087	2	-0.43 [0.083]
Open-heart surgery	250,000-500,000	47,568,181-54,363,636	0.006	1	-0.25 [0.099]
Angioplasty	1,000,000-1,700,000	8,261,508-13,218,413	0.126	3	-0.57 [0.139]

CRR refers to the cost-Reimbursement Ratio.

* The reimbursement figures are on an outpatient basis with the exception of Open-Heart Surgery and Angioplasty. For these last cases, the figures relate to the corresponding DRG reimbursement. Approximately, half of the amount is directly involved in the procedure and the other half pays for the days of stay in the hospital, drug expenditure, etc. To estimate the lifetime reimbursement, we only considered the part of the reimbursement associated with the procedure itself.

The figures correspond to expected lifetime cost and reimbursements.

' This ranking is determined based on existing literature on cost-effectiveness analysis on the technologies under study, as well as from interviews with hospitals' financial personnel.

" These coefficients correspond to the HMO enrollment coefficients of Table 5. Robust standard error values appear in brackets.

Table 5. Hazard Rate Model Regressions

	Diagnostic Radiology Procedures					Radiation Therapy Procedures					Cardiac Procedures		
	Diagnostic Radioisotope	Ultrasound	CT-Scanner	MRI +	PET +	X-ray Therapy	Therapeutic Radioisotope	Radioactive Implants	Megavoltage Radiation	Stereotactic Radiosurgery +	Cardiac Catheterization	Open-Heart Surgery	Angioplasty
Variables													
Insurance													
Predicted HMO enrollment	-0.22*	-0.13**	-0.26**	-0.43**	-2.83**	-0.60**	-0.47**	-0.53**	-0.69**	-0.76*	-0.43**	-0.25**	-0.57**
	[0.059]	[0.029]	[0.065]	[0.151]	[1.028]	[0.122]	[0.135]	[0.148]	[0.133]	[0.475]	[0.083]	[0.099]	[0.139]
Medicare enrollment	0.05	-0.27**	-0.02	0.13	2.65	0.43	0.91**	0.85**	1.12**	3.14**	-0.18	-0.35	-0.40*
	[0.056]	[0.036]	[0.098]	[0.402]	[4.789]	[0.534]	[0.198]	[0.180]	[0.179]	[0.725]	[0.138]	[0.523]	[0.233]
Medicaid enrollment	-0.14	0.03	-0.19**	0.21	4.06	-0.72**	0.34	0.13	-0.54**	0.72	-0.21**	-0.52	-0.70**
	[0.134]	[0.029]	[0.068]	[0.160]	[4.441]	[0.253]	[0.254]	[0.194]	[0.195]	[0.824]	[0.097]	[0.63]	[0.217]
Percentage uninsured	0.29	0.11	0.32**	0.19	-6.84**	0.247	0.60**	1.00**	0.12	-0.13	-0.61**	0.43	-0.49*
	[0.101]	[0.076]	[0.084]	[0.252]	[3.298]	[0.468]	[0.218]	[0.224]	[0.437]	[0.647]	[0.291]	[1.217]	[0.275]
Hospital Controls													
Not-for-profit	0.11**	0.05**	0.08**	0.15**	0.56	0.46**	0.27**	0.22**	0.53**	1.04**	0.11**	0.14*	-0.01
	[0.007]	[0.011]	[0.009]	[0.037]	[0.641]	[0.073]	[0.029]	[0.026]	[0.039]	[0.23]	[0.02]	[0.087]	[0.033]
Government	0.01	-0.01	0.001	0.11**	1.22*	0.40**	0.21**	0.12**	0.50**	1.19**	0.06**	0.05	-0.07*
	[0.010]	[0.009]	[0.006]	[0.038]	[0.691]	[0.055]	[0.027]	[0.031]	[0.052]	[0.359]	[0.027]	[0.089]	[0.046]
Teaching	-0.004	-0.004	-0.008	-0.07**	0.56	-0.05	-0.03*	-0.04**	-0.02	-0.03	-0.02	-0.03*	-0.03**
	[0.007]	[0.007]	[0.010]	[0.025]	[0.516]	[0.037]	[0.019]	[0.018]	[0.020]	[0.204]	[0.02]	[0.017]	[0.13]
Rural	-0.07**	-0.03**	-0.06**	-0.24**	0.92	0.17**	0.01	-0.20**	0.08	-3.60**	-0.33**	-1.02**	-0.59
	[0.010]	[0.004]	[0.012]	[0.056]	[1.364]	[0.088]	[0.081]	[0.089]	[0.094]	[1.095]	[0.119]	[0.477]	[0.458]
Regulation													
Rate regulation	-0.03**	-0.03**	-0.04**	-0.11**	-1.65	0.01	-0.10**	-0.02	0.03	0.24**	-0.09**	-0.34**	-0.03
	[0.006]	[0.005]	[0.005]	[0.041]	[1.124]	[0.042]	[0.017]	[0.031]	[0.030]	[0.085]	[0.023]	[0.064]	[0.062]
CON	0.01**	0.01**	0.002	-0.03**	0.11	-0.03**	-0.02**	-0.02**	-0.03**	0.02	-0.02**	-0.04**	-0.03*
	[0.004]	[0.002]	[0.002]	[0.013]	[0.182]	[0.009]	[0.007]	[0.007]	[0.010]	[0.028]	[0.006]	[0.010]	[0.018]
Market Structure													
Share of other hospitals	0.47**	0.34**	0.63**	0.87**	3.29**	0.84**	0.55**	0.72**	0.49**	1.10**	0.52**	0.56**	0.64**
with technology in area	[0.027]	[0.023]	[0.041]	[0.048]	[1.485]	[0.249]	[0.029]	[0.035]	[0.048]	[0.237]	[0.047]	[0.133]	[0.080]
Demographics													
Log of family income	0.03	0.01	-0.04	-0.02	0.36	-0.38**	0.04	0.04	-0.11**	-0.11	-0.227**	-0.41	-0.34**
	[0.035]	[0.013]	[0.028]	[0.083]	[0.885]	[0.131]	[0.071]	[0.045]	[0.018]	[0.155]	[0.063]	[0.621]	[0.060]
Population	-1.6*10^-8**	-1.7*10^-8**	-2.3*10^-8**	-5.1*10^-8**	-6.7*10^-7	-1.5*10^-10	-9.1*10^-9**	-2.4*10^-8*	-1.9*10^-9	-1.0*10^-7**	-4.1*10^-8 **	-3.1*10^-8	-6.5*10^-8**
	[4.2*10^-9]	[2.3*10^-9]	[1.2*10^-9]	[7.6*10^-9]	[2.0*10^-7]	[7.8*106-9]	[4.5*10^-9]	[7.1*10^-9]	[8.6*10^-9]	[4.0*10^-8]	[6.2*10^-9]	[2.3*10^-9]	[-1.2*10^-8]
N	5374	5474	5418	3938	448	3678	4072	3917	3535	744	3955	2922	2750
Prob>chi2	0	0	0	0	0	0	0	0	0	0	0	0	0

+ Technology diffusing in the 90s

Robust standard error values appear in brackets below the regression coefficient

All regressions include demographic and market structure variables as well as 13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.

All regressions controlled for heteroskedasticity and autocorrelation.

* Statistically significantly different from zero at the 10 percent lev

** Statistically significantly different from zero at the 5 percent level

Table 6. Hazard Rate Model Regressions Including Cost-Reimbursement Ratio Variable

	Diagnostic Radiology Hazard	Radiation Therapy Hazard	Cardiac Hazard
Variables			
Insurance			
HMO enrollment	-1.62 **	-8.37 **	-5.99 **
	[0.116]	[0.574]	[0.783]
HMO enrollment * diff90	-0.98 **	-1.00 **	-0.43 **
	[0.227]	[0.299]	[0.130]
Cost-benefit ratio (ranking)	-0.03 **	-0.27 **	-0.02
	[0.011]	[0.088]	[0.015]
Medicare enrollment	-0.08 *	1.467 **	-0.34 **
	[0.050]	[0.150]	[0.151]
Medicaid enrollment	0.07 **	-0.07	-0.41 *
	[0.023]	[0.264]	[0.229]
Percentage uninsured	0.49 **	0.45	0.54
	[0.081]	[0.328]	[0.371]
Hospital Controls			
Not-for-profit	0.06 **	0.33 **	0.119**
	[0.012]	[0.024]	[0.029]
Government	-0.01	0.27 **	0.01 **
	[0.008]	[0.022]	[0.045]
Teaching	-0.02 **	-0.04 **	0.03
	[0.007]	[0.017]	[0.028]
Rural	-0.07 **	0.001	-0.51 **
	[0.005]	[0.020]	[0.152]
Regulation			
Rate regulation	-0.001	-0.04	-0.05
	[0.007]	[0.026]	[0.041]
CON	-0.01 **	-0.02 **	-0.13 **
	[0.002]	[0.007]	[0.020]
Market Structure			
Share of other hospitals	0.98 **	0.69 **	0.99 **
with technology in area	[0.016]	[0.075]	[0.088]
Demographics			
Log of family income	0.11 **	-0.11	0.10 **
	[0.014]	[0.137]	[0.022]
Population	-2.2*10^-8 **	-1.12*10^-8 **	-3.10*10^-8 **
	[2.23*10^-9]	[5.37*10^-9]	[7.16*10^-9]
N	18736	15945	7895
Prob>chi2	0	0	0

Robust standard error values appear in brackets below the regression coefficient
All regressions include demographic and market structure variables, 13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.
All regressions controlled for heteroskedasticity and autocorrelation.
* Statistically significantly different from zero at the 10 percent level
** Statistically significantly different from zero at the 5 percent level

Table 7. Effect of Managed Care on the Diffusion of Technologies

Technology	Change in adoption probability	Share of hospitals with technology in 1995	Estimated share of hospitals with technology in 1995*
Diagnostic radiology			
Diagnostic radioisotope	2.0%	60.6%	61.8%
Ultrasound	1.2%	84.6%	85.6%
CT-Scanner	2.4%	75.3%	77.1%
MRI	3.9%	37.2%	38.7%
PET	22.8%	2.8%	3.4%
Radiation Therapy **			
X-Ray therapy	5.3%	18.2%	19.2%
Radioactive implants	5.6%	23.4%	24.7%
Therapeutic radioisotope	4.2%	24.4%	25.4%
Megavoltage radiation	6.3%	19.0%	20.2%
Stereotactic radiosurgery	6.7%	7.0%	7.5%
Cardiac			
Cardiac Catheterization	3.8%	30.8%	32.0%
Open-heart surgery	2.3%	17.4%	17.8%
Angioplasty	5.1%	20.1%	21.1%

* The estimated share of hospitals with technology in 1995 assumes that HMO enrollment has been constant at its 1984 level.
** Given data availability, the information for all Radiation Theraphy tecnologies corresponds to year 1993 instead of year 1995.

Table 8. Logit Rate Model Regressions for Technologies Already at Their Steady State Level

	Diagnostic Radiology Procedures		Radiation Therapy Procedures		Cardiac Procedures	
	Diagnostic Radioisotope	Ultrasound	X-ray Therapy	Radioactive Implants	Cardiac Catheterization	Open-Heart Surgery
Variables						
Insurance						
HMO enrollment	0.01	-2.28 **	-0.90 **	-1.16 **	-0.50 **	-0.31 *
	[0.344]	[0.781]	[0.469]	[0.305]	[0.253]	[0.182]
Medicare enrollment	1.18	-1.68 **	2.97 **	4.07 **	0.39	-0.81
	[0.822]	[0.854]	[0.843]	[1.664]	[2.056]	[1.646]
Medicaid enrollment	0.01	-1.01	0.68	0.05	-1.73 **	-2.17 **
	[0.845]	[1.636]	[1.463]	[0.552]	[0.412]	[0.697]
Percentage uninsured	0.75	2.64 **	1.76 **	2.58 **	-6.59 **	1.01 **
	[0.856]	[1.097]	[0.593]	[0.831]	[0.509]	[0.119]
Hospital Controls						
Not-for-profit	0.33 **	0.11	0.36 **	0.39 **	-0.01	-0.03
	[0.040]	[0.182]	[0.113]	[0.176]	[0.077]	[0.193]
Government	-0.02	-0.06	0.37 **	0.27	-0.58 **	-0.69 **
	[0.071]	[0.124]	[0.128]	[0.198]	[0.077]	[0.203]
Teaching	0.13 *	-0.23	0.07	0.02	-0.38 **	0.04
	[0.0717]	[0.259]	[0.131]	[0.142]	[0.153]	[0.136]
Rural	-0.32 **	-0.18	0.37 **	-0.12	0.12	-1.03 **
	[0.013]	[0.209]	[0.159]	[0.180]	[0.487]	[0.290]
Regulation						
Rate regulation	-0.16 **	-0.65 *	-0.43 **	-0.46 **	-0.60 **	-0.89 **
	[0.077]	[0.348]	[0.119]	[0.063]	[0.109]	[0.039]
CON	0.03	-0.02	-0.05	-0.03 **	-0.11	-0.27 **
	[0.034]	[0.085]	[0.035]	[0.015]	[0.073]	[0.083]
Market Structure						
Share of other hospitals	0.77 **	0.34**	-0.58 **	-0.01	2.39 **	0.61 **
with technology in area	[0.146]	[0.023]	[0.165]	[0.149]	[0.249]	[0.296]
Demographics						
Log of family income	0.29	0.01	0.80 **	0.56 **	-1.23 **	-0.75 **
	[0.234]	[0.013]	[0.121]	[0.174]	[0.222]	[0.084]
Population	-1.1*10^-7**	-1.7*10^-8**	-6.1*10^-8	-5.8*10^-8*	-2.4*10^-8 **	-3.2*10^-7 **
	[2.8*10^-8]	[2.3*10^-9]	[4.1*10^-8]	[7.0*10^-8]	[5.1*10^-8]	[1.4*10^-8]
Prob>chi2	0	0	0	0	0	0

Robust standard error values appear in brackets below the regression coefficient
All regressions include demographic and market structure variables as well as 13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.
All regressions controlled for heteroskedasticity and autocorrelation.
* Statistically significantly different from zero at the 10 percent level
** Statistically significantly different from zero at the 5 percent level

Table 9. Effect of Managed Care on the Diffusion of Technologies Already at their Steady State Level

Technology	Hospital's Adoption Probability	Hospital's Adoption Probability (considering HMO enrollment at its 1984 level)	Change in Hospital's Adoption Probability
Diagnostic Radiology			
Diagnostic Radioisotope	80.93%	80.92%	-2.00%
Ultrasound	98.51%	98.78%	0.31%
Radiation Therapy**			
X-Ray Therapy	3.46%	3.77%	8.91%
Radioactive Implants	7.75%	8.60%	11.09%
Cardiac			
Cardiac Catheterization	9.91%	10.19%	2.81%
Open-Heart Surgery	22.10%	22.94%	3.92%

Appendix 1

Technology description

a. Diagnostic Radiology

The first set of technologies we analyze is Diagnostic Radiology procedures. These procedures refer to techniques used to diagnose abnormal conditions and cancer diseases.

The specific technologies we have included in this group are *diagnostic radioisotope, ultrasound, CT-scanner, MR*I and *PET*.

Diagnostic radioisotope uses radioisotopes to provide information about a person's anatomy and the functioning of specific organs. A radioisotope is an artificially created combination of neutrons and protons, which have very useful properties. First, radioactive emissions are easily detected. Second, they can be tracked until they disappear leaving no trace. These radioisotopes are detected by a gamma camera that can view organs from many different angles. Organ malfunction can be indicated if the isotope is either partially taken up in the organ or taken up in excess.

Diagnostic *ultrasound* is an established method of diagnostic medical imaging using a high frequency sound wave and the principle of sonar. Short bursts of sound are sent into the ultrasound transmission medium at regular intervals. Between bursts, sound echoes return from reflecting objects or interfaces. The reflected waves are received by an electronic device that determines both the position of the tissues giving rise to the echoes and the intensity of the echoes. The resulting images can be displayed in static form, or they can provide a moving picture of the inside of the body through the use of rapid multiple scans.

Ultrasound is a reliable, cost effective means of evaluating many internal organs, including the liver, pancreas, spleen, kidneys, aorta, gall bladder, ovaries, uterus, prostate, testicles and thyroid. As *ultrasound* causes no damage to human tissues, is non-invasive, involves neither radiation nor bleeding, and it is 5 to 10 times cheaper than *CT-scanner* and *MRI*; it is the most commonly used imaging technique for diagnosis treatment. However, *ultrasounds* have some limitations. First, *ultrasound* beams cannot penetrate bone or gas-filled cavities. Second, ultrasonographic images are much more difficult to interpret than those from CT or MRI.

CT-scanner is an X-ray imaging technique used to visualize thin slices of the body. The CT-scanner opening encircles your body during examination. This opening contains an x-ray tube and receptors that are mounted opposite each other. These rotate around your body. With each rotation, or scan, a portion of the total image is accumulated by the receptor. The receptor then feeds information into a computer which calculates the density of each area within the body, based on the energy absorbed as the scanner rotates, and converts it into a picture of a section of your body.

CT-scanning is simple, quick, accurate, and carries a modest exposure of radiation. *CT* provides cross-sectional images, which are ideal for radiation oncology treatment planning. *CT* images have already gained widespread utilization in various areas of radiation oncology, including (1) the delineation of the target volume, (2) the determination of the relative geometry of critical structures, (3) the optimal placement of beams and the shaping of apertures, (4) the calculation of dose distribution, and (5) follow-up evaluation of treatment outcome.

Appendix 1 (continued)

The *CT-scanner* has been particularly useful for planning treatments to the brain, head and neck, lung, pelvis, breast, and prostate and for treatment of sarcoma and gynecologic disease.

However, *CT-scanner* images also have limitations. First, although *CT* images show exquisite cross-sectional anatomy, in some cases they do not allow one to differentiate diseased from normal tissue. Furthermore, various artifacts due to beam hardening, bone-soft tissue interfaces, detector imbalances and algorithm peculiarities can have a significant impact on the accuracy of *CT* numbers.

MRI is a diagnostic technique used by physicians to visualize internal organs of the human body and obtain diagnostic information. *MRI* provides high quality cross-sectional images of organs and structures within the body without the use of x-rays or other radiation. *MRI* utilizes the physical properties of magnetic fields, radio waves, and computers to generate images of the body in any plane. During the imaging, the patient lies down surrounded by electromagnets and is exposed to short bursts of a powerful magnetic field that stimulate hydrogen atoms in the patient's tissues to emit the necessary signals.

Images from *MRI* are similar in many ways to those produced by *CT-scanning*, but *MRI* generally gives much greater contrast between normal and abnormal tissues. MRI offers the possibility of excellent discrimination of certain tumors with high contrast, the ability to select arbitrary planes for imaging, and very good resolution. *MRI* presents unique anatomical information and tumor detail. There are no known risks or side effects of *MRI. MRI* has been effectively utilized for the treatment planning of brain, pelvis and prostate disease.

One disadvantage of *MRI* is that the images may be distorted by variations in local magnetic fields caused by the presence of metal objects in the environment and within the patient. Other disadvantages include the high cost of the equipment and site preparation, the longer examination times (1.5 to 2.0 times more than those required for *CT*), a limited diameter of the patient tunnel opening in the magnet, and magnetic and radiofrequency shielding problems.

PET is a new technology, still in its very early stages of diffusion. It consists of the employment of radioisotopes to scan metabolic processes in the human brain. *PET* exploits the physical characteristics of radioisotopes that decay by positron emission, to supply localized physiologic information on the function of organs and the presence of tumors.

PET images do not provide the resolution of *CT* or *MRI* images. However, they do provide physiologic information that may be important for localizing certain diseases and for determining responses to radiation therapy. To localize the data from *PET* accurately relative to the patient anatomy, the *PET* images must be correlated with those from higher-resolution imaging methods such as *CT* or *MRI*. A major disadvantage of *PET* is the need for positron-emitting nuclides, most of which have extremely short half-lives.

Appendix 1 (continued)

b. Radiation Therapy

Radiation Therapy is a branch of medicine that is based on the use of radioactive substances to prevent metastases and to increase the probability of survival for patients with cancer. The technologies included in this group are *X-ray therapy, therapeutic radioisotope, radioactive implants, megavoltage radiation and stereotactic radiosurgery.*

X-ray Therapy consists of the use of x-ray radiation to treat diseased tissues or tumors. X-ray energies can be used in different intensities, but *X-ray therapy* usually uses low dosages of radiation (no more than 250 KV). This makes the technology appropriate for the treatment of superficial cancers like skin cancer or eyelid carcinomas. Given that irradiation of deep internal tissue increases the likelihood of conspicuous scarring, the main advantage of x-rays is that the target area receives a lower dose of radiation.

The *therapeutic radioisotope* technique consists of the use of radioisotopes to treat diseased organs or tumors. The therapeutic use of radioisotopes is based on the fact that rapidly dividing cells are particularly sensitive to damage by radiation. For this reason, some cancerous growths can be controlled or eliminated by irradiating the area containing the growth, using certain emitters of radiation. Different radioisotopes emit different kinds of radiation. The radioisotopes can be introduced into the target area through a catheter, or in some cases they can also be given by injection or orally. The main advantage of using this technique to treat cancer is that this procedure gives less overall radiation to the body as it is more localized to the target tumor. Different radioisotopes are indicated for different kinds of cancer. In general, radioisotopes are used for thyroid tumors, ovarian metastases, bone metastases and leukemia.

Radioactive implants, also called brachytherapy, use a small amount of radioactive material that is implanted inside the body, either directly into the tumor or into the body cavity adjacent to the cancer. Almost all the implants are temporary and can be classified in two categories: intracavity implants, which consist of positioning radioactive beams into a body cavity close to the tumor; and intra-operative implants in which the sources are placed into a surface applicator that is in direct contact with the tumor. *Radioactve implants* are used to treat tumors that are less than 5 or 6 centimeters in diameter and they are frequently employed in gynecological tumors, prostate cancers, or small brain tumors. The main advantage of brachytherapy is that it allows for the safe delivery of high doses of radiation to a localized target region while limiting the dose of the surrounding tissue.

Megavoltage radiation is a radiation oncology technique that consists of the delivery of high dosages of radiation into the tumor. Previously to *megavoltage radiation*, most treatment units were x-ray machines capable of producing only radiation with limited permeability. With megavoltage radiation, the radioactive beams can reach internal regions and allow for the treatment of tumors that could not be reached by x-ray radiation. In some cases, megavoltage radiation is combined with more aggressive cancer treatments like stereotactic radiosurgery or radioactive implants.

Stereotactic radiosurgery is an external radiation technique in which multiple beams of radiation are aimed at a target volume to deliver a single, high dose of radiation to a small volume of tissue. This target must have been previously identified using a precise imaging

Appendix 1 (continued)

technique (MRI or CT-Scanner). The two most frequently used types of devices for *radiosurgery* are the gamma knife and the linear accelerator. Radiosurgery differs from megavoltage radiation in two important aspects. First, it is indicated when small lesions are treated. Second, it uses a small, large dose of radiation. Radiosurgery is mainly used to treat malignant brain tumors and arteriovenous malformations and brain tumors.

c. Cardiac technologies

The last set of technologies that we analyze is cardiac technologies. The specific technologies included in this group are *cardiac catheterization, open-heart surgery* and *angioplasty*.

Cardiac catheterization is a diagnostic test in which a fine tube called a catheter is introduced into the heart, via a blood vessel, to investigate its condition. The technique is used to diagnose and assess the extent of congenital heart disease and valvular defects. The procedure allows physicians to measure blood pressure within the heart, withdraw blood to measure its oxygen content and take x-ray photographs of cavities of the heart.

If *catheterization* detects blockage, revascularization procedures may be used to eliminate it. We analyze two of the more widely used types of revascularization procedures: *open-heart surgery* and *angioplasty*.

Open-heart surgery is a major operation in which the heart beat is temporarily stopped and its function taken over by a mechanical pump. During the operation, the heart is kept cool through techniques of surgical hypothermia, which help prevent damage to the heart muscle from lack of oxygen. The surgeon can open the heart, repair defects and reconstruct the main chambers more efficiently. The main applications of *open-heart surgery* have been the correction of congenital heart defects, surgery for heart valve insufficiency or narrowed heart valves, and coronary artery bypass surgery.

Angioplasty is a technique for treating narrowing or occlusion of a blood vessel or heart valve by introducing a balloon into the constricted area to widen it. Angioplasty is used in the treatment of peripheral vascular disease to increase or restore the flow of blood through a significantly narrowed artery in a limb; it is also used in the treatment of stenosis of the coronary arteries.

Appendix 2

Table A. First Stage Regression for Diagnostic Radiology, Radiation Therapy and Cardiac Technologies

Dependent variable: HMO enrollment

	Diagnostic Radiology	Radiation Therapy	Cardiac
Variables	**OLS**	**OLS**	**OLS**
Instrumental Variable			
Average firm size	0.001 *	0.001 **	0.001 **
	[0.0005]	[0.00005]	[0.0004]
Insurance			
Medicare enrollment	-0.01	0.12 **	-0.01
	[0.066]	[0.038]	[0.084]
Medicaid enrollment	-0.05 *	-0.01	-0.09 **
	[0.031]	[0.028]	[0.035]
Percentage Uninsured	0.09 **	0.11 **	-0.06 **
	[0.037]	[0.040]	[0.033]
Hospital Controls			
Non-for-profit	0.001	0.001	0.003 *
	[0.007]	[0.002]	[0.002]
Government	-0.01 **	-0.01 **	-0.005 **
	[0.001]	[0.002]	[0.002]
Teaching	-0.002 **	-0.001	0.01 **
	[0.001]	[0.001]	[0.002]
Rural	-0.003 *	-0.01 **	0.002
	[0.002]	[0.003]	[0.006]
Regulation			
Rate regulation	-0.0003	-0.01 **	-0.01
	[0.008]	[0.005]	[0.009]
CON	-0.01 **	-0.01 **	-0.02 **
	[0.001]	[0.001]	[0.002]
Market Structure			
Percentage specialists	0.004	-0.005	-0.04
	[0.003]	[0.011]	[0.030]
Share of other hospitals	-0.01 **	-0.001	0.02 **
with technology in area	[0.004]	[0.008]	[0.010]
Demographics			
Log of family income	0.05 **	0.08 **	0.02
	[0.018]	[0.015]	[0.019]
Population	7.62 *10^-9	5.93 *10^-9	5.44 *10^-9
	[2.27 *10^-9]	[2.31 *10^-9]	[2.66 *10^-9]
N	5390	5390	5390
R-squared	0.6	0.67	0.6

Robust standard error values appear in brackets below the regression coefficient

All regressions include 13 year dummy variables, 9 region dummy variables,

8 dummy variables for bed size and 7 MSA size dummy variables.

All regressions controlled for heteroskedasticity and autocorrelation.

* Statistically significantly different from zero at the 10 percent level

** Statistically significantly different from zero at the 5 percent level

Table B. OLS Regressions

	Diagnostic Radiology Procedures					Radiation Therapy Procedures					Cardia
	Diagnostic Radioisotope	Ultrasound	CT-Scanner	MRI +	PET +	X-ray Therapy	Therapeutic Radioisotope	Radioactive Implants	Megavoltage Radiation	Stereotactic Radiosurgery +	Cardiac Catheterization
Variables											
Insurance											
Predicted HMO enrollment	-0.08**	-0.08**	-0.14**	-0.10**	-0.15*	-0.15**	-0.12**	-0.14**	-0.18**	-0.24**	-0.12**
	[0.020]	[0.015]	[0.030]	[0.052]	[0.093]	[0.041]	[0.060]	[0.056]	[0.038]	[0.121]	[0.041]
Medicare enrollment	0.12**	-0.10**	0.09	0.09	0.07	0.16	0.44**	0.41**	0.36**	0.86**	0.01
	[0.037]	[0.036]	[0.067]	[0.132]	[0.396]	[0.233]	[0.112]	[0.086]	[0.092]	[0.172]	[0.074]
Medicaid enrollment	0.12**	0.08	-0.12*	0.05	0.67*	-0.22**	0.08	-0.07	-0.21**	0.18	-0.16**
	[0.036]	[0.043]	[0.061]	[0.080]	[0.338]	[0.075]	[0.088]	[0.096]	[0.059]	[0.327]	[0.066]
Percentage Uninsured	0.21**	0.17**	0.35**	0.06	-0.56**	0.08	0.27**	0.47**	0.11	-0.03	-0.27*
	[0.065]	[0.065]	[0.055]	[0.074]	[0.254]	[0.165]	[0.080]	[0.092]	[0.156]	[0.054]	[0.137]
Hospital Controls											
Non-for-profit	0.02**	-0.02**	0.01*	0.02	0.001	0.08**	0.06**	0.06**	0.083**	0.06**	0.03**
	[0.005]	[0.005]	[0.003]	[0.014]	[0.040]	[0.016]	[0.008]	[0.008]	[0.007]	[0.022]	[0.010]
Government	-0.03**	-0.06**	-0.04**	0.001	0.08	0.05**	0.03**	0.02**	0.06**	0.07	-0.003
	[0.005]	[0.005]	[0.004]	[0.014]	[0.053]	[0.011]	[0.008]	[0.008]	[0.009]	[0.05]	[0.013]
Teaching	-0.001	0.001	-0.004	-0.03**	0.07	-0.02	-0.02*	-0.03**	-0.01	-0.01	-0.01*
	[0.005]	[0.005]	[0.007]	[0.013]	[0.068]	[0.014]	[0.010]	[0.009]	[0.008]	[0.038]	[0.009]
Rural	-0.04**	-0.03**	-0.04**	-0.06**	-0.001	0.01	-0.01	-0.01	-0.01	-0.12**	-0.03**
	[0.007]	[0.003]	[0.004]	[0.012]	[0.065]	[0.020]	[0.013]	[0.012]	[0.010]	[0.033]	[0.012]
Regulation											
Rate regulation	-0.02**	-0.02**	-0.03**	-0.05**	-0.13**	-0.01	-0.05**	-0.02*	-0.002	0.03*	-0.05**
	[0.004]	[0.003]	[0.004]	[0.015]	[0.045]	[0.012]	[0.008]	[0.013]	[0.008]	[0.018]	[0.008]
CON	0.001	0.01**	-0.001	-0.01**	0.01	-0.01**	-0.01**	-0.01**	-0.01**	-0.004	-0.01**
	[0.001]	[0.001]	[0.001]	[0.004]	[0.019]	[0.004]	[0.003]	[0.003]	[0.004]	[0.006]	[0.003]
Market Structure											
Percentage specialists	0.25**	0.38**	0.24**	0.05	0.34	0.28**	0.20**	0.44**	0.35**	0.38**	1.91**
	[0.031]	[0.032]	[0.050]	[0.091]	[0.231]	[0.040]	[0.033]	[0.053]	[0.063]	[0.145]	[0.113]
Share of other hospitals	0.29**	0.23**	0.39**	0.38**	0.38**	0.32**	0.24**	0.32**	0.20**	0.25**	0.26**
with technology in area	[0.013]	[0.017]	[0.016]	[0.013]	[0.186]	[0.089]	[0.013]	[0.016]	[0.016]	[0.049]	[0.018]
Demographics											
Log of family income	0.06**	0.04**	0.01	-0.01	-0.019	-0.13*	-0.005	-0.01	-0.07**	-0.02	-0.15**
	[0.011]	[0.009]	[0.016]	[0.036]	[0.070]	[0.073]	[0.031]	[0.34]	[0.033]	[0.104]	[0.027]
Population	-1.2*10^-8**	-1.2*10^-8**	-1.7*10^-8**	-2.0*10^-8**	-2.6*10^-8**	-3.6*10^-9	-4.7*10^-9**	-1*10^-8**	-5.3*10^-9*	-2.1*10^-8**	-2.0*10^-8**
	[3.2*10^-9]	[2.4*10^-9]	[1.1*10^-9]	[4.1*10^-9]	[8.3*10^-9]	[3.0*10^-9]	[2.3*10^-9]	[3.6*10^-9]	[3.3*10^-9]	[8.7*10^-9]	[2.8*10^-9]
N	38935	52202	38913	9625	480	9816	13134	12738	9615	835	15250
R-squared	0.34	0.21	0.37	0.32	0.25	0.36	0.37	0.38	0.35	0.35	0.51

+ Technology diffusing in the 90s

Robust standard error values appear in brackets below the regression coefficient

All regressions include 13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.

All regressions controlled for heteroskedasticity and autocorrelation.

* Statistically significantly different from zero at the 10 percent level

** Statistically significantly different from zero at the 5 percent level

Table C. Hazard Rate Model Regressions with IVs using Baker's definition of HMO penetration

	Diagnostic Radiology Procedures					Radiation Therapy Procedures					Cardiac I	
	Diagnostic Radioisotope	Ultrasound	CT-Scanner	MRI +	PET +	X-ray Therapy	Therapeutic Radioisotope	Radioactive Implants	Megavoltage Radiation	Stereotactic Radiosurgery +	Cardiac Catheterization	Open-Heart Surgery
Variables												
Insurance												
Predicted HMO enrollment	0.048	0.296**	-0.153 **	-3.132**	-20.274**	-6.408 **	-3.999 **	-4.156 **	-5.642 **	-14.646 **	-3.422**	-4.137**
	[0.077]	[0.090]	[0.027]	[0.518]	[6.495]	[1.105]	[0.654]	[0.319]	[0.771]	[3.259]	[0.457]	[0.709]
Medicare enrollment	-0.049	-0.206**	-0.107	-0.729**	2.839	-0.188	0.547 **	0.393 **	0.541 **	3.223 **	-1.090**	-1.172**
	[0.085]	[0.045]	[0.220]	[0.349]	[2.545]	[0.734]	[0.281]	[0.131]	[0.278]	[1.272]	[0.457]	[0.293]
Medicaid enrollment	-0.054	0.078**	-0.215 **	0.005	2.664	-1.115 **	-0.168	-0.327	-1.489 **	-3.175 *	-0.821**	-1.034**
	[0.169]	[0.025]	[0.063]	[0.159]	[2.804]	[0.277]	[0.460]	[0.273]	[0.265]	[1.876]	[0.346]	[0.217]
Percentage Uninsured	0.176	0.077	0.246	0.668**	-5.136	0.311	0.443	1.057 **	-0.123	-0.429	-0.48	0.949**
	[0.157]	[0.097]	[0.174]	[0.319]	[4.815]	[0.577]	[0.393]	[0.339]	[0.610]	[1.525]	[0.581]	[0.403]
Hospital Controls												
Non-for-profit	0.091**	0.040**	0.067**	0.132**	0.628	0.459 **	0.251 **	0.219 **	0.500 **	0.939 **	0.076**	0.138**
	[0.009]	[0.014]	[0.012]	[0.041]	[0.644]	[0.073]	[0.038]	[0.026]	[0.041]	[0.240]	[0.024]	[0.043]
Government	-0.003	-0.015	-0.012	0.080**	1.100*	0.376 **	0.184 **	0.111 **	0.464 **	1.132 **	0.02	0.084
	[0.007]	[0.010]	[0.008]	[0.045]	[0.687]	[0.054]	[0.029]	[0.032]	[0.057]	[0.347]	[0.028]	[0.054]
Teaching	-0.006	-0.014**	-0.007	-0.042	0.374	-0.008	-0.01	-0.007	0.014	0.056	-0.007	-0.001
	[0.007]	[0.006]	[0.010]	[0.029]	[0.550]	[0.021]	[0.023]	[0.013]	[0.019]	[0.155]	[0.020]	[0.019]
Rural	-0.076**	-0.028**	-0.044**	-0.283**	0.613	0.017	-0.118 *	-0.355 **	-0.125	-34.452 **	-0.406**	-0.954**
	[0.015]	[0.004]	[[0.014]	[0.055]	[1.414]	[0.053]	[0.067]	[0.115]	[0.126]	[1.139]	[0.143]	[0.465]
Regulation												
Rate regulation	-0.030**	-0.005	-0.046**	-0.015	-1.202	-0.049	-0.204 **	-0.017	0.028	0.812 **	-0.008	-0.187**
	[0.009]	[0.005]	[0.008]	[0.031]	[1.059]	[0.068]	[0.056]	[0.071]	[0.085]	[0.055]	[0.028]	[0.074]
CON	-0.011**	-0.016**	-0.003*	-0.037**	-0.114	-0.072 **	-0.038 **	-0.035 **	-0.051 **	-0.074 *	-0.023**	-0.048**
	[0.003]	[0.002]	[0.002]	[0.011]	[0.196]	[0.015]	[0.009]	[0.008]	[0.011]	[0.046]	[0.007]	[0.010]
Market Structure												
Percentage specialists	0.820**	0.0647**	0.740**	0.514	4.124	2.130 **	1.101 **	2.027 **	2.974 **	4.028 **	4.117**	5.510**
	[0.067]	[0.042]	[0.093]	[0.379]	[4.335]	[0.277]	[0.244]	[0.299]	[0.526]	[1.843]	[0.202]	[0.383]
Share of other hospitals with technology in area	0.464**	0.340**	0.621**	0.968**	3.596**	1.067 **	0.658 **	0.834 **	0.692 **	1.930 **	0.624**	0.731**
	[0.020]	[0.023]	[0.051]	[0.060]	[1.512]	[0.268]	[0.041]	[0.037]	[0.058]	[0.357]	[0.058]	[0.065]
Demographics												
Log of family income	0.028	0.001	-0.053*	0.024	0.754	-0.270 *	-0.006	-0.005	-0.206 **	-0.031	-0.301	-0.270**
	[0.058]	[0.018]	[0.027]	[0.079]	[0.592]	[0.164]	[0.192]	[0.084]	[0.011]	[0.319]	[0.255]	[0.066]
Population	-1.6*10^-8**	-1.2*10^-8**	-2.33*10^-8**	-6.5*10^-8**	-7.2*10^-7**	2.95*10^-9**	-1.34*10^-8**	-2.90*10^-8**	3.40*10^-9	-2.01*10^-7**	-4.3*10^-8**	-6.4*10^-8**
	[3.6*10^-9]	[2.1*10^-9]	[2.26*10^-9]	[6.6*10^-9]	[1.2*10^-7]	[8.74*10^-9]	[3.87*10^-9]	[4.73*10^-9]	[7.87*10^-9]	[8.39*10^-8]	[6.2*10^-9]	[7.2*10^-9]
N	4878	4968	4911	3570	412	3678	3520	3917	3535	744	3507	2541
Prob>chi2	0	0	0	0	0	0	0	0	0	0	0	0

+ Technology diffusing in the 90s

Robust standard error values appear in brackets below the regression coefficient

All regressions include 13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.

All regressions controlled for heteroskedasticity and autocorrelation.

* Statistically significantly different from zero at the 10 percent level

** Statistically significantly different from zero at the 5 percent level

Table D. Hazard Rate Model Regressions with IVs

	Diagnostic Radiology Procedures					Radiation Therapy Procedures					Cardiac Procedures		
	Diagnostic Radioisotope	Ultrasound	CT-Scanner	MRI +	PET +	X-ray Therapy	Therapeutic Radioisotope	Radioactive Implants	Megavoltage Radiation	Stereotactic Radiosurgery +	Cardiac Catheterization	Open-Heart Surgery	Angioplasty +
Variables													
Insurance													
Predicted HMO enrollment	-0.32**	0.06	-0.49*	-5.22**	-25.16**	-10.5**	-7.0**	-7.4**	-9.4**	-17.3**	-4.77**	-5.99**	-7.15**
	[0.075]	[0.088]	[0.303]	[0.600]	[9.951]	[1.428]	[0.699]	[0.343]	[0.748]	[2.340]	[0.640]	[1.712]	[1.082]
Medicare enrollment	-0.07	-0.27**	-0.13*	-0.12	8.20**	1.32**	1.47**	1.32**	1.76**	6.03**	-0.29**	-0.29	-0.57**
	[0.063]	[0.040]	[0.081]	[0.406]	[3.575]	[0.481]	[0.144]	[0.165]	[0.306]	[1.427]	[0.118]	[0.459]	[0.273]
Medicaid enrollment	-0.05	0.06**	-0.15*	0.52**	5.28*	-0.06	0.44	0.33	-0.67**	0.76	-0.23*	-0.47	-0.43**
	[0.119]	[0.022]	[0.082]	[0.153]	[3.045]	[0.254]	[0.311]	[0.232]	[0.254]	[1.013]	[0.136]	[0.546]	[0.194]
Percentage Uninsured	0.23**	0.06	0.38**	1.13**	-3.11	1.15**	1.01**	1.63**	0.60	2.84	0.08	1.50	0.70**
	[0.111]	[0.097]	[0.123]	[0.331]	[4.555]	[0.609]	[0.328]	[0.278]	[0.660]	[1.873]	[0.366]	[0.987]	[0.270]
Hospital Controls													
Non-for-profit	0.09**	0.04**	0.06**	0.12**	0.64	0.43**	0.24**	0.21**	0.48**	0.87**	0.08**	0.13**	-0.37
	[0.009]	[0.014]	[0.013]	[0.041]	[0.647]	[0.070]	[0.034]	[0.026]	[0.039]	[0.246]	[0.022]	[0.042]	[0.413]
Government	-0.01	-0.02*	-0.02*	0.07*	1.11*	0.35**	0.17**	0.10**	0.46**	1.07**	0.02	0.07	-0.12**
	[0.007]	[0.009]	[0.009]	[0.043]	[0.662]	[0.054]	[0.030]	[0.033]	[0.058]	[0.374]	[0.029]	[0.055]	[0.426]
Teaching	-0.003	0.02*	-0.02*	-0.04	0.29	-0.02	-0.01	-0.01	0.01	0.02	-0.01	-0.01	-0.02**
	[0.007]	[0.007]	[0.007]	[0.032]	[0.529]	[0.024]	[0.024]	[0.014]	[0.020]	[0.157]	[0.020]	[0.024]	[0.012]
Rural	-0.08**	-0.06**	-0.06**	-0.30**	0.62	-0.01	-0.13**	-0.37**	-0.14	-37.82**	-0.39**	-0.94**	-0.62
	[0.015]	[0.015]	[0.015]	[0.056]	[1.412]	[0.047]	[0.069]	[0.113]	[0.118]	[1.138]	[0.134]	[0.462]	[0.454]
Regulation													
Rate regulation	-0.03**	-0.003	-0.02**	-0.04	-1.41	-0.08	-0.22**	-0.04	0.02	0.76**	-0.02	-0.21**	0.10**
	[0.009]	[0.006]	[0.008]	[0.032]	[1.055]	[0.072]	[0.050]	[0.067]	[0.083]	[0.057]	[0.027]	[0.077]	[0.050]
CON	0.01**	0.02**	0.004	-0.08**	-0.06	-0.16**	-0.098**	-0.10**	-0.13**	-0.22**	-0.06**	-0.09**	-0.10**
	[0.003]	[0.002]	[0.004]	[0.014]	[0.165]	[0.024]	[0.011]	[0.008]	[0.015]	[0.051]	[0.007]	[0.018]	[0.021]
N	4878	4968	4911	3570	412	3678	3520	3917	3535	744	3507	2541	2531
Prob>chi2	0	0	0	0	0	0	0	0	0	0	0	0	0

+ Technology diffusing in the 90s

Robust standard error values appear in brackets below the regression coefficient

All regressions include market structure and demographic variables as well as13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.

All regressions controlled for heteroskedasticity and autocorrelation.

* Statistically significantly different from zero at the 10 percent level

** Statistically significantly different from zero at the 5 percent level

Table 2.E. Logit Rate Model Regressions with IVs for Technologies Already at Their Steady State Level

	Diagnostic Radiology Procedures		Radiation Therapy Procedures		Cardiac Procedures	
	Diagnostic Radioisotope	Ultrasound	X-ray Therapy	Radioactive Implants	Cardiac Catheterization	Open-Heart Surgery
Variables						
Insurance						
HMO enrollment	2.96**	-10.82**	-4.69**	-3.21**	-16.76**	-8.89**
	[1.125]	[1.506]	[2.063]	[0.872]	[3.601]	[1.530]
Medicare enrollment	0,26	-2.71**	2.72**	3.76**	-0,92	-0,84
	[0.776]	[1.284]	[0.775]	[1.722]	[1.475]	[1.922]
Medicaid enrollment	-0,41	-1,11	0,32	-0,31	-1,57	-1,79
	[1.003]	[2.062]	[1.469]	[0.457]	[1.129]	[1.302]
Percentage uninsured	0,49	2.96**	0,72	2.61**	-2.87*	4.29**
	[0.942]	[1.190]	[1.093]	[0.754]	[1.762]	[1.053]
Hospital Controls						
Not-for-profit	0.33**	0,04	0.31**	0.38**	-0,11	-0,11
	[0.040]	[0.175]	[0.116]	[0.174]	[0.112]	[0.191]
Government	0,04	-0.16*	0,22	0,21	-0.76**	-0.83**
	[0.069]	[0.092]	[0.146]	[0.184]	[0.036]	[0.218]
Teaching	0,13	-0,33	0,06	0,06	-0.18**	0,11
	[0.086]	[0.309]	[0.143]	[0.145]	[0.056]	[0.275]
Rural	-0,26	-0,22	0,26	-0,27	-0,19	-1.28**
	[0.180]	[0.219]	[0.176]	[0.189]	[0.634]	[0.218]
Regulation						
Rate regulation	0,07	-0.88**	-0.60**	-0.43**	-0,14	-0.58**
	[0.087]	[0.333]	[0.131]	[0.137]	[0.194]	[0.199]
CON	0.09**	-0.11*	-0.12**	-0,01	-0.32**	-0.41**
	[0.038]	[0.062]	[0.053]	[0.037]	[0.031]	[0.039]
Market Structure						
Share of other hospitals	0.79**	3.14**	-0,39	0,21	0.352**	1.18**
with technology in area	[0.198]	[0.284]	[0.294]	[0.231]	[0.394]	[0.318]
Demographics						
Log of family income	0,02	-0,01	0.85**	0.51**	-0,04	0,13
	[0.225]	[0.396]	[0.297]	[0.252]	[0.072]	[0.277]
Population	-6.4E-8**	-1.5E-7**	-5,00E-08	-4,70E-08	-2.5E-7**	-3.2E-7**
	[2.6E-8]	[3.4E-8]	[4E-8]	[7.3E-8]	[5.4E-8]	[3.0E-8]
Prob>chi2	0	0	0	0	0	0

Robust standard error values appear in brackets below the regression coefficient. All regressions controlled for heteroskedasticity and autocorrelation.

All regressions include 13 year dummy variables, 9 region dummy variables, 8 dummy variables for bed size and 7 MSA size dummy variables.

* Statistically significantly different from zero at the 10 percent level. ** Statistically significantly different from zero at the 5 percent level