The Diffusion of Telemedicine in the Southeastern United States: A Rural–Urban Perspective

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North Carolina Rural Health Research Program

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THE DIFFUSION OF TELEMEDICINE IN THE SOUTHEASTERN UNITED STATES: A RURAL–URBAN PERSPECTIVE

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Executive Summary

Aim: The objectives of this research were fourfold: 1) to identify characteristics of hospitals and their economic environment that are related to the adoption of telemedicine, 2) to utilize theory, quantitative and qualitative research to make reasonable and informed inferences about the types of benefits hospitals obtain and expect to derive from these technologies, 3) to relate these findings back to current rural health policy objectives and identify feasible and appropriate roles for government in the development of telemedicine, and 4) to evaluate interventions targeted specifically to rural areas.

By understanding patterns of diffusion and the implied and explicit benefits these technologies confer to rural and urban hospitals, it is possible to determine an appropriate role for government in the development of these technologies. Such an analysis is particularly relevant in light of the many federal and state initiatives to promote telemedicine and telecommunications infrastructure, in general.

Methods: All general hospitals in North Carolina, South Carolina, and Georgia were surveyed to explore 1) whether and when they had adopted telemedicine; 2) why they have adopted these technologies; and 3) from what sources the investment capital and operating expenses for telemedicine are financed. These data were combined with data from the American Hospital Association (AHA) *Guide to hospitals in the U.S.* and the 1995 Area Resource File (ARF) to construct a model of telemedicine diffusion.

In this economic diffusion model, the dependent variable was the probability of adopting telemedicine, which is a function of independent variables representing the hospital's market, hospital characteristics, and management characteristics.

Results: The results of the quantitative analyses revealed that each of the following factors: not-for-profit status, affiliation with a multi-hospital system, affiliation with an integrated delivery network, and characteristics of "urban-ness"—most prominently larger hospital size, independently increases the odds of adopting telemedicine. Qualitative data revealed that the adoption of telemedicine represents a form of non-price competition among hospitals, and thus is an important component of hospitals' competitive strategies. Moreover, as managed care and capitated pricing of health services become more prevalent, telemedicine could reduce costs within hospital networks by improving the decision making with regard to patient admission or transfer from a community hospital to an expensive tertiary care center.

Policy Implications: These results indicate a mis-match between telemedicine policies, which are driven by concerns about rural health, and the actual patterns of adoption of telemedicine among hospitals in the study region.

telemedicine \'tel-I-'med-ə-sən\ *n* : technologies that allow for medical consultation between health care providers in geographically separate locations, ranging from telephone consultations to interactive video sessions using state-of-the-art technologies.

I. INTRODUCTION

In 1968, Dr. Kenneth D. Bird solved a problem for Massachusetts General Hospital. The hospital had been responsible for staffing the medical station at Boston's Logan International Airport. While a physician's expertise was rarely required, emergencies demanded an immediate, highly skilled response. For the majority of the clinic's staffed time, therefore, the physician's time and labor were underutilized—a major cost to the hospital and the airport. Dr. Bird developed a system using remote transmission of voice and images that allowed doctors working at Massachusetts General to perform physical examinations remotely, make diagnoses, and even deliver limited treatments to ailing travelers who utilized the airport's medical station. (New York Times, Feb. 16, 1991).

Dr. Bird was not the first innovator of telemedicine, but his project was among a handful of initiatives in the 1960s and early 1970s that used microwave television technologies to transmit medical images and education. These new telemedicine technologies promised to change the delivery of and improve access to health care and medical education in rural areas. Individually, those pioneer telemedicine projects were very successful in achieving these visions. Yet, in its early applications telemedicine failed to diffuse widely or to change health care dramatically. Now, more than twenty-five years later, advances in medical and telecommunications technologies have transformed the original telemedicine innovations. Once again, telemedicine holds promise as a partial solution to the health care crisis in many urban centers and rural areas of the U.S.

Telemedicine, literally medicine across distance, has captured the attention of legislators as well as policy makers, scholars, and practitioners in the fields of health services, rural development, and telecommunications. Telemedicine is exciting because it combines two dynamic policy areas, health care and telecommunications, with emerging technologies to come up with imaginative solutions to previously intractable problems. These technologies potentially improve access to health care in under served areas, and by doing so enhance prospects for economic development. Such a combination would be difficult for even the most jaded policy maker to overlook. Indeed, several states, including North Carolina, have cited telemedicine as a partial justification for public investment in telecommunications infrastructure, or "the Information Superhighway." (Raleigh News and Observer, May 11, 1993).

The increase in the number of active telemedicine projects in the U.S. is evidence of this enthusiasm. In 1993, fewer than 30 active telemedicine programs existed nationally (Wyman, 1994). By 1996, there were over 40 telemedicine linkages in North Carolina alone. Despite this phenomenal growth rate and the high visibility of telemedicine in the popular press and in the national policy arena, uncertainty about acceptance and financing of these technologies creates doubt over whether telemedicine will become an important component of health care at the turn of the millennium and fulfill the promises and vision that these technologies inspire.

What is different about the context of the 1990s that would make telemedicine a more viable medical technology than it was in earlier decades? First, advances in telecommunications and medical technologies have increased the reliability, resolution, and speed of transmitting medical images between remote locations. Thus, telemedicine is simply more medically useful.

Second, these same advances in telecommunications technologies are part of, and have fostered, changes in the national and global economies, which the health care industry has not escaped. By diminishing geographical barriers to competition, telecommunications technologies have intensified competition in many industries, including health care. Telecommunications, in concert with information systems, has become one of the tools with which managed care corporations and hospital networks establish competitive advantage (Coopers and Lybrand, 1994; Neuberger, 1995), and on which smaller and rural hospitals increasingly depend for survival (Size, 1995). It is not difficult to imagine how telemedicine could become a component of these competitive strategies (Neuberger, 1995).

Finally, rural hospitals in particular suffered during the 1980s as a result of sweeping changes in payment systems, a declining patient base due to rural out-migration, and decreased inpatient utilization (Halpern, et al., 1992; OTA, 1990). As a result, the imperative to bolster rural hospitals both financially and medically has become increasingly important in the 1990s. State and federal policy makers, as well as some rural hospital administrators and larger hospital networks, see telemedicine as one way to increase rural access to health care, to augment the range of medical specialties available in rural areas, and to retain patients in rural hospitals safely.

The combination of dramatically improved medical efficacy, a changing health care marketplace, and a growing crisis in rural health care makes a compelling case for seriously considering the resurgence of telemedicine in the 1990s. Two central questions emerge: does telemedicine improve rural health care delivery, and does telemedicine play a role in the transformation of the economic organization of the health care industry? These questions, in turn, prompt multiple subsidiary questions, such as: what types of social and economic benefits does telemedicine offer? Who benefits from telemedicine technologies—hospitals, health care corporations, communities? How do we account for or measure these benefits? How are these benefits distributed, and do they balance the costs[1]? What is the appropriate level of government involvement in promoting telemedicine adoption and its continued use? Because it is so early in this new round of telemedicine diffusion, definitively answering these questions is like shooting at a moving target. Indeed, published information that would answer these questions exists in anecdotal form, at best, and consists largely of logical deductions. As one researcher aptly explains, "The problem with telemedicine is that there is very little good information about it." (Perednia, quoted in Scott, 1994).

In order to obtain the necessary information to address these issues a mail survey of all general hospitals in North Carolina, South Carolina, and Georgia was conducted. The survey explored six aspects of telemedicine: 1) whether and when hospitals had adopted telemedicine; 2) for what clinical and/or administrative purposes they use these technologies; 3) whether and for what business purposes they have adopted these technologies; 4) how much money they have invested in these technologies and from what sources these funds originate; 5) what they consider to be the barriers to adopting telemedicine; and 6) how much experience they have with other information technologies. These results were combined with data obtained from the American Hospital Association (AHA) *Guide to Hospitals in the U.S.* and the Area Resource File (ARF) to create a working data base. In addition, telephone interviews were conducted with hospital

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[1] The original aim of this research project was to ascertain the extent to which telemedicine affected hospitals' costs. In the course of the primary data collection, it became apparent for a variety of reasons, which will be addressed in section II, that the data do not yet exist that would allow us to determine whether and how telemedicine affects costs. As a result, it became necessary to refocus the research, taking a step backwards in the line of questioning about telemedicine, to ask simply who is adopting these technologies and why. By answering these questions, we can better understand what benefits hospital *expect* to derive from telemedicine, and we can also establish a basis for predicting how the eventually-quantifiable effects of telemedicine will be distributed.

administrators, telemedicine project directors and medical practitioners in this region to obtain a richer understanding of individual telemedicine projects, general attitudes toward and beliefs about telemedicine, and the relationship between managed care and telemedicine.

With this information, a model of the diffusion of telemedicine was constructed. The theoretical underpinnings of the model represent a synthesis of sociology, management, and economic theories. The modeling begins with an assumption that telemedicine adoption is a result of a combination of observable hospital and market characteristics. The functional relationship used in this research is presented below:

> Probability of adopting telemedicine = *f*(hospital location, teaching status, size, ownership, affiliations, technological sophistication, competition from other hospitals, HMO penetration, and local population and per capita incomes).

The probability of adopting telemedicine is a function of hospital and market characteristics. Establishing the relationships between these characteristics and adoption allows us to make inferences about the types of benefits telemedicine technologies offer and their strategic role in the hospital's mission.

This research represents a critical first step in understanding the many and complex policy questions that have emerged in this second round of telemedicine development. Using diffusion modeling techniques, it describes and explains hospitals' adoption of telemedicine technologies in three states in the Southeastern U.S. The diffusion model utilized in this research makes it possible to predict what types of hospitals will adopt telemedicine and to relate that information to the types of benefits telemedicine confers and to whom. By examining the economic and policy context in which telemedicine is diffusing in this region, along with the characteristics of the hospitals adopting telemedicine, this research provides the foundations for understanding the role of telemedicine in the changing health care market place. This research takes a snapshot of a dynamic process, providing feedback for current policy initiatives about the types of hospitals adopting telemedicine, their location, their experience with other information technologies, and their current status in the evolving market.

The findings from the analyses have important policy implications. While telemedicine holds great promise to help rural communities and hospitals improve the quality of health care available and the financial viability of rural hospitals, this research shows that rural areas are not realizing these benefits. Despite federal and state programs aimed at improving rural health through the use of telemedicine, rural hospitals are not adopting these technologies at the rate of their urban counterparts. At the same time, urban hospitals are finding ways to utilize telemedicine as a powerful marketing tool; they are also envisioning ways in which telemedicine will reduce hospital costs in a managed care environment by enhancing patient management and resource utilization. These findings suggest unrealized potential for public benefit from telemedicine, and uncover substantial private—or internalizable—benefits from these technologies as well.

These results suggest a mis-match between the objectives of federal and state policies and the adoption and use of telemedicine technologies by hospitals. By identifying this incongruity, this research will help policy makers target their efforts to encourage telemedicine where it is most needed, to take advantage of market forces, and to evaluate the efficacy and necessity of their current efforts.

This research provides some of the first empirical data about telemedicine, forming the building blocks for future research in the field. This work also represents the first exploration into the relationship between telemedicine and managed care.

The remainder of this report is organized as follows: section II provides background, section III describes the research framework, section IV summarizes the background data, section V analyzes the diffusion model, and section VI provides a summary of conclusions and policy implications.

II. BACKGROUND

In order to determine the economic feasibility and utility of telemedicine, and thus to determine the appropriate role for government as these technologies evolve and diffuse, it is first necessary to understand the theoretical benefits of telemedicine and, if possible, to measure those benefits. If telemedicine technologies create public-type benefits, the role for government is well-established. Public-type benefits occur when there are spill-over effects, which cannot be captured in an economic transaction, from the provision of a good or service. Common examples include police and fire protection and education (Mueller, 1989). The collective benefits produced by the provision of such services exceed the benefits any individual obtains from providing them or consuming them. Thus, in a free-market transaction, the price of providing these services would not fully capture their value and theoretically the market would therefore supply a less-than-optimal amount of these services; in this case, the role for government is clear.

On the other hand, private benefits exist when the value of providing or consuming a good or service can be captured largely in an economic transaction, or internalized between the parties to the transaction. Usually, this means that the benefits from the good or service are relatively concentrated, involving little spill-over. In this case, there is little justification for government involvement because the incentive to provide a good or service that creates private-type benefits is clearly defined.

This research aimed to uncover the relative size and distribution of the public and private benefits that telemedicine technologies provide to hospitals, and thus to evaluate current federal and state telemedicine initiatives.

There are several reasons to suggest that telemedicine creates the public type of benefits that justify government involvement in the financing and implementation of these technologies. Standard in the telemedicine literature are several examples of how telemedicine can help overcome disadvantages rural hospitals face, which can be attributed to market failures due to geography (Grigsby, et al., 1993; Puskin, 1992; Sanders and Tedesco, 1993; Randall, 1994). For example, telemedicine potentially reduces physician isolation by enabling rural practitioners to participate in distance medical education programs (Preston, Brown and Hartley, 1992). This overcomes two rural health problems: 1) the disincentive, caused by professional isolation, for physicians to settle in rural areas, and 2) the difficulty rural physicians face in keeping up with state-of-the-art practices. In addition, telemedicine potentially improves rural access to specialty care, which is limited by concentration of resources and specialty care in urban centers (Walker, 1992; Preston, Brown and Hartley, 1992; Grigsby et al., 1994). By allowing patients to stay in rural hospitals, rather than transporting them to specialty care in urban centers, telemedicine may reduce health care costs in two ways: 1) by eliminating transportation costs, and 2) by keeping patients in rural, and typically less expensive, hospitals. Moreover, by helping rural hospitals to retain patients, telemedicine may improve the financial viability of rural hospitals (Arthur D. Little, Inc., 1992).

The types of benefits listed above represent public-type benefits, and thus have provided justification for state and federal government involvement in the promotion of telemedicine and telecommunications infrastructure. In fact, improving rural health and the viability of rural hospitals through the use of telemedicine is the explicit goal of several state and federal telemedicine and telecommunications grant programs (Federal Register, 1994; Lipson and Henderson, 1994; Puskin, 1993). To the extent that telemedicine addresses market failures, such as the unequal distribution of physicians or the creation of externalities like improved community health, the basis for government involvement is well-established (Mueller, 1989).

Telemedicine is also well-suited, however, to improving hospitals' competitiveness—and thus generating private benefits, which do not justify government intervention. There are two ways in which telemedicine may produce internalizable benefits for hospitals using these technologies: 1) by generating cost savings, and 2) by increasing market share. As explained above, by allowing patients to stay in their community, telemedicine may reduce the cost of care. In a cost-based insurance environment, these savings may be—at least partially—passed through the health care system, and viewed as partial externalities. In a capitated pricing environment, where hospitals enter contracts with insurers for a flat rate, such savings are directly internalizable. As one administrator interviewed for this research aptly explained, " the name of the game in managed care is keeping the patient in the right place." Cave (1995) phrases this strategy more academically, stressing the imperative in a capitated pricing environment to match the needs and location of enrollees to physician supply. If telemedicine facilitates decision-making and resource utilization, and also augments expertise in rural areas without adding personnel, it can contribute to this type of efficiency (McCaughan, 1995).

In addition telemedicine can extend a hospital's market. Whether this is a public-good- or a private-good-type benefit is a matter of perspective. On the one hand, these technologies expand the range of specialties available in rural communities and thus potentially improve the quality of rural health care. On the other hand, telemedicine also potentially increases the number of services a hospital is able to offer and/or increases the geographic range over which a hospital offers its services, thus enhancing its competitiveness. In the case of a struggling rural hospital, improved competitiveness may translate to survival and thus to externalities (diffuse benefits) such as employment and improved health for the community; in the case of an already thriving hospital, increased competitiveness simply generates more profit (or reserves for not-for-profit institutions).

The issues of who benefits from telemedicine, and how these benefits manifest, are clearly complex. So far, the potential public benefits from improved rural health care have dominated discussions about telemedicine and justified government involvement at the state and federal levels. But little empirical evidence exists to support or refute this assumption.

Empirical documentation of telemedicine benefits

One of the original objectives of this research project was to collect data on hospital investments in telemedicine technologies and analyze how these technologies affected hospitals' operating costs. The goal was to identify one type of benefit derived from telemedicine adoption: internalizable financial benefits. During the course of the data collection and research for this project, this goal was modified to examine the patterns and reasons for the diffusion of telemedicine technologies. Two factors prompted this decision.

Early stages of adoption: First, the survey revealed that telemedicine is in the *very early* stages of adoption. Of the 63 adopters of telemedicine in our sample, 27 (43%) reported the year of adoption. Of those hospitals, one (3.7%) reported the earliest year of adoption of any type of telemedicine technologies as 1993; 6 (22%) reported 1994 as the earliest year of adopting any type of telemedicine; 19 (70.4%) reported earliest telemedicine adoption in 1995, and 1 (3.7%) reported anticipated adoption in 1996. Telephone interviews with telemedicine adopters in North Carolina helped to fill in information that the survey did not capture. These interviews confirmed what the survey had suggested: the vast majority of hospitals who have adopted telemedicine have done so in late 1994 or during 1995. In fact, *only one* of the over 35 hospitals in North Carolina with telemedicine that were contacted or identified in the phone interviews had adopted telemedicine before 1994.

Recent adoption creates two major difficulties for determining the impact of these technologies on hospitals' operating costs. One is logistical: the survey asked for financial information as recent as fiscal year 1994 because at the time of the survey hospitals were in the middle of fiscal year 1995. With the majority of hospitals implementing telemedicine in 1995, it would be impossible to calculate the financial impact of telemedicine for more than the handful of hospitals who reported adoption in 1993 or 1994. In fact, many hospitals were unable to report financial information for telemedicine investments. Of the 63 survey respondents who reported adopting telemedicine, 25 (39%) reported information about their financial investments in telemedicine over the past 5 years[2]. Valid statistical techniques require more than 25 observations

[2]Interestingly, 6 of the reported non-adopters supplied financial information for telemedicine investments. Phone interviews with the hospital administrators revealed that 4 of these 6 hospitals had not, in fact, adopted any

for even the simplest models; therefore, the data were insufficient to make calculations of the aggregate cost effects of telemedicine. Secondly, it is well known that in the very early stages of technology adoption it is difficult, if not impossible, to determine the long run or equilibrium impact of an innovation on an organization's costs (Porter, 1980). Thus, even for those few early adopters, the financial information could not be considered reflective of true costs of operating telemedicine programs.

Complex financial arrangements: The second and most interesting reason why the cost model was abandoned is the complexity of the network and financing arrangements hospitals use to purchase and deploy these technologies. Because most telemedicine consultations are not currently reimbursed through the standard insurance channels, hospitals have little financial documentation of the costs and revenues generated by the purchase and use of these technologies. As a result, telemedicine projects are typically operated on an experimental basis, often funded largely with grant monies, and frequently treated like research and development activities.

The inter-organizational linkages that telemedicine activities require complicate the financial accounting. Most of the telemedicine networks in the study region are arranged in hub-and-spoke configurations. In many cases, the control of a telemedicine network is centralized at the hub and the remote sites are unaware of the financial details of telemedicine projects. Thus, even when financial benefits may exist for the outlying hospitals, they may not yet have integrated telemedicine into their operations extensively enough to maintain financial records because the project has been driven and financed in its early stages by the hub hospital.

In addition, separate financial entities are often intermingled and new ones created to administer the multiple relationships entailed in a telemedicine network. Financial arrangements between medical schools, hospital corporations, and physicians' practices are common components of telemedicine projects. Thus, the costs and the benefits of these technologies do not accrue to a single financial entity, even when the programs are initiated under the auspices of a single hospital. Such complexities make the accounting of cost and benefits at a macro-economic, or cross-sectional, level very difficult. Below, an examination of the financial and network arrangements of several North Carolina telemedicine projects illustrates this problem.

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form of telemedicine and therefore the entries were mistakes. The other two non-adopters each had recently purchased telemedicine equipment but had not yet begun transmissions.

Models of telemedicine financing: The first example represents a centralized model of telemedicine planning and financing. Although one entity has planned and implemented a network of telemedicine, the financial arrangements are complex: Six hospitals, a clinic, and a prison are all linked by telemedicine to East Carolina University (ECU) Medical School in Greenville, North Carolina. This is one of the largest systems in the state, and is among the pioneer telemedicine programs in the U.S. (Wyman, 1994). ECU Medical School uses Pitt County Memorial Hospital as its hospital, but the university is an independent financial entity. The Medical School has obtained federal grant monies to develop and operate the telemedicine project; the project employs medical school staff. These activities all occur at Pitt County Memorial Hospital, but are not part of the financial records of the hospital, since they are administered by the medical school. Therefore, it is impossible to determine on initial inspection whether telemedicine has made an impact on the hospital's operating costs. Further complicating the scenario, the smaller hospitals connected to ECU have no record of the capital costs of implementing telemedicine because ECU has administered the grant monies which have purchased the telemedicine equipment and financed the operating costs of the project[3]. Again, it is impossible to determine whether telemedicine has affected these hospitals' costs.

The University of North Carolina at Chapel Hill provides another example of the complexity of the financial arrangements within a telemedicine network. Unlike the ECU model, the UNC telemedicine network is not a centralized, coordinated effort. Similar to ECU, the UNC Hospitals are separate financial entities from the UNC School of Medicine, but share many resources and costs with the medical school. Between the Hospitals and the medical school, there are five active telemedicine linkages, four with other hospitals, and one with a pathology laboratory in Western North Carolina. Each of these projects is administered by a different department within the Hospitals and medical school. For example, the hospital operates a linkage with the emergency room at Wake Medical Center in Raleigh, North Carolina; although UNC Memorial Hospital has purchased the equipment, and supports the operating costs of this linkage, the purpose of this project is resident training—a function of the medical school[4]. On the other hand, the department of pathology in the medical school maintains a telemedicine connection with

[3] Personal communication, C. Coker, Chowan Hospital 11/8/95.

[4] Personal communication, 11/8-12/95. Dr. Henry Hsiao, Professor of Biomedical Engineering, UNC-CH.

a pathology laboratory in Asheville, NC. The pathology specimens of *Memorial Hospital* patients may be transmitted over this *medical school* linkage to the private clinic in Asheville. Each of the UNC telemedicine projects is administered independently by various programs or departments within the medical school. None of the programs is coordinated with other telemedicine projects at UNC-CH. Members of different projects are often unaware of the existence of or details about the other UNC telemedicine programs. According to one program manager, "there is no one at UNC who knows about all the telemedicine activities."[5] Each telemedicine project at UNC-CH is funded by separate grant monies, which are distributed through the individual programs or departments to the remote sites. As with the ECU projects, the remote sites are largely unaware of the capital costs of the technology, although many share in the operating costs.

The North Carolina Baptist Hospital and Wake Forest University's Bowman-Gray School of Medicine provide yet another model of telemedicine implementation and accounting. Although this telemedicine program demonstrates the most developed system of cost accounting, the intricate financial arrangements involved with this network make the assignment of costs or savings very difficult. Interestingly, only one of the eight telemedicine projects at Bowman-Gray is financed with grant money. The remaining seven linkages are financially self-sustaining. Similar to the telemedicine programs at ECU and UNC, each of the telemedicine projects at North Carolina Baptist Hospital is affiliated with the Bowman-Gray Medical School. Unique to Bowman-Gray is that the telemedicine projects are actually part of a separate corporate entity, Wake Forest University Physicians, an organization consisting of physicians from each of the clinical departments of the medical school. Through this organization, departments within the medical school submit a business plan for a proposed telemedicine project to the medical school. If the department can demonstrate that its telemedicine project would be financially viable, then the medical school will purchase the necessary equipment, and the department, through Wake Forest University Physicians, will support the telemedicine project's operating expenses.[6] Since the hospital, the medical school, and Wake Forest University Physicians are financially

[5] Ibid.

[6] Personal communication 11/17/95 with Ed Rouliski, Technical Director for Bowman-Gray School of Medicine.

independent entities, it is impossible to link telemedicine investments to the hospital's operating costs.

These three university-based examples of telemedicine linkages account for over half of the telemedicine activity in the state of North Carolina. The above examples illustrate a broad range of coordination and accountability between the remote sites and the various departments within hospitals or medical schools. The lack of standardization across programs, or even of coordination within programs, is confusing and makes financial accounting of telemedicine all but impossible. However, this situation is reflective more of the early stage of the development and diffusion of telemedicine technologies than of the success or failure of particular arrangements for managing telemedicine. Telemedicine is simply not well enough integrated into the operation of hospitals or the delivery of health care to determine how it affects the costs of delivering health care.

In light of the newness of telemedicine technologies and the complexities of the financial arrangements, it is most reasonable first to examine how these technologies are diffusing, and what are the implications of these patterns. From this information it is possible to infer what types of social and economic benefits telemedicine offers, who derives benefits from these technologies, and how these benefits are distributed. This will allow a comparison of policy goals to early outcomes. The next step is then to determine how these benefits compare to the costs of telemedicine, and whether government is playing an appropriate role in the development of these technologies. Thus, the diffusion model, described below, represents a critical first step in understanding complex policy questions.

III. RESEARCH FRAMEWORK

Very simply stated, economic theory holds that firms—in this case, hospitals—will adopt a technology if the benefits exceed the costs: if it is profitable to adopt the technology. Absent market imperfections, such as differential access to information or capital, this theory predicts that, in general, larger, urban organizations will be more likely to profit from and thus to adopt an innovation. Other factors such as competitiveness of the local market, ownership structure, and other hospital characteristics have been found to be important, but the direction of their influence on adoption is uncertain. These factors are of particular interest, however, in the context of this research because of their importance in determining the appropriate role for government in the financing and diffusion of telemedicine.

Often direct measures of profitability are unavailable, and thus characteristics of the innovation or the firm are used as proxies, or alternative measures of potential profitability. This situation is certainly the case for telemedicine; in many cases, hospitals themselves do not yet know whether these technologies will be profitable.

Modeling the problem

This research models the adoption of telemedicine as a function of twelve independent variables:

Adoption = *f* (distance to the next closest hospital, HMO penetration in the hospital's market, size of market [population], per capita income in the market, hospital location, teaching status, hospital size, ownership structure, three types of affiliations with other hospitals, and experience with similar technologies).

This section presents the development of the above model. A synthesis of economic, sociology, and management theories provides the theoretical framework for this model of technology adoption. The value of this synthesis derives from the fact that health care in the U.S. is a quasi-economic industry with market and non-market characteristics and incentives. For example, some hospitals are investor-owned businesses, and as such are considered for-profit institutions. Consequently they can be assumed to conform to the profit-maximization assumptions of an economic diffusion model. Other hospitals are not-for-profit institutions, with community service mandates that may be as important as profit-motives.

Additionally, sociology and management theories of diffusion do a better job of accounting for access to and communication of information about an innovation within firms, or hospitals, than do economic diffusion theories. Although access to information is an important concept in general theories of economics, these ideas frequently are ignored by economic theories of diffusion. Therefore, the inclusion of these non-economic variables not only accounts for the complexity of the health care market, it is also quite consistent with general economic theory.

Finally, the model building component of this research also reflects the fact that many of the other variables included in economic models of diffusion are also included in sociological diffusion models. Many of these variables have no economic interpretation, *per se*, but improve the explanatory power of the models. Because they figure prominently in both theory bases, and because they can explain the behavior of hospitals, they are included in the framework used in this research. Below, the categories of variables included in the model are described and rationalized.

Identifying the dependent variable

Whether or not a hospital has adopted telemedicine by the end of fiscal year 1995 is represented as a binary dependent variable: its value is zero if the hospital had not adopted telemedicine at the time of the survey, and one if it had adopted.

Identifying independent variables

As explained above, economic diffusion theory can be summarized neatly: firms will adopt a technology if they expect it to be profitable to do so. This simplicity quickly becomes complex when we try to understand what factors influence these expectations, and hence predict adoption. Although economists differ widely in the particular variables with which they choose to explain diffusion, economic theory suggests three broad categories of relevant variables:

1. Real or expected returns on innovation-investments
2. Market characteristics
3. Firm characteristics

The first category is a direct measure of firms' (or hospitals') actual or expected returns from investments in an innovation; the second two categories are more indirect measures of, or contributing factors to, an innovation's profitability.

Because it is so early in the diffusion of telemedicine technologies, financial data about telemedicine are virtually nonexistent.[7] Moreover, because insurers do not yet reimburse for most telemedical consultations, the anticipated revenue stream from these technologies is not a predictable variable that would improve the model's explanatory powers. Therefore, this research project focuses on modeling the effects of *market* and *firm* characteristics on the adoption of telemedicine. To these categories, this research adds an additional category of explanatory variables drawn from sociological or communications theory, and denotes them as *behavioral* variables. Specifically, this research includes two types of variables measuring sociological concepts: 1) a variable that measure hospitals' experience with or exposure to other

[7] As described in footnote 1, the original objective of this study was to collect financial information about telemedicine. It became clear that these data were impossible to obtain, given the time and personnel resources of this study and the lack of information possessed by the hospitals themselves.

telecommunications and information technologies which are akin to telemedicine, and 2) three variables that account for associations with other hospitals. While these behavioral variables logically could be included among hospital characteristics as one of the economic typologies, they are separated here because the sociology theory base provides a more robust and well-developed framework for understanding their role in organizations' decisions to adopt innovations.

Thus, the model employed in this research project uses three categories of variables to explain hospitals' adoption of telemedicine technologies:

adoption of telemedicine = *f* (market characteristics, hospital characteristics, behavioral characteristics).

Table 1 provides a summary of the variables included in the diffusion model, their sources, and their hypothesized effect on adoption:

Table 1
Diffusion Model Variables for Telemedicine

Variable	Concept/type of variable	Source/ hypothesized effect
Dependent Variable Q1ANEW	*(categorical)* Coded as 1 if hospital adopted Telemedicine; 0 if not.	Survey
Market Characteristics		
Competition from other hospitals NEAREST	*(continuous)* Distance to next closest hospital; a measure of competition from other hospitals.	Area Resource File (ARF) data Hypothesized effect: (?)
Managed care penetration HMOPEN	*(continuous)* Percentage of population in MSA or county enrolled in an HMO.	ARF data Hypothesized effect: (+)
Size of patient base POPULAT	*(continuous)* Population of the MSA or county (in 1000s)	ARF data Hypothesized effect: (+)
Potential ability to pay for services INCOME	*(continuous)* Per capita income of MSA or county (in 100s).	ARF data Hypothesized effect: (+)
Hospital Characteristics		
Location RURAL	*(categorical)* Variable coded as 1 if hospital located in non-MSA; 0 otherwise.	ARF data Hypothesized effect: (-)
Teaching status TEACH	*(categorical)* Variable coded as 1 if hospital is a member of the Council of Teaching Hospitals (COTH).	AHA Guide Hypothesized effect: (+)
Size SIZE	*(categorical)* Number of licensed beds.	AHA Guide Hypothesized effect: (+)

<u>Ownership status</u> NOTPROFT	*(categorical)* Variable coded as 1 if hospital is owned by state, county, city, city-county, hospital district or authority, church or other non-governmental not-for-profit organization, or the federal government; coded as 0 if the hospital is investor owned.	AHA Guide Hypothesized effect: (?)
Behavioral Characteristics		
<u>Affiliations</u> AFFILMHS	*(categorical)* Variable coded as 1 if hospital is a member of a multi-hospital system; 0 otherwise.	Survey Hypothesized effect: (+)
<u>Affiliations</u> AFFILGPA	*(categorical)* Variable coded as 1 if hospital is a member of a group purchasing alliance; 0 otherwise.	Survey Hypothesized effect: (+)
<u>Affiliations</u> AFFILIDN	*(categorical)* Variable coded as 1 if hospital is a member of an integrated delivery network; 0 otherwise.	Survey Hypothesized effect: (+)
<u>Technological sophistication</u> TECHINDX	*(categorical)* Additive index of technological sophistication, ranging from 0 to 9.	Survey Hypothesized effect: (+)

Specification of the functional form

The adoption of telemedicine is modeled as a logit in matrix notation:

$$L = \ln (P/1\text{-}P) = \alpha + \sum \beta_r X_r$$

where L is the log of the odds ratio of adopting telemedicine; P is the probability that a hospital adopts telemedicine. The X_r are the independent variables—or market, hospital, and behavioral characteristics—that influence the probability of the hospital adopting telemedicine. Thus, the β_r measure the change in the log-odds of adopting telemedicine as the X_r change by a unit; and the intercept, α, is the log-odds of adopting telemedicine if the independent variables are all zero.

Thus, the model employed in this research project can be written as follows:

$$L_i = \ln (Q1ANEW_i/1\text{-}Q1ANEW_i) = \alpha + \beta_1 NEAREST_i + \beta_2 HMOPEN_i + \beta_3 POPULAT + \beta_4 INCOME_i + \beta_5 RURAL_i + \beta_6 TEACH_i + \beta_7 BEDS_i + \beta_8 NOTPROFT_i + \beta_9 AFFILMHS_i + \beta_{10} AFFILGPA_i + \beta_{11} AFFILIDN_i + \beta_{12} TECHINDX_i$$

IV. BACKGROUND AND DATA ANALYSES

This section reports information about the survey population, the respondents, and telemedicine adopters. It also provides analyses of the variables of interest that were not included in the diffusion model, as well as qualitative analyses of these concepts. The qualitative and quantitative analyses of contextual information that was not part of the diffusion modeling provide important insights about hospitals' reasons for adopting telemedicine, and their expectations about the future of telemedicine. This component of the research uncovered strategic business applications of telemedicine, including marketing and projected cost reductions under managed care. It also substantiated an oft-cited barrier to the diffusion of telemedicine: lack of insurance reimbursement and the related issue of the large expenses involved in adopting telemedicine. This information does not stand alone, but provides a context for the multi-variate analyses.

Table 2 provides summary statistics from the survey about the survey population, the respondents, and telemedicine adopters.

Table 2 Population, response, adoption, and rural-ness

Group	Total N	Rural (non-MSA)	Urban (MSA)	χ^2 (prob) {Fisher's exact Test: 2-tail}
Population	349	186 (53%)	163 (47%)	N/A
Respondents	166 (48% of population)	100 (60% of respondents)	66 (40% of respondents)	$X^2 = 6.13$ (P= 0.013) {0.014}
Telemedicine Adopters	66 (40% of respondents)	32 (48% of adopters)	34 (52% of adopters)	$X^2 = 6.32$ (P= 0.012) {0.015}

The 349 hospitals in the study population are approximately evenly divided between rural (53%) and urban (47%) locations, with slightly more rural hospitals in the region. A total of 166 or 48% of the hospitals in the population responded to the survey. The responses were biased toward rural hospitals. In other words, proportionally more rural hospitals responded to the survey than are represented in the population. This bias is statistically significant, as indicated by the low probability[8] (0.013) of a chi-square score of 6.13. This fact creates an imperative to weight the model appropriately to compensate for the fact that the respondents do not accurately represent the population for this characteristic.

Of the respondents, 66 (40%) reported adopting telemedicine. Of the telemedicine adopters, 32 (48%) were rural hospitals and 34 (52%) were urban hospitals. Given that urban hospitals are statistically under-represented among respondents, they are over-represented among telemedicine adopters. This urban bias in telemedicine adoption is statistically significant (χ^2 = 6.32; p = 0.012).

Hospital strategy and the role of telemedicine

Table 3 describes telemedicine adopters' responses to questions about the role of telemedicine in their hospital's strategic, or competitive, plans. These questions asked the hospitals to rank on a Likert scale, ranging from 1 (not at all important) to 5 (very important), how important they consider the adoption of telemedicine relative to their competitive strategies.

Table 3 Strategic importance of telemedicine

Importance of telemedicine to:	highly important
Providing quality health care in the local market	72%
Technological leadership in the local market	69%
Managed care strategy	63%
Price competitiveness in the local market	25%

[8] As explained in Hatcher and Stepanski (1994), "when analyzing a 2x2 classification table, it is best to use *Fisher's exact test* rather than the standard chi-square test of independence" (p. 169). When the p value for the Fisher's exact test is less than a designated level of significance, the null hypothesis that there is no difference between the two groups may be rejected. Because the interpretation of this test is analogous to the Chi-square test and because this test did not differ from the results of the Chi-square test in any of the analyses herein, the probability of the Fisher's exact test is reported below the Chi-square analyses throughout this paper.

To be considered highly important, the hospitals had to rank telemedicine as a 4 or 5 on the Likert-scaled questions. Thus, 63% (38 hospitals) of adopters reported that the adoption of telemedicine was highly important to their managed care strategy. Of the 51 adopters (81%) who stated that they face competition in their local market, 13 (25%) ranked the adoption of telemedicine as highly important to their price competitiveness in the local market; 35 (69%) stated that the adoption of telemedicine was highly important to the hospital's role as a technological leader in the local market; and 37 (72%) maintained that telemedicine adoption was highly important to providing quality health care in the local market.

These results are interesting because they reflect the self-reported importance of telemedicine adoption to various competitive strategies. As such, it is important to keep in mind that the range of socially-appropriate responses may have been narrower than the actual range of the Likert scale. For example, it is unlikely that administrators would answer that telemedicine is less than highly important to delivering quality health care in the local market. Therefore, caution in interpreting these results is warranted. Nonetheless, the responses reflect strategic perspectives about telemedicine that heretofore have not been explored. The fact that 69% of the adopters in competitive markets indicated that telemedicine adoption was highly important to their role as technological leaders in the local market place demonstrates an important marketing function that telemedicine may perform. Similarly, the fact that so few hospitals (25%) in this group indicated that telemedicine was highly important to their price competitiveness in the local market suggests the possibility that most administrators do not expect telemedicine to reduce costs sufficiently to reduce prices correspondingly, or that they have not thoroughly calculated the potential price and cost impacts of telemedicine. Either way, these results show that the financial impact of telemedicine is overshadowed by the potential marketing effect.

Interviews with hospital administrators, subsequent to the survey, helped to flesh out the reasons administrators identified for adopting telemedicine. Four were prominent among the administrators interviewed. The most commonly cited reason was marketing, followed by improving care in remote locations, extending medical education, and reducing the cost of care. Without prompting from the interviewer, administrators never independently identified a role of telemedicine in a managed care strategy. Their thoughts about this subject were nonetheless very interesting, and are described below.

Marketing: When confronted with the question of why did their hospital adopt telemedicine, administrators invariably related telemedicine to some aspect of marketing. One Chief Financial Officer summed up the hospital's decision to adopt telemedicine in one word: "positioning." Another administrator of a rural hospital said that telemedicine was driven by patients' requests: "patients expect hi-tech assistance. It makes them feel special. The physicians feel that it's a gimmick." He went on to explain that telemedicine did not change how physicians at his hospital practice medicine, rather it made his hospital competitive because patients demanded state-of-the-art technologies. In the words of another administrator, "we see everybody else turning to telemedicine, and we know we need to keep up."

One hospital administrator likened telemedicine to clinical consultation services, where physicians in remote areas dial a toll-free number to receive consultations from a tertiary care center; the tertiary care center offers this service in an effort to establish relationships and referral patterns between the physicians and the hospital. This administrator saw telemedicine as an extension of this idea.

Quality of care: After marketing, the ability to improve access to health care in rural areas was the next most frequently specified reason for adopting telemedicine. One administrator of a tertiary care hospital indicated that the impetus to adopt telemedicine came from the rural hospitals affiliated with this larger hospital; the rural hospitals seemed convinced that telemedicine could bring higher quality care to their communities. This administrator characterized the arrangement as win-win, since the rural areas received improved care, and the urban hospital gained or solidified referral patterns. The telemedicine director at another tertiary care center echoed this story: rural hospitals affiliated with the tertiary care center were seeking assistance at a time when the larger hospital was examining its strategic planning for the next 5 years; telemedicine fit the objectives of all parties involved.

Other rural hospitals indicated that they had adopted teleradiology out of necessity: few or no radiologists practiced in their communities. In order to gain access to radiologic services, they adopted telemedicine. In several cases, radiologists in other communities shared the cost of the system. Radiology was the only specialty mentioned in the context of the medical necessity of adopting telemedicine.

Medical education: One hospital administrator among those interviewed stated that medical education was of primary importance in his hospital's adoption of telemedicine.

Interactive video connections with a medical school over 100 miles away allowed this rural hospital with only 42 beds to offer a residency program for rural primary care physicians. For a hospital this size to run a residency program is unprecedented.

Several administrators explained that, while not the primary reason, medical education served as a supporting rationale for adopting telemedicine. There are two ways that telemedicine can play this role. The most obvious is the analogy between telemedicine and distance learning. Hospitals can subscribe to, or offer, continuing medical education using teleconferencing technologies. One physician, who had used telemedicine, described a more subtle form of medical education: the remote physician learns from the specialist in the urban center when a consultation occurs; the next time the rural doctor encounters a similar case, she or he will better know how to treat it before engaging in a telemedical consultation. One administrator explained how he expected this transfer of skills to also reduce the cost of care, as physicians share "best practice" guidelines using telemedicine.

Managed care: Few hospitals among those surveyed and interviewed in the Southeast identified an explicit strategic role for telemedicine in their long range plans to adapt to managed care. One hospital indicated plans to supply telemedicine consultations on a contract basis, whereby for a negotiated flat rate they would provide clinical consultations in a variety of specialties to other hospitals or physicians' practices. In essence, this hospital planned to establish its own capitated pricing for telemedicine. Another administrator explained that under managed care, hospitals face an incentive to avoid bringing patients into the hospital, where care is expensive. In his words, "Under managed care, you want to keep 'em down on the farm, where it's cheaper." Therefore, if telemedicine could allow patients to remain in their communities, it could be an important component of a managed care strategy. This same administrator also stressed that this technology could also help him to be more competitive in a managed care environment because patients who stay in their own community would have less travel time to receive care, and therefore experience greater satisfaction. Other hospital administrators painted scenarios where, under a capitated pricing regime, they could foresee using telemedicine to reduce costs in outlying affiliated medical centers or clinics by substituting telemedicine for a reduced staff. Thus, where the hospital or clinic now employed a general practitioner or internist, and supplemented this care with specialty consultations using telemedicine, the physician or part of the physician's time could be replaced by a mid-level practitioner supplemented with telemedicine.

The majority of administrators interviewed indicated no explicit strategy for utilizing telemedicine to gain advantage in a managed care environment. As one administrator in North Carolina explained,

> "in our region, no one is further than 45 miles from a primary care provider. The personal contact is too important to people: they will drive for an hour to see a physician. Where telemedicine comes in, is for specialty visits. But I can't imagine substituting the technology for a professional for primary care visits."

This perspective illustrates two important points. First, this administrator recognizes the potential for reducing costs by substituting telemedicine for physicians in a capitated pricing environment. Second, he dismisses this strategy in markets like that of central North Carolina, where distances to the nearest primary care provider are relatively small; he believes that people value the personal contact enough that his hospital would lose patients to the competition if his hospital utilized telemedicine as a substitute for a primary care physician. As he continued to think out loud about this issue, however, his comments echoed those of other administrators. In a capitated pricing environment, several administrators reasoned that utilizing telemedicine to access specialty consults would be less expensive than transporting patients to a tertiary care center. Thus, telemedicine could allow smaller hospitals to improve their competitiveness by increasing the mix of services they could offer and reducing their cost of providing these services. It is important to note, however, that among this group of administrators, such a strategy was not an explicit component of their reasons for adopting telemedicine.

In sum, for the most part the interviews confirmed the survey results for the question about *why hospitals are adopting telemedicine*. Interestingly, price competitiveness was never brought up by administrators in the interviews. When asked directly about this issue, most paused to think about it, but responded that it is too early to tell how costs and prices will be determined for telemedicine-related activities. The interviews brought to the fore the role that telemedicine plays in medical education, in both direct and indirect ways.

Financing telemedicine

Question 2 on the survey asked hospitals to rank the sources of capital for telemedicine projects, in order of the largest dollar amounts. Table 4 summarizes these results:

Table 4 Sources of capital for telemedicine projects

Most Important Source	Frequency
1. Operating revenues	24 (38%)
2. Federal grants	10 (16%)
3. Other sources	6 (9.5%)
4. State grants	5 (8%)
5. Foundation grants	4 (6.3%)
6. Other hospital sources	1 (1.6%)
7. Affiliated hospitals	1 (1.5%)

The category most often indicated as the primary source of telemedicine funds was operating revenues; 38% of telemedicine adopters ranked this category highest. Federal grants accounted for the next most important source of funds for adopting hospitals in this sample; 15% ranked this category highest. Other sources, such as the Department of Defense and private physicians, were most important for 9.5% of the adopters. State and foundation grants were the most important sources of revenue for 8% and 6.3% of the adopters, respectively. Finally, other hospital sources and affiliated hospital sources were the most important means of financing telemedicine projects for a very few hospitals in the sample. None of these results reflected any geographical biases.

The information about telemedicine financing obtained from the survey is fairly straightforward. The interesting questions involve how hospital administrators plan to pay for telemedicine in the future. Hospital administrators and telemedicine project coordinators interviewed for this research held one of two viewpoints about this subject. The clear majority expressed vague expectations that the Health Care Financing Administration (HCFA) would ultimately reimburse for telemedical consultations, thus offsetting a large portion of the expenses[9]. Administrators in this group had not developed plans beyond continued grant monies or hopes for a change in HCFA regulations to financially sustain their telemedicine activities.

[9] The Health Care Financing Administration (HCFA) sets reimbursement policies for Medicare and Medicaid. Most other insurers follow HCFA in their reimbursement policies. Currently, HCFA does not reimburse for "non-face-to-face consultations," which include telemedicine (Smits and Baum, 1995). The exceptions are for radiology and pathology consultations, which do not take place "face-to-face" under normal circumstances.

Administrators in the second, minority, group had initiated telemedicine projects on a limited basis, offering only image-based services, such as radiology, pathology and limited cardiology. Such projects could be financially self-supporting (in terms of operating expenses) from the outset because HCFA and other insurers will re-imburse for these types of consultations that do not involve face-to-face patient encounters even without telemedicine.

With respect to the financing of telemedicine, the lack of certainty about future HCFA reimbursement for telemedicine is a critical issue for administrators. Without this reimbursement, few hospital administrators were able to identify applications of telemedicine that would make sense for their hospital. As explained above, increased managed care penetration and capitated pricing for health care may make this point obsolete. Capitated pricing regimes fundamentally change the reimbursement scenario and therefore the incentives hospitals face. In such an environment, hospitals would choose to employ telemedicine technologies if they reduce costs, and prices or reimbursement would be irrelevant.

Specialties using telemedicine

Question 5 on the survey asked hospitals to indicate how frequently various medical specialties, or departments in the hospital, were utilizing telemedicine. Table 5 shows the distribution of which specialties employ telemedicine at least monthly (i.e., either daily, weekly, or monthly):

Table 5 Telemedicine usage by specialty

Specialty	Percent of hospitals using telemedicine daily, weekly, or monthly
Radiology	23 (37%)
Emergency Medicine	14 (22%)
Pathology	11 (17%)
Cardiology	9 (14%)
Internal Medicine	7 (11%)
Pediatrics	6 (9.5%)
Psychiatry	5 (8%)
OB/GYN	5 (8%)
Other	5 (8%)
Dermatology	4 (6%)
Surgery	4 (6%)
Urology	2 (3%)

Table 5 shows that radiologists use telemedicine the most. This is followed by emergency medicine, pathology, cardiology, internal medicine, and pediatrics, in order. Departments of psychiatry, obstetrics and gynecology, dermatology, surgery, and urology use the technology with decreasing frequencies. Applications of telemedicine reported in the "Other" category included dentistry, oral surgery, oncology, family practice, and geriatrics. It is interesting to note that there is a statistically significant bias toward urban hospitals using telemedicine for emergency medicine more frequently than rural hospitals (χ^2=9.3, p=0.002). Similarly, a bias exists toward urban hospitals using the technology for pathology more frequently than rural hospitals (χ^2=9.02, p=0.003). These are the only two specialties for which such geographic biases are statistically significant[10].

The fact that radiology and pathology are among the most frequent users of telemedicine is not surprising in light of the fact that insurers will reimburse for these types of consultations,

[10] The small number of responses in each of the other categories may explain the lack of geographic bias in these categories. Based on these numbers, it is not prudent to rule out such a bias.

but not for other telemedical consultations. Another explanation of the relatively high frequency with which these two specialties utilize telemedicine is the image-based, as opposed to "hands-on", nature of their practice. The adoption of telemedicine, therefore, requires less change in practice routines.

Barriers to adoption

Question 3 in the survey helps disentangle some of the complexities of the financial and behavioral forces that explain whether a hospital will adopt telemedicine. This question probed the barriers to adopting telemedicine. Again using a Likert scale, where 1 indicated a very significant barrier and 5 indicated that the potential barrier was not significant, hospital administrators ranked the significance of ten potential barriers to adopting telemedicine. Table 6 reports the results of this inquiry:

Table 6 Barriers to adoption

Important Barrier (received score of 4 or 5 on Likert scale)	Frequency (Percentage) of "Important" ranking
Cost of purchasing technology	40 (64%)
Physician acceptance	32 (51%)
Cost of telecommunications	31 (49%)
Lack of insurance reimbursement	29 (46%)
Lack of industry standards	24 (38%)
Lack of internal interest or expertise	18 (29%)
Medical liability issues	17 (27%)
Patient acceptance	11 (18%)
Medical licensure issues	9 (13%)

In the table above, a barrier is considered important to a hospital if it received a ranking of 4 or 5 on the Likert scale. Thus, the cost of telemedicine technology was ranked as an important barrier by 64% of hospitals. Physician acceptance was the second most frequently cited important barrier, with 51% of hospitals ranking it with a 4 or 5. These were followed, in order of frequency, by the cost of telecommunications, lack of insurance reimbursement, lack of industry standards, lack of internal interest or expertise, medical liability issues, patient acceptance, and medical licensure issues.

Of the top four barriers to adopting telemedicine, three are financial issues and only one—physician acceptance—is a behavioral issue. The three financial issues are inter-related because the hospitals cannot allocate the costs of telemedicine technologies or the attendant telecommunications expenses across patient visits—as they would with other clinical technologies such as CT scanners—because many types of telemedicine consultations are not reimbursed by insurance.

The remaining five potential barriers merit some explanation: lack of industry standards refers to the fact that telemedicine equipment is not standardized. Thus, not all equipment will inter-operate with other types of telemedicine equipment, making the purchase of telemedicine technologies not only expensive, but complicated and risky. If industry standards are developed or evolve, owners of equipment that does not conform to these standards will have equipment of limited use, similar to owners of Beta-type video cassette recorders (VCRs) (OTA, 1992).

Lack of internal interest is a barrier when the hospital administrator and/or the hospital staff simply have no interest in adopting telemedicine.

Medical liability issues constitute a barrier to adoption if the practice of telemedicine involves greater or unforeseen medical liabilities on the part of the hospital. Since telemedicine is such a new technology neither legal precedents nor practice guidelines yet exist to deal with liability issues.

Patient acceptance is a barrier to adoption if the administrator and/or medical practitioners believe that patients would be uncomfortable with telemedicine technologies. The risk of losing patients, or of purchasing a technology that would remain unused in order to avoid making patients uncomfortable, may deter adoption.

Finally, medical licensure issues would be a barrier to adoption if a telemedicine linkage crosses state borders and the two states' medical boards do not recognize the other's licenses to practice medicine. This issue is very real, as evidenced by recent legislation introduced in Kansas, Nevada, Oklahoma, and South Dakota, which makes it illegal for physicians without a state medical license to practice telemedicine in these states (Richards, 1996). These are merely the first examples of efforts to geographically restrict telemedicine practice. Policies aimed at limiting physician competition from outside the state are currently under consideration in at least 20 other states. As such initiatives become more commonplace and widely understood, this type of legislation may become an important factor in the extent and speed with which telemedicine diffuses.

Background summary

The questions on the survey that produced the information presented above represent exploratory research. The answers from these questions will help to fill in the story told by the theory and modeling used in this research. Because this section reported exploratory research, the answers to the questions do not stand alone, but must be examined in the context of the larger design and questions of this research project.

V. MULTIVARIATE ANALYSES: THE DIFFUSION MODEL

Table 7 provides a summary of the parameter estimates, their standard errors, the Wald Chi-square statistic and the probability value of the Chi-square statistic, the odds ratios and their confidence intervals. The variables indicated with one asterisk are statistically significant at the 0.10 level; those indicated with two asterisks are significant at the 0.05 level.

Table 7 Diffusion model results

Variable	Parameter Estimate (Standard Error)	χ^2 (probability)	Odds Ratio	Wald Confidence Limits for Odds Ratio: Lower-Upper Bounds
INTERCEPT	-6.02 (2.56)	5.54 (0.02)	Not Applicable	Not Applicable
NEAREST	0.26 (0.27)	0.92 (0.34)	1.3	0.76 2.22
HMOPEN	0.015 (0.055)	0.08 (0.78)	1.01	0.91 1.13
POPULAT	-0.27 (0.31)	0.76 (0.38)	0.76	0.41 1.41
INCOME	0.005 (0.014)	0.16 (0.69)	1.00	0.98 1.03
RURAL	-1.03 (0.76)	1.84 (0.17)	0.36	0.08 1.58
TEACH	-0.13 (1.14)	0.01 (0.91)	0.88	0.09 8.28
NOTPROFT**	2.11 (0.98)	4.60 (0.03)	8.24	1.20 56.61
BEDS*	0.53 (0.32)	2.77 (0.096)	1.70	0.91 3.19
AFFILMHS**	1.13 (0.55)	4.18 (0.04)	3.09	1.05 9.09
AFFILGPA	0.84 (0.81)	1.09 (0.29)	2.32	0.48 11.30
AFFILIDN*	0.82 (0.44)	3.52 (0.06)	2.28	0.97 5.37
TECHINDX	0.05 (0.09)	0.30 (0.58)	1.05	0.87 1.27

**significant at 0.05 level.
*significant at 0.10 level.

By several measures, the model described above fits the data well. The -2 Log Likelihood test statistic had a chi-square value of 24.73, with 12 degrees of freedom and a probability of 0.016. This test is analogous to the F-test of the joint significance of the independent variables from ordinary least squares (OLS) regression (Stokes, Davis, and Koch, 1995). It is interpreted as meaning that a probability of 0.0026 exists that all of the parameter estimates (the β's) are truly equal to zero, a sufficiently low probability to indicate that the model fits the data adequately. Another indicator of goodness-of-fit: the model correctly predicts 71.8% of the responses; the pseudo-R^2=25%, a value comparable to similar models in the literature[11].

Several diagnostic tests were run to assess the strength of the model. Various techniques were applied because the diagnostics for logistic regressions are much less developed than those for ordinary least squares regression (Stokes, Davis, and Koch, 1995). Although these tests generated somewhat conflicting results, they suggested there might be multicollinearity between the variables representing rural location, teaching status, size of the population of the hospital's county or MSA, the log of the distance to the next closest hospital, HMO penetration, per capita income, size of the hospital and technological sophistication (RURAL, TEACH, POPULAT, NEAREST, HMOPEN, INCOME, BEDS, and TECHINDX). This possibility would make the interpretation of coefficients and odds-ratios of these variables difficult. In order to better understand the nature of these inter-relationships, extensive statistical testing of various functional forms of the model specification was conducted. After exploring and implementing alternative methods of analysis to correct for the problems with the data, the initial model remained the best, and hence is reported with the attendant caveats.

The model shows that not-for-profit status, hospital size, affiliation with a multi-hospital system and affiliation with an integrated delivery network (NOTPROFT, BEDS, AFFILMHS, and AFFILIDN) are statistically significant variables predicting the adoption of telemedicine. Not-for-profit status and affiliation with a multi-hospital system (NOTPROFT and AFFILMHS) are significant at the 0.05 level, and size and affiliation with an integrated delivery network (BEDS and AFFILIDN) are significant at the 0.10 level. These results predict that a not-for-profit (NFP) hospital is approximately 8.2 times as likely as an investor-owned hospital to adopt telemedicine. Hospitals that are members of multi-hospital systems are roughly three times as likely as independent hospitals to adopt telemedicine. An increase in a log-transformed unit of

[11] The pseudo-R^2 is calculated as ESS/(ESS+3.29*N), where ESS is the explained sum of squares and N is the total sample size. This calculation follows the technique described in Aldrich and Nelson (1984). As a comparison, Tepelensky, et al., report a pseudo-R^2 of 5% (although their calculation is somewhat different). If the model offers no improvement over a restricted model, with all the parameters set to zero, the pseudo-R^2 will be zero; if the model perfectly describes the observations, the pseudo-R^2 will approach one. The main difficulty with this measure of fit is that it "does not incorporate a penalty for increasing the number of exogenous variables," nor is it universally accepted or used (Aldrich and Nelson, 1984).

beds increases the odds of adoption by a factor of 1.7; this means that larger hospitals are more likely than smaller hospitals to adopt telemedicine. And members of integrated delivery networks (IDNs) are slightly over twice as likely as unaffiliated hospitals to adopt telemedicine.

VI. SUMMARY AND CONCLUSIONS

The original purpose of this research was to investigate whether and how telemedicine influences hospitals' costs and whether rural and urban hospitals faced different cost functions. By determining whether telemedicine generates internalizable cost savings for hospitals, such a study would have provided important documentation of one type of benefits that these technologies may confer. This information, in combination with other studies about the potential health care benefits of these technologies, could be compared to the costs—both to hospitals and government organizations—of implementing and utilizing telemedicine. This type of cost-benefit analysis would help to clarify the appropriate role for government in the development of telemedicine and information infrastructure technologies.

The necessary data to carry out that project were unobtainable, and in many cases intractable due to the complex and multiple financing arrangements for telemedicine within and across individual hospitals. As a result, it was necessary to re-assess the goals of this project and redirect the empirical components of this research to take into account the paucity of data about this very interesting and policy-driven subject. Accordingly, the objective of this research evolved into a study of how telemedicine is diffusing in its early stages of development. By understanding what the characteristics of adopters imply about the potential and actual benefits these technologies offer, it would be possible to make plausible inferences about answers to the same types of questions the study set out to research. Therefore, the modified objectives of this research were to 1) identify characteristics of hospitals and their economic environment that are related to the adoption of telemedicine technologies, 2) utilize theory, quantitative and qualitative research to make reasonable and informed inferences about the types of benefits hospitals obtain and expect to derive from these technologies, 3) relate these findings back to current rural health policy objectives and identify feasible and appropriate roles for government in the development of telemedicine, and 4) utilize this framework to evaluate current interventions targeted to rural areas.

To reiterate the empirical findings reported above, the results of the quantitative analyses reveal that each of the following factors: not-for-profit status (NOTPROFT); affiliation with a multi-hospital system (AFFILMHS); affiliation with an integrated delivery network (AFFILIDN); and characteristics of "urban-ness"—most prominently larger hospital size (BEDS), independently increases the odds of adopting telemedicine. Thus, not-for-profit hospitals are much more likely to adopt telemedicine than are investor-owned hospitals; telemedicine is more attractive for hospitals who are members of integrated delivery networks or multi-hospital systems. The fact that larger hospitals are more likely to adopt telemedicine suggests that some form of economies of scale is involved with the decision to adopt telemedicine. These results are summarized in Table 8:

Table 8 Factors increasing the odds of telemedicine adoption

Characteristic	Increase in odds of adoption
Not-for-profit status	7.5
Affiliation in an integrated delivery network (IDN)	2.3
Affiliation in a multi-hospital system (MHS)	2.6
Hospital Size (measured in log-transformed units of beds)	1.60

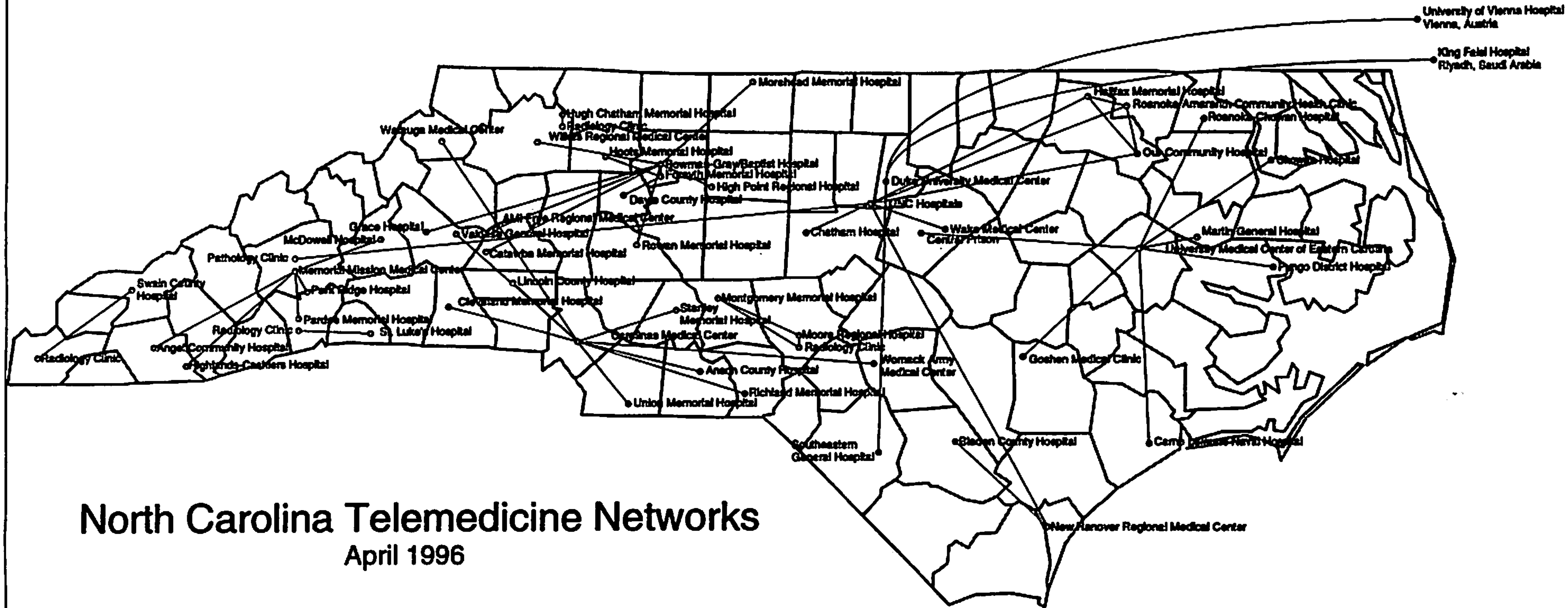
The qualitative research from the survey suggests that telemedicine plays an important role in hospitals' plans for competitiveness and adaptation to managed care, although quantitative evidence to support this conclusion is less definitive. HMO penetration was not a significant predictor of telemedicine adoption in the diffusion model, nor was competitiveness of the local hospital's market, as measured by distance to the next closest hospital. The interviews indicated that hospital administrators had not necessarily adopted telemedicine with a managed care strategy in mind, but they invariably could envision ways that telemedicine could prove profitable in a capitated pricing environment where the incentives to keep patients out of the hospital—particularly expensive tertiary care centers—are great.

Conclusions and Policy Implications

The findings described above represent a critical first step in understanding the "second wave" of telemedicine diffusion. From a policy perspective, one of the most important findings from this research became clear before the analyses were started: information about how these technologies affect hospital costs is unavailable for research because it is also largely unavailable to the hospital administrators investing in telemedicine. As described above, the financing and implementation of telemedicine projects are complex, often involving several departments within one hospital, various grant and operating funds, and managers who know little about other telemedicine activities within one institution. This scenario does not necessarily represent poor management; rather, it reflects the newness of the technologies.

With little consensus about medical efficacy and appropriate medical applications of telemedicine, no information about how telemedicine affects hospital costs, and no uniform reimbursement policies, telemedicine investments represent considerable risks in terms of capital and personnel investments. As such, it is not surprising that these technologies are being adopted on almost an experimental basis, by innovative hospitals or individuals within innovative departments of hospitals.

This study provides a profile of the types of hospitals adopting telemedicine. In the absence of financial data, this type of information allows for inferences about the how and why hospitals are adopting telemedicine. Figure 1, below, illustrates the configuration of telemedicine networks in North Carolina and presents a visual representation of the major findings of the empirical work presented above: this map shows the hub-and-spoke structure of the state's telemedicine networks.



North Carolina Telemedicine Networks

April 1996

Produced by: North Carolina Rural Health Research Program, Cecil G. Sheps Center for Health Services Research, University of North Carolina at Chapel Hill. RKR

It is interesting to note that the hubs are located in the major metropolitan regions of the state, while the spokes are in outlying, but rarely rural areas[12]. It is also interesting to visualize the geographic range of these networks. To date, the state's major hospitals—the network-hubs—have not affiliated with outlying hospitals—or spokes—in a way that would greatly infringe upon or compete with each others' networks. As can be seen, this is not strictly the case in the Western part of the state, and would certainly bear further investigation before conclusions were drawn. Such research is outside the current scope and resources of this project, and thus will be left for future inquiry. The sections below provide discussion about the characteristics of hospitals adopting telemedicine and inferences about the benefits that these patterns imply and the attendant policy consequences.

Size and location

That larger hospitals located in urban locations are more likely to adopt telemedicine is strong evidence that telemedicine is not reaching rural areas. Whether this can be explained by the smaller size of rural hospitals—and hence smaller financial, technical, and personnel resource base available in rural hospitals—or by other factors related to rural location, the fact remains that smaller, more rural hospitals are not participating in telemedicine initiatives at the rate that larger, urban hospitals are. Since improving *rural* health is the stated goal of many federal and state telemedicine grant programs, this research suggests that these programs are falling short of this objective. If federal and state governments aim to promote telemedicine as a technology to improve rural health and the viability of rural hospitals, these programs need to target these small, rural hospitals better.

This report described the barriers to adoption reported by telemedicine adopters. In brief, the most important barrier was cost, followed by physician acceptance, lack of reimbursement, and lack of internal expertise. It is likely that small, rural hospitals face these same barriers, but are unable to overcome them. Assistance in gaining access to investment capital for telemedicine, either through private or public sources, would diminish this barrier for smaller hospitals; technological transfer, or assistance in understanding and implementing telemedicine, could reduce the barrier of lack of knowledge about the technology. These types of targeted initiatives could potentially improve small hospitals' ability to finance and deploy

[12] The reference to rural areas connotes those regions outside a metropolitan statistical area, as classified by the U.S. Office of Management and Budget.

telemedicine technologies, and thus better fulfill the mission of many of the telemedicine grant programs.

The fact that small, rural hospitals are not adopting telemedicine at the rate of their urban counterparts is typical of the burden rural areas have persistently faced in virtually all matters of economic development (OTA, 1991). Without a critical mass of resources—financial, technical, and human—small, rural communities and their hospitals cannot compete in the market place, nor can they compete effectively for government programs designed specifically to help them. Therefore this research provides more evidence that policy makers need to pay special attention not only to the symptoms of rural distress, but also to its causes.

Ownership status

The profound difference in patterns of telemedicine adoption between not-for-profit (NFP) and investor-owned hospitals signals the existence of public benefits that make telemedicine an unattractive investment for hospitals with a single objective, to maximize profit. Nonetheless, this finding alone does not prove this notion. It is important for policy makers to understand the alternative explanations about why NFP hospitals are much more likely to adopt telemedicine, and the policy implications of this fact. If NFPs' broader mission and/or their greater access to grant monies explains this phenomenon, does that mean that these technologies create a diffuse benefit that is not internalizable as reduced costs or improved revenues? If so, these technologies may be unattractive investments for investor-owned hospitals. In this scenario, the role for government involvement with telemedicine could extend beyond funding start-up costs; if telemedicine has public-good characteristics, there is a well-precedented role for government. If, however, these diffuse benefits—or externalities—do not explain the greater rate of NFP adoption, then future government involvement with this technology may become unnecessary as the technologies become better established and more profitable. More research about the financial, medical, and community benefits of telemedicine is necessary to answer this question. It is important also to discover whether investor-owned hospitals are simply waiting for the barriers of cost, lack of reimbursement, lack of standards, and lack of physician acceptance to fall before adopting telemedicine, allowing NFPs to experiment with the technologies and work out some of these difficulties. In this case, the government's role could be seen as temporary, fostering innovation then allowing the internalizable benefits of the technologies to sustain telemedicine development. These questions and scenarios are suggested by this research, but more investigation and more experience with the technologies are necessary to make sound conclusions.

Strategic role of telemedicine

This research suggests that telemedicine plays an important role in hospitals' competitive strategies. Telemedicine clearly functions as a marketing tool—or form of non-price competition—for many adopters. Most administrators envision telemedicine to be an important component of their managed care strategy, both by increasing their market share and by enhancing patient management—and thus reducing costs. Several administrators explained ways in which telemedicine could be used to allow patients to stay in their community hospital or out of the hospital altogether. In a capitated pricing environment, where patient management is a critical focus, the ability to appropriately determine who should be admitted and who can avoid a hospital stay will be a critical component of minimizing costs. These findings point to characteristics of telemedicine that resemble private goods, with internalizable benefits.

If telemedicine becomes an important tool for minimizing costs in a managed care environment, the current debate about whether the Health Care Financing Administration (HCFA) should re-imburse for telemedical consultations could become moot. As one administrator put it, "managed care may be just the ticket for telemedicine." In other words, administrators currently hesitant to implement these technologies without third-party insurance reimbursement would readily use telemedicine if the technology enhanced patient management in a managed care environment.

Although the existence of actual and expected internalizable benefits from telemedicine provides little justification for government involvement, these private benefits do not rule out a role for government. If telemedicine improves the quality of health care in rural areas, allows rural hospitals to remain accredited and in operation, or plays a role in the economic development of a rural community, the argument could be made that the public benefits created by these technologies justify government involvement. This is particularly so if small and/or rural hospitals are unable to realize the internalizable benefits that telemedicine may confer absent federal or state assistance. Again, more research is necessary to establish the magnitude of these types of internalizable benefits relative to the more diffuse benefits, or externalities, that these technologies offer. It is a very important finding, however, that these internalizable benefits exist and are expected by hospital administrators in the future as managed care evolves.

Affiliations

This research empirically demonstrates the common-sense notion that hospitals with affiliation relationships are more likely to adopt telemedicine. This finding is important for three reasons:

First, it provides guidance for policy makers to improve the reach of telemedicine to smaller hospitals. By conditioning grant awards to encourage networking between large and smaller hospitals and by encouraging small hospitals to participate in affiliation arrangements, policy makers can facilitate the establishment of the types of linkages between hospitals that enable telemedicine to make practical sense.

Second, this finding suggests another strategic role for telemedicine. If the growth of hospital networks is a step along the path to managed care (Cave, 1995; Curran and O'Connor, 1995; Hospitals and Health Networks, 1995; Kripke Byers and Levi-Baumgarten, 1995; Nurkin, 1995; Shortell, Gillies, and Devers, 1995), the fact that members of these networks are twice as likely as non-members to adopt telemedicine reinforces the point identified above, that telemedicine is an important strategic technology in a competitive hospital marketplace; it also provides further evidence that telemedicine will be an important technology in a managed care environment.

Third, it brings telemedicine into a larger policy debate about affiliations between hospitals. While hospitals and their advocacy organizations argue that affiliations are necessary in a very competitive health care market place, the Justice Department, the Federal Trade Commission, and unaffiliated hospitals maintain that these alliances represent anti-competitive activity and potentially violate anti-trust laws. To the extent that telemedicine strengthens affiliations, it could play an important role in this debate; to the extent that rural hospitals may be at a particular competitive disadvantage without these types of affiliations raises the possibility that exceptions to anti-trust concerns may exist.

Summary of policy implications

The findings of this research help to focus the many unanswered questions about telemedicine. Importantly, this research identified a lack of financial information about telemedicine, a debilitating limitation to discovering how telemedicine affects the costs of delivering health care. This finding also calls into question whether telemedicine adopters are able to determine the benefits of the technology in their own institutions. Until more uniform accounting of telemedicine programs within hospitals is available, qualitative research, cost-finding studies and case-study methods will have to substitute for cross-sectional analyses of the cost effects of telemedicine.

This research also identified a gap between the diffusion of telemedicine and the goals of federal and state policy makers: telemedicine is not reaching small and rural hospitals. Programs to target these hospitals for technical and financial assistance could improve small hospitals' access to telemedicine technologies. In addition, the fact that not-for-profit hospitals and members of integrated delivery networks are more likely to adopt telemedicine provides information that allows policy makers to utilize these relationships to better target telemedicine grant programs. In essence, these findings identify key leverage points which policy makers can utilize to more effectively meet their goals of extending telemedicine technologies into rural communities.

These findings identify a set of questions regarding the types of benefits that telemedicine provides. Are not-for-profit hospitals adopting these technologies out of altruistic commitments to community service, but with little expectation of internalizing the benefits of telemedicine technologies? Or does the broader mission of not-for-profit hospitals enable them to experiment with nascent technologies in order to gain experience and figure out how to make an interesting and seemingly useful technology profitable in the future? Answering these questions will clarify the role for government in the diffusion of telemedicine technologies.

Importance and limitations of this research

This research represents the first cross-sectional empirical study of economic and management aspects of telemedicine adoption. As such, it identifies as many questions as it answers. Nonetheless, important policy implications derive from the findings of this study. With these results, policy makers can better identify the types of hospitals adopting telemedicine, compare this to their program objectives, and make appropriate improvements to their programs. This research also helps to narrow the huge number of questions about telemedicine into a more focused set of inquiries.

In addition to uncovering findings about particular issues of telemedicine and hospitals, this study also highlights issues of perennial concern to rural communities and policy makers concerned with rural issues. Rural areas are often ill suited to attract or compete for many of the resources that would benefit them specifically. Concern about unequal economic opportunities in rural areas is not new, but this study provides a current example of this phenomenon.

Although this study examines hospitals within the Southeastern region of the U.S., the limitations in its generalizability are minimal. The parameters of hospital size, ownership structure, and hospital affiliations are not unique to this region. Moreover, with the exception of the West Coast of the U.S. and selected cities in the Northeast, most of the U.S. faces health care markets that are in a similar state of managed care evolution to that of these three states. As many states are in early stages of planning their telecommunications policy, the states studied for this research can serve as an example of what to expect in telemedicine diffusion.

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