POLICY SYSTEMS AND THEIR COMPLEXITY DYNAMICS: ACADEMIC MEDICAL CENTERS AND MANAGED CARE MARKETS

By

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Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Public Administration and Policy

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April 14, 2003
Falls Church, Virginia

Key Words: Nonlinear Dynamic Systems, Academic Medical Centers, Managed Care, Complexity Theory, Strategic Policy Systems

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(ABSTRACT)

This dissertation examined how complexity theory might offer insight into the behavior of a population of large-scale networked organizational groups. Academic medical centers (AMCs), a large-scale social and policy system that plays a key role in the education of physicians, the conduct of research, and the provision of specialized clinical care, were chosen as an example to demonstrate the enhanced understanding that can be obtained from the application of complexity theory. Graphical and nonlinear mathematical tools were chosen to place this research study in contrast to studies that metaphorically apply the concepts of complexity theory to social systems.

Complexity science suggests that AMCs will demonstrate both nonlinearity and the emergence of patterned behaviors characteristic of self-organization in complex adaptive systems. Changes in the fiscal environment of AMCs, influenced by federal policy and the health care delivery market, were hypothesized to be among the factors that mediated changes in AMCs' activities and organizational relationships during a twenty-year period. The collection and examination of multiple indicators within the framework of a study model allowed development of a rich description of the AMC system and identification of patterned behaviors. Graphical analysis was used to identify underlying periodic and chaotic attractors in the AMC system. A logistic equation was used to confirm the presence of nonlinearity.

The presence of nonlinearity and the emergence of patterned behavior within schools in different managed care market groups suggested that it is appropriate to treat the population of AMCs as a complex adaptive system. The results of this research study also showed that AMCs have responded to the rise of managed care in the health care delivery marketplace by leveraging their institutional strengths. Identification of nonlinear properties offers a new perspective for understanding the behavior of a population of networked organizations, the management of large-scale systems, strategic planning, and policy formulation. Until researchers and managers recognize the coexistence of nonlinear and linear processes in social systems, they will make decisions on the basis of incomplete information.

ACKNOWLEDGEMENTS

I would like to thank the faculty of the Virginia Tech Center for Public Administration and Policy (CPAP) for providing a warm and welcoming academic home for me during my graduate studies. The CPAP community offered scholarly challenges, intellectual stimulation, and personal growth in a nurturing framework that combined rigor and humanity.

Special appreciation goes to my academic advisor and mentor, Professor Phil Kronenberg, who encouraged and supported my exploration of complexity science and policy systems. His enthusiasm for teaching and learning and his dedication to quality were an inspiration. His support and advice, his insightful comments on my dissertation drafts, and his consistently high standards surely resulted in a finer manuscript.

Members of my committee—Professors Jim Wolf, Joe Rees, and Terry Herdman, and Dr. Lynn Nonnemaker—each deserve my appreciation. Dr. Wolf, the first faculty member I met in the program, and whose engaging manner at the program orientation was singularly responsible for my entry into the program, has demonstrated his dedication to teaching and scholarship in many ways. His support and his willingness to chair my dissertation defense in the temporary absence of Dr. Kronenberg added an immeasurable sense of stability to an otherwise hectic time. Dr. Rees' continuing interest in my intellectual journey and his perceptive comments on my research were most useful. Dr. Herdman was so very generous with his time; his patient explanations and willingness to help me understand the mathematical underpinnings of my research made the mathematical analyses possible. Dr. Nonnemaker's insights on the academic medical community, which were based on her own research, were very important to the successful completion of my research project. A special thanks is due to Dr. Larry Lane, who agreed at the last minute to serve on my committee for the dissertation defense.

I would also like to recognize the contribution of Dr. Orion White to my intellectual growth. Dr. White introduced me to chaos theory in my first course in the program. Our conversations over the years have been a continuing source of new ideas and a challenge to broaden my perspective in all realms.

I also need to acknowledge my editor, Adam T. Monroe, whose flexibility, good humor, and tenacity were indispensable during the process of turning my text and multitudes of graphs into a coherent document. His tactful suggestions greatly improved the manuscript.

I owe a debt of gratitude to the management of Quantum Research Corporation (QRC), my employer when I began my graduate studies, and Macro International Inc., of which QRC is now a division, for their interest, encouragement, and support (financial and otherwise). I am particularly appreciative of the understanding, support, and patience of the staff of the QRC Division, with whom I have shared, or perhaps inflicted, the enthusiasms and frustrations of my journey to the doctoral degree.

I also want to express my appreciation to my daughter, Amy Look, who has progressed through her secondary and postsecondary education while I have pursued my graduate education. She has been remarkably tolerant in sharing our time together with my educational goals. Amy and Michael Henry also were very helpful with the data collection.

Finally, I cannot forget my friends and colleagues from CPAP – Cathy Gromek, Jane Misheloff, Mary Rawlings-Milton, Ann Simeone, Jane Tatum, and Colleen Woodard – who served as inspiring role models and steadfast dinner companions. To other friends who have encouraged me and believed in me, I express my lasting appreciation.

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Chapter 1. Overview

Introduction

This dissertation arose from my dual interests in complexity theory and the organization and functioning of medical schools. To understand how the theoretical perspective of complexity science can enhance our understanding, the concepts of nonlinear dynamic systems were applied to academic medical centers, which served as an example of a group of networked organizations. The result was an exploratory study that demonstrated the use of graphical and nonlinear mathematical analysis as tools that could be applied to a complex social system; more specifically, this study illustrated the way in which these tools could be applied to populations of organizations and to large-scale networked organizational groups.

The application of the concepts of complexity theory to social and policy systems was appealing because systems involving human interaction are thought to invariably contain a nonlinear component. This dissertation was designed to broaden the application of complexity theory to social systems through the use of graphical analysis and mathematical tools, and to demonstrate, rather than assert, the presence of nonlinearity. Use of the complexity perspective as a metaphor is frequently encountered in the literature; it is abundantly suggestive but usually stops short of identifying the underlying mechanisms that generate the emergence of patterns or self-organization. As such, the metaphorical application of complexity theory fails to fully realize the nonlinear implications of the approach.

In this dissertation, I acknowledge the value of the metaphorical application of complexity to analysis of social systems. The translation of observations about large-scale complex networks into the language of complexity is a valuable first step toward exploring the potential of this new theoretical approach. I take the position, however, that regardless of the richness of the metaphors of complexity, it is preferable to now begin to move up the operational hierarchy, toward the specification of plausible models, empirical collection of trend data on the key variables in the model, and tests of the predictions of the computational models, including the identification and interpretation of attractors. This dissertation was an attempt to apply the methodological tools of complexity theory to a population of networked organizational groups—academic medical centers—to enrich our understanding of large-scale social systems. Collectively, medical schools and academic medical centers—in which medical schools are an important component—comprise a social system. The analytic context of this research study is the social system structures in these large-scale networked organizational groups for which long-term policy making is a strategic problem. Academic medical centers operate in several market niches—they supply physicians, contribute to the national biomedical research enterprise, conduct clinical trials of new drugs and medical devices, and compete with community hospitals and other health care providers for patients. Key strategic policy decisions affect resource allocation, market position, and institutional relationships.

Academic medical centers are interesting subjects of study for several reasons. They provide an essential service by educating new doctors and by training residents; by performing basic, clinical, and translational research; and by providing specialized medical care and care for indigent patients. Academic medical centers have been functioning in a changing environment, as managed care has become, over the past fifteen years or so, the predominant mode of health care delivery. Managed care markets vary by state and metropolitan statistical area, but where market penetration is high it has threatened to decrease the number of patients available for clinical studies—patients who utilize higher-cost teaching hospitals. As managed care has increased its market share, academic medical centers have faced the prospect of reduced hospital and faculty practice plan revenues which have historically been used to help offset costs of their education and research missions. This situation suggested that new patterns of institutional behavior may be emerging, and that academic medical centers might therefore serve as a useful example to illustrate the application of complexity theory to a population of networked organizations.

Purpose of the Dissertation

The purpose of this dissertation was to examine the ways in which complexity science might offer insight into the adaptive behavior of a population of organizations. In particular, I wanted to demonstrate the use of some of the graphical and mathematical tools that are appropriate for applying nonlinear dynamic systems to enrich our understanding of complex social and policy systems. The choice of these tools was intended to position this research study in contrast to studies that metaphorically applied the concepts of complexity theory to social systems. Academic medical centers were chosen as an example of a population of complex, networked organizations with which to illustrate the application of complexity theory. The choice of complexity theory and its methodological tools was also intended to illustrate the added value of examining social and policy systems from a nonlinear perspective. Correspondingly limited are other theoretical approaches, such as population ecology and the "new institutionalism," that are based on linear assumptions or that focus primarily or exclusively on linear characteristics. This dissertation was intended to demonstrate the use of nonlinear dynamic system tools to extend our understanding of complex systems.

To illustrate the enriched understanding that can be derived from the application of complexity theory, I examined the changes exhibited by a population of organizations—academic medical centers—concurrent with the market growth of a health care delivery model—managed care. In order to achieve this purpose, I developed a study model showing proposed relationships among managed care markets and academic medical centers' activities and functions related to their missions, and depicting the policy environment. U.S. medical schools were classified according to their managed care market environment, and data on key study model variables related to their three missions—teaching, research, and patient care—were collected and summarized. These data included information on academic medical center revenues and research expenditures, data on faculty, teaching responsibility, enrollment and graduates, and institutional linkages such as clinical affiliations. This information was used to create a rich and detailed data-based description of the population of academic medical centers.

While academic medical centers as a group have several distinctive characteristics, their experience, with a newly challenging environment, and this research study's approach to examining their behavior may prove extensible to analyses of other large systems of organizations and strategic policy systems.

The Academic Medical Center Population

Academic medical centers are an important group of institutions that fulfill society's fundamental need for medical education, research, and specialized clinical care. Teaching undergraduate medical students, and training residents and fellows is the only unique mission of academic medical centers. Universities, research institutes, and private firms such as pharmaceutical companies also undertake research; community hospitals, the federal government, and many private health care providers also provide patient care. However, translational research, provision of care to indigent patients and other underserved groups (including assumption of the cost of charity care and bad-debt expense), and the assurance of quality standards in the training of physicians (e.g., through accreditation and licensing) are not effectively or efficiently produced or distributed by the private health care market.

Since World War II, academic medical centers have undergone three eras. In the post-war period through the mid-1960s, which saw the passage of Medicare legislation, the influence of medical professionals and of professional associations and norms predominated. Following the passage of Medicare legislation in 1965, through the early 1980s, academic medical centers were heavily influenced by federal involvement, both through funding of patient care and through research funding support. With rapidly rising health care costs, the 1980s ushered in an era of managerial control and market mechanisms in which managed care became the predominant model of health care delivery.

The increasing dominance of the managed care model in the U.S. health care delivery system has posed a series of financial and organizational challenges for academic medical centers. Long-term policy, a central strategic problem for large scale networked organizations, had to account for the influence of managed care on resource allocation and network relationships. These challenges therefore provided an opportunity to examine the adaptive behavior of a population of organizations as it responded to environmental uncertainties and changes—changes which affected the financial viability, core missions, and structure of the population. This dissertation offers a systematic examination of the behavior of academic medical centers over the past twenty years, through the lens of complexity theory.

Research Approach

This dissertation illustrates the application of complexity theory to populations of organizations that make up a large-scale social and policy system. It is a descriptive research study that used a nonexperimental research design. The research was based on a study model that identified dependent variables which described changes in the characteristics and behavior of academic medical centers, and independent variables hypothesized to influence and mediate those changes. Each academic medical center represented a constellation of interacting formal organizations: a medical school, a teaching hospital, a parent university, a faculty practice plan, an allied health school, and other components. The time dimension of the research approach was retrospective. That is, I first collected observations of dependent variables in 2000 or 2001 and then compiled twenty years' worth of annual data describing both the dependent variables and the independent variables in order to develop a rich description of academic medical centers. The research study observations included data for the entire population of accredited U.S. medical schools. The schools were grouped into three managed care market groups on the basis of multiple sources of information on health care market penetration. By studying the entire population of 125 institutions, I avoided the potential problems associated with statistical sampling and extrapolation of the results of the sample to the population.

Complexity theory provided a new lens for observing and understanding social system behavior. It is still an emerging field of study, and has not yet stood the test of time. It has become somewhat of a movement, in the field of management for example, but unlike some movements it spans almost every discipline in the physical, natural, and social sciences. The key concepts that were proposed for describing and explaining the behavior of academic medical centers were nonlinearity, logistic equations, phase planes and phase portraits, attractors, sensitive dependence on initial conditions, complex adaptive systems, self-organization, and emergence. I also discussed the nature of prediction in deterministic nonlinear systems.

The lens of complexity science suggested that academic medical centers would demonstrate both nonlinearity and the emergence of patterned behaviors that are characteristic of self-organization in complex adaptive systems. To examine this hypothesis, I investigated changes in academic medical centers' fiscal environment, institutional linkages, and activities related to teaching, research, and patient care, for evidence of nonlinearity and the emergence of patterns.

One challenge of this dissertation was to find a way to make analyses, based on complexity theory, accessible to public administration and policy students. Some students have a physical science, mathematics, or engineering background and are therefore not particularly unsettled by the mathematical origins of chaos and complexity theory. For students with a social science background, even one that contains a solid grounding in statistics, the inherent difficulties in understanding the mathematics of nonlinear dynamics described in complexity theory can be daunting.

One solution to this dilemma was to focus on graphical analysis of the data using phase portraits. In the phase portraits, time series data points were plotted on a phase plane and a line was drawn connecting the points in chronological order to create a trajectory. The trajectory of a study variable was plotted on the phase plane using the values for pairs of successive years. That is, each data point on the phase plane represented the values of the variable at the current time period, plotted on the Y-axis, and the value of the variable at the immediately previous time period, plotted on the X-axis. Connecting the points created a trajectory that showed both the direction and amount of change from the previous state of the system, at each period of time examined.

The phase portrait trajectories created a visual display of information regarding change in the academic medical center system as it transformed over time. Year-to-year differences that were plotted reflected the direction and flow of the variables; the dynamic evolution of the system was captured in a way that static values such as means or totals could not capture. Moreover, the lens of complexity science enables us to interpret phase portrait trajectories as representations of the underlying structure of the system—the pattern that the deterministic nonlinear system follows, and to which the system typically returns if disturbed. This underlying structure, called an attractor, defines the bounds within which the system is likely to behave. The purpose of the graphical analysis was to identify the underlying attractors in the academic medical center system and assist with the identification of emerging patterns of system behavior.

In addition to graphical interpretation of the phase portraits, I used a logistic equation to model the observed data and provide evidence of nonlinearity in the system. In a logistic equation, the value of a time-dependent variable is a function of the value of that variable at the immediately previous time period. The software package MATLAB was used to create functions and discover a mathematical definition of the observed data that could be used to generate data that would closely match the observed data and predict system behavior in the short term.

Dissertation Setting

The dissertation's research took place in the Washington, D.C. area where the National Institutes of Health (NIH) and the Association of American Medical Colleges (AAMC) are located. Both of these organizations provided important sources of data, as did the Uniformed Services University of the Health Sciences (USUHS) on the campus of the Bethesda Naval Hospital. The National Library of Medicine (NLM) on the NIH campus, and the USUHS Learning Resource Center in Bethesda are public libraries; the AAMC Learning Resource Center is open to non-member researchers by appointment. These three resources proved to be very valuable sources of information for this study.

During the entire research period, I was a consultant with a research and information technology firm with public sector clients; my primary business practice focused on the NIH. At the beginning of the research study period, I managed database and evaluation projects in a small firm. By the end of the research period, the small firm was a 110-person division of a much larger corporation and I was the division's general manager. This dissertation reflects my continuing interest in and knowledge of federal funding of biomedical research and the health of the medical education enterprise in general.

Contributions of the Dissertation

By offering an example of the application of complexity theory to an analysis of the dynamics of a population of organizations, this research is intended to illustrate the added value of examining large-scale social and policy systems from a nonlinear dynamic systems perspective. In this research study, I applied the tools of nonlinear system dynamics and complexity science to help formulate an understanding of changes in academic medical centers that were concurrent with major changes in the health care delivery sector. In contrast to metaphorical applications of the concepts of chaos and complexity, which have more often dominated the literature, I sought to apply complexity science as a graphical and mathematical tool. I have attempted to shift the traditional applications of complexity theory to analysis of strategic policy systems, up the operational hierarchy toward model specification, data collection, and the use of graphical and nonlinear mathematical tools. The success of this dissertation's contribution to the literature of complexity science may be judged by the extent to which it has provided a useful example of the application of the methodological tools of nonlinear dynamic systems to a population of complex, networked organizations.

By using the medical school population as an example, this research also provides insight into recent changes observed in the U.S. medical education enterprise that were concurrent with the rise of managed care to a dominant position in the health care delivery market. To accomplish this, I compiled an unusually large amount of data—both in scope and variety. The longitudinal nature of data used in the study meant that the total accumulation of information for this study was substantial and possibly unique among studies of the medical education enterprise. The rich description developed from the data that were amassed for this research study can serve as the basis for other explorations of the nature and evolution of academic medical centers.

Limits of the Dissertation

There were several limits to this dissertation. First, this dissertation represents an illustrative and exploratory effort to apply complexity theory to large social and policy systems. To illustrate the enriched understanding that might result, complexity science was applied as a methodological tool rather than a metaphorical concept. This research study represents only a small step toward the use of graphical and nonlinear mathematical tools to analyze empirical time series data and to provide descriptions of underlying system structures. The limited success of this endeavor, particularly in illuminating and articulating the sources of the underlying system dynamics and the mechanisms that generated the patterns of behavior that emerged, is indicative of the challenges of moving from the idealized illustrations found in the literature to the analysis of real data in real systems, with all of their inconsistencies and deficiencies. The analyses presented in this dissertation did not fully explain the “why’s” of the behavior of academic medical centers.

Second, the theoretical framework and research approach were illustrative and descriptive, not prescriptive. The reader will not find prescriptive statements that would assist a medical school dean or hospital administrator in adapting to his or her local managed care market environment; the array of data I have compiled and the tools I have used might suggest some ways in which these individuals might take a different approach to understanding their own academic medical center from a complexity perspective.

Third, some of the data, particularly financial data at the medical school level, were not available for the full time period of the study. The collection of high quality time series data is difficult to accomplish for most social systems, and the system of academic medical centers was no exception. It would have been particularly useful to have data for faculty practice plan or hospital fee revenue, for each school, over a longer period of time, but the academic medical community does not publish these data except in aggregate form. Because financial variables were hypothesized in the study model to mediate between the managed care market and academic medical center activities, it would have been preferable to have data for more years.

Structure of the Dissertation

The literature and concepts of chaos and complexity are reviewed in the next chapter. Chapter 2 also contains a discussion of a recent longitudinal study of health care delivery organizations from an institutional theory perspective. Chapter 3 continues the examination of complexity science with a discussion comparing the metaphorical use of complexity and the use of specific methodological tools to apply complexity theory.

Chapter 4 discusses the academic medicine literature, briefly describing the historical context of medical schools and their three missions: teaching, research, and patient care. The chapter closes with a discussion of the legislation and policies affecting academic medical centers, particularly their financial condition.

Chapter 5 presents the research methodology and study design, the data collection and coding methodology, and the analytic approach used in the dissertation. Chapters 6, 7, and 8 present the study findings. Each chapter presents data on the financial and institutional characteristics for all academic medical centers, and for three groups of medical schools based on their managed care market environment. Chapter 6 focuses on current data, chapter 7 describes the trend data, and chapter 8 presents the results of the graphical and nonlinear mathematical analyses. Chapter 9 presents general comments and conclusions.

Chapter 2. Review of the Literature

Contribution

To examine the benefits of applying complexity theory to an analysis of the system dynamics of a population of networked organizations, this research focused on the U.S. medical education enterprise. The audience for this research study includes managers and students of very large-scale complex networks and policy systems; those who are currently attempting to extend the new sciences of chaos and complexity to social systems; and policy makers and academic health administrators who are interested in the conduct and management of medical education. Because the research focused on changes in academic medical centers and managed health care delivery markets in the framework of nonlinear dynamics, there are two bodies of relevant literature. The first body of literature derives from the complexity sciences; the second is found in academic medicine—published writings from educational, research, clinical, and other organizations that constitute the enterprise of medical education. The complexity science literature is addressed in this chapter. The literature describing the medical education enterprise is discussed in chapter 4.

In addition, it should be noted that there is a long tradition of population ecology and institutional approaches to organizations, organizational fields and organizational populations. While it is not the intent of this dissertation to add to these theoretical approaches, I have included a brief discussion of these perspectives at the end of this chapter to acknowledge prior work that has focused on populations of networked organizations, and to note the presence of implicit assumptions about linearity and stabilizing or equilibrium forces on organizational behavior. A study by Scott et al. was chosen to illustrate some similarities between concepts discussed in institutional and complexity theories.[1]

The primary conceptual literature that was used as the basis for identifying and explaining patterns in the behavior of academic medical centers was complexity science. Complexity science is the study of complex adaptive systems, and is highly interdisciplinary. It originated in

[1] Scott et al., *Institutional Change and Health Care Organizations: From Professional Dominance to Managed Care*.

the physical and biological sciences, and was subsequently adopted by anthropologists, economists, sociologists, organizational and management theorists, and policy analysts to address fundamental questions about social systems. Complexity science is grounded in a number of interrelated concepts that are independent of the particular discipline to which it is applied. In fact, the seemingly universal application of the concepts of complexity across disciplines accounts for their appeal to researchers of diverse disciplines. This research study applied the methodological tools of complexity science to facilitate an understanding of large-scale networked groups of organizations.

In this research study, I used complexity science to examine the actions of a population of organizations to gain a better understanding of their behavior as a nonlinear dynamic system. Specifically, I applied complexity science as a methodological tool for understanding changes in academic medical centers that were concurrent with major changes in the health care delivery sector. Application of the complexity perspective as a metaphor has dominated the literature on chaos and complexity in social systems. While the use of complexity science has introduced new and useful concepts and approaches for describing and interpreting the behavior of organizations, discussions of the mathematical tools associated with this perspective have more often remained theoretical and illustrative than applied to real data. One of the major contributions of this dissertation is the extension of the application of complexity science beyond metaphor toward model specification, data collection, and nonlinear analysis.

The other major contribution of this dissertation is to the medical education literature. Both the scope and variety of the data that were brought to bear on the research question were unusually large. The longitudinal nature of data used in the study meant that the total accumulation of information for this study was substantial and possibly unique among studies of the medical education enterprise. The rich description developed from the data that were amassed for this research study can serve as the basis for other explorations of the nature and evolution of academic medical centers.

Background

To understand the context of the development of the sciences of chaos and complexity, it is helpful to briefly review the tradition and some of the concepts of system dynamics. System dynamics developed from the same intellectual foundation as cybernetics, which was built on the engineer's framework of system control and focused on negative feedback loops. System dynamics was built on models of economic and industrial systems in mathematical terms.[2,3] System dynamics and cybernetics differ in some important assumptions, most notably on the issue of nonlinearity and the possibilities of positive as well as negative feedback and non-equilibrium as well as equilibrium. Nonlinearity occurs when some action or system condition has a variable (rather than proportional) effect on an outcome or output.

System dynamics models systems at a macro level and assumes the presence of nonlinear relationships among variables in the system. The models are specified in mathematical terms in which the variables affecting the system are "set" externally by the environment. Although the system may adapt to its environment, it is seen as a closed system. It operates with reference to a point at the boundary with its environment, either amplifying or damping in relation to that point. Because the system dynamics approach invokes the idea of feedback, the notion of an external point of reference is key. The development of system dynamics and its application to social systems is associated with Forrester (1958)[4]. He noted that:

> Systems of information feedback control are fundamental to all life and human endeavour, from the slow pace of biological evolution to the launching of the latest satellite. A feedback control system exists whenever the environment causes a decision which in turn affects the original environment.

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[2] Gareth Morgan, *Images of Organization*, 2nd ed. (Thousand Oaks, CA: Sage Publications, 1997).
[3] W. Richard Scott, *Organizations: Rational, Natural, and Open Systems*, third ed. (Englewood Cliffs, New Jersey: Prentice Hall, 1992).
[4] Jay Forrester, "Industrial Dynamics: A Major Break-through for Decision-Making," *Harvard Business Review* 36, no. 4 (1958): 4.

Stacey (2000) described the application of the principles of system dynamics to complex human systems in the following terms:[5]

- Complex systems often produce unexpected and counter-intuitive results
- In complex systems—nonlinear relationships with positive and negative feedback—the links between cause and effect are distant in time and space
- Complex systems are highly sensitive to some changes but remarkably insensitive to many others

The system modeled by system dynamics is not capable of moving from one qualitative state or type of behavior to another of its own accord; a triggering event from the environment is needed.[6]

Scott (1995) cited general systems theory for contributing a focus by institutional theory on the environment.[7] According to institutional theory, institutions operate as important components of the environments of all organizations. Scott defined social institutions as follows: "Institutions consist of cognitive, normative and regulative structures and activities that provide stability and meaning to social behavior." Economists and legal scholars have emphasized the regulative environment, while political scientists and sociologists have stressed the importance of normative systems. Institutional forms vary in the degree to which they emphasize each of the three elements from which institutions are constructed, but each element focuses on stability and equilibrium. Regulatory and normative structures, for example, consist of formal and informal rules and sanctions designed to provide stability in transactions and other social interactions. Although institutional theory takes the environment into account, the assumption is that the environment has a stabilizing effect, moving systems toward equilibrium through feedback. Later in this chapter, I discuss a study of health care delivery systems based on a framework of

[5] Ralph D. Stacey, *Strategic Management and Organisational Dynamics*, 3rd ed. (London: Prentice Hall, 2000) 157.
[6] Ralph D. Stacey, *Strategic Management and Organizational Dynamics*, 2nd ed. (London: Pitman Publishing, 1996).
[7] W. Richard Scott, *Institutions and Organizations* (Thousand Oaks, CA: Sage, 1995) 33.

institutional theory by Scott et al. (2000), and compare some of the concepts to those developed by complexity theory.[8]

Concepts of Chaos and Complexity

A relatively small list of books covers the basics of chaos and complexity theory. Waldrop (1992) provided an overview of the origins of complexity theory, through the eyes of its earliest researchers, in *Complexity: The Emerging Science at the Edge of Order and Chaos*.[9] Gleick's book, *Chaos*, is considered a classic in the field and introduced the public to chaos theory.[10] Kauffman's book, *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity* (1995), explored the application of complexity theory to evolution, and possible implications of complexity theory for economics and organizational studies.[11] *Leadership and the New Science: Learning about Organization from an Orderly Universe* (Wheatley, 1992) provided a broad survey of quantum mechanics and complexity theory, and speculated on their relevance to organizations and leadership.[12]

The following sections briefly describe several of the concepts of chaos and complexity that were most useful in understanding the behavior of academic medical centers. They include nonlinearity, logistic equations, phase planes and phase portraits, attractors, sensitive dependence on initial conditions, complex adaptive systems, self-organization, emergence, and the nature of prediction in deterministic nonlinear systems.

Nonlinearity

Most of the characteristics of chaos and complexity are related to the nonlinear nature of systems—often unacknowledged in mathematics, physics, biology, ecology, economics, and most other scientific and social scientific disciplines. Gleick's 1987 book *Chaos*, that introduced

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[8] W. Richard Scott et al., *Institutional Change and Health Care Organizations: From Professional Dominance to Managed Care* (Chicago: The University of Chicago Press, 2000).
[9] M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon & Schuster, 1992).
[10] James Gleick, *Chaos: Making a New Science* (New York: Penguin Books, 1987).
[11] Stuart Kauffman, *At Home in the Universe* (New York: Oxford University Press, 1995).

chaos theory to the broader public, noted that when scientists encountered nonlinear systems, they could not “see” what they really were but believed they were aberrations that could be dismissed. Few recognized that linear systems were actually the aberrations. As more and more investigators came to the realization that a large “realm of physical experience” did not fit in the current framework, the stage was set for the nonlinear revolution.[13]

Calculus, the quintessential Newtonian tool, profoundly shaped our vision of the world. Differential calculus allowed mathematicians to solve certain types of problems, working with a certain set of assumptions. The result was that the world came to be defined as a system that (at least in principle) embodies the same characteristics as integrable problems: independent elements changing in isolation from each other; smooth continuous change; reducibility to simpler parts; approximation by smooth curves; and prediction and control. Holland (1995) noted that it is much easier to use mathematical tools when systems have linear properties.[14] Stacey (1996) similarly noted that considerable effort is often expended to justify the assumption of linearity.[15] A straight line can rarely describe the long-term behavior exhibited by social systems; eventually, most events that involve human action exhibit nonlinearity.

Nonlinear systems, in which input is not proportional to output, were traditionally neglected by Newtonian mechanics because they did not fit the image of the world accepted by science. More recently, nonlinear systems were approached as if they had only one function and/or independent variables, i.e., special cases of nonlinearity. With the advent of chaos theory, scientists and mathematicians were given a framework for thinking about nonlinear, interdependent systems; the development of tools followed.

Goldstein (1994) suggested a new approach to organizational change based on the theory of self-organization.[16] He noted that conventional approaches to organizational change assumed that

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[12] Margaret J. Wheatley, *Leadership and the New Science: Learning About Organization from an Orderly Universe* (San Francisco: Berrett-Koehler Publishers, Inc., 1992).
[13] Gleick, *Chaos: Making a New Science* 67-68.
[14] John H. Holland, *Hidden Order* (Reading, MA: Helix Books, 1995).
[15] Stacey, *Strategic Management and Organizational Dynamics*.
[16] Jeffrey Goldstein, *The Unshackled Organization: Facing the Challenge of Unpredictability Through Spontaneous Reorganization* (Portland, Oregon: Productivity Press, 1994).

systems were linear—a questionable assumption. Goldstein identified the following differences between linear and nonlinear systems:

- In linear systems change is gradual and incremental, whereas in nonlinear systems change can be precipitous and revolutionary
- In linear systems the whole is merely the sum of the parts, whereas in nonlinear systems the whole is greater than the sum of the parts
- In linear systems interaction is only one-way, whereas in nonlinear systems interaction is multidirectional
- Linear systems have predictable outcomes, whereas nonlinear systems may have unpredictable outcomes
- Linear systems at equilibrium conditions remain the same, whereas nonlinear systems at far-from-equilibrium conditions can undergo transformation

Logistic equations

Unfortunately, there are no simple or general solutions to nonlinear mathematical problems. In the past, there was a tendency to deal with the problem of nonlinearity by either treating it as a deviation, or random "noise," and ignoring it, or by transforming the data so that a linear solution could be applied. Transformations—taking the logarithm of a variable, for example—assumed a continuous function with a slope that could be calculated at each point. This assumption is fundamental to calculus. Since nonlinear phenomena may have discontinuities and/or oscillations, the tools of calculus and linear regressions (even with transformed data) often cannot be used. There are, however, equations that can describe the behavior of nonlinear systems. Such equations are usually identified in complexity science literature as logistic equations, first-order difference equations, or logistic difference equations.[17,18,19] A first-order difference equation is a recursively defined sequence of values; what makes the equation first-order is that we only need to know the immediately previous value to find the next value. It is also worth noting that the first-order difference equation describes a deterministic system—a

[17] A. B. Çambel, *Applied Chaos Theory: A Paradigm for Complexity* (Cambridge, MA: Academic Press, Inc., 1993).
[18] L. Douglas Kiel and Euel Elliott, *Chaos Theory in the Social Sciences: Foundations and Applications* (Ann Arbor: The University of Michigan Press, 1997).

system value at a point in time is dependent on or determined by the value that immediately preceded it.

Logistic equations can take a number of forms, but one of the simplest forms is the one typically discussed in the literature—one that has been applied to biology, epidemiology, economics, and various other disciplines. May (1976) published a review article that provides one of the best summaries of the mathematical basis of first-order difference equations.[20] He noted that the "very simplest nonlinear difference equations can possess an extraordinarily rich spectrum of dynamical behaviour, from stable points, through cascades of stable cycles, to a regime in which the behaviour (although fully deterministic) is in many respects 'chaotic,' or indistinguishable from the sample function of a random process."

Expressed in its discrete form, the equation is

$$N_{t+1} = F(N_t)$$

N represents a time-dependent variable. The value of N at time $t+1$ is a function of the value of N at the immediately preceding time, t.

The general form $F(N_t)$ can contain a parameter that "tunes" the equation's description of a system's behavior. Tuning does not refer to something that is imposed on the system by either the equation or someone whose responsibility it is to manage the system; rather, it is a way of referring to the effect of the value of the tuning parameter on the way in which the logistic equation describes the behavior and limits of the system. The following paragraphs illustrate mathematically and graphically the influence of a parameter on the values that can be iteratively generated from the logistic equation.

Many social systems of interest grow or evolve; population dynamics therefore serves as a useful example of a system that shows growth behavior. An analysis of population dynamics using the

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[19] J.M.T. Thompson and H.B. Stewart, *Nonlinear Dynamics and Chaos*, Second ed. (Chichester, England: John Wiley & Sons, Ltd., 2002).
[20] Robert M. May, "Simple Mathematical Models with Very Complicated Dynamics," *Nature* 261, no. 10 (1976): 459.

equation, $N_{t+1} = F(N_t)$, illustrates the effect of a tuning parameter on the limits of a system. If 1,000 young salmon are introduced into a river each year and they have a 30% survival rate (i.e., 30% of them return to the river the following year), the number of salmon in the creek each year is described by the following equation:

$$N_{t+1} = .3(N_t) + 1{,}000$$

The parameter value, .3, determines the annual population of salmon in the river.

The general form $F(N_t)$ may contain more than one parameter. Two parameters appear in the equation as follows:

$$N_{t+1} = N_t(a - bN_t)$$

Continuing to use population studies as an example, these parameters (*a* and *b*) can be considered proportionality constants, representing birth rate and death rate, respectively. When $b = 0$ (no deaths are occurring) and $a > 1$ (births are occurring), the equation describes a population that is growing. That is, if $b = 0$, N_{t+1} is allowed to increase by the constant product, $N_t(a)$, or the birth rate.

An important property of this equation is that the carrying capacity of the system—in this example, the population limit—is defined by the ratio *a/b*. If the initial value of N is greater that the ratio *a/b*, the population will decrease. If the initial value of N is less than the ratio *a/b*, the population will increase toward *a/b.* These relationships and the effect of the parameters on system behavior are easier to see if the equation is rewritten to include only the parameter *a*, and iterative values of N_t are graphed using various values of *a* in the equation. By writing $X = bN/a$, the equation may be brought into a form that is frequently encountered in complexity science literature:[21,22,23]

[21] John Briggs and F. David Peat, *Turbulent Mirror: An Illustrated Guide to Chaos Theory and the Science of Wholeness* (New York: Harper & Row, 1989).
[22] Çambel, *Applied Chaos Theory: A Paradigm for Complexity*.
[23] H. Richard Priesmeyer, "Logistic Regression: A Method for Describing, Interpreting, and Forecasting Social Phenomenon with Nonlinear Equations," in *Chaos and Society*, ed. A. Albert (Amsterdam: IOS Press, 1995).

$$X_{t+1} = aX_t(1 - X_t)$$

Multiplying out the terms yields another form of the equation:

$$X_{t+1} = aX_t - aX^2_t$$

In this form, it can more readily be seen that the first term on the right-hand side of the equation is positive and linear but the second term is squared, which makes it quadratic or nonlinear. The second term is the mathematical fingerprint that identifies the logistic equation as nonlinear; this is an equation that can be used to describe nonlinear behavior.

If the initial value of X_t is very small, the second term on the right side is also very small (regardless of the value of a) and can be disregarded. The value of X_{t+1} is nearly equal to aX_t, so the growth appears to be substantially linear. This is illustrated by the broken line sections of the curve in Figure 2-1, which has been calculated and drawn with the value of a = 2.707.

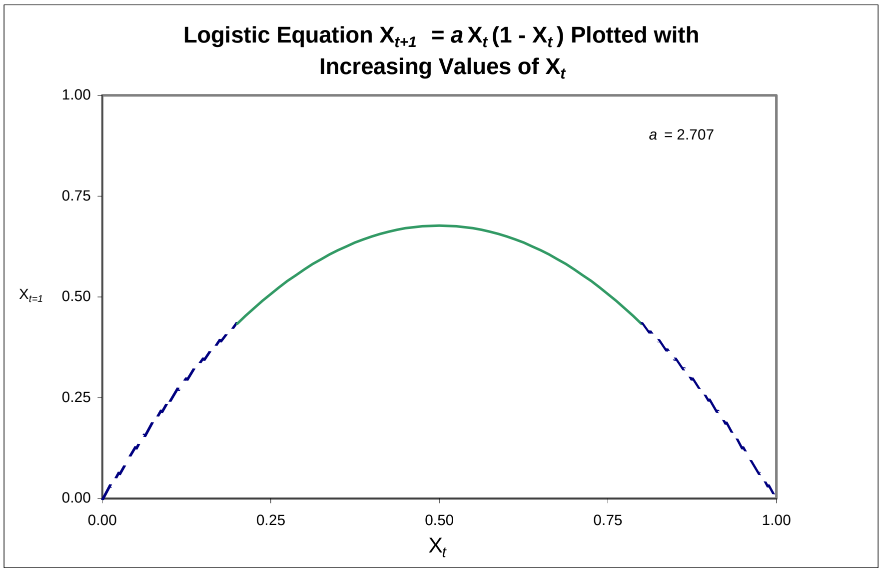

Figure 2-1

As the values increase, the nonlinear term of the equation ($-aX_t^2$) will become larger and cannot be ignored. Moreover, the negative sign eventually causes the values to begin to decrease. Exactly when this inflection point is reached depends on the value of *a*, which is why *a* is considered the tuning parameter in the equation; its value determines both the steepness of the function and the point at which the curve changes from increasing to decreasing. In population studies, this relationship illustrates the propensity of populations to increase when their numbers are small and to begin to decrease when their numbers get large—exactly how large is determined by the population's limit or carrying capacity.

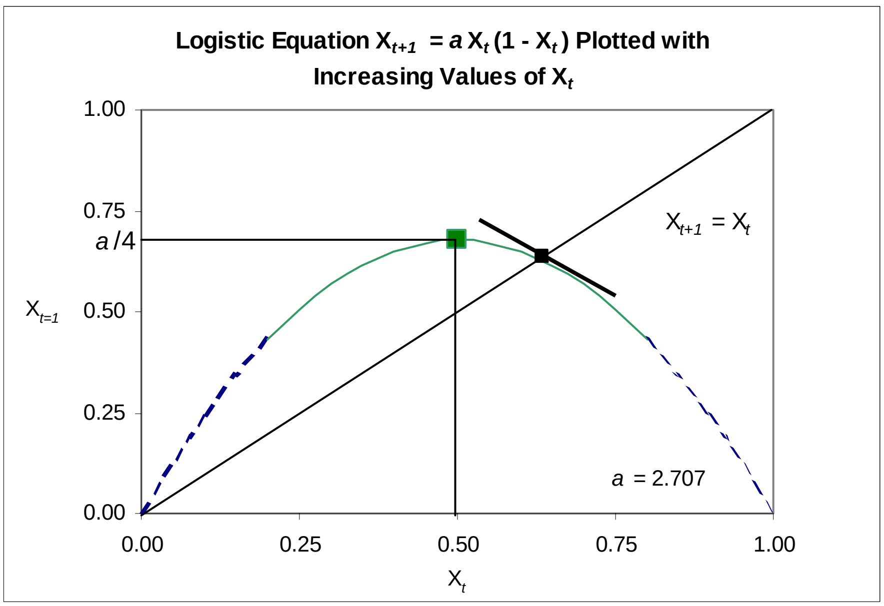

Figure 2-2

The relationships among X_t, X_{t+1}, and *a*, and the intervals over which these relationships can be defined can be further illustrated using the values in Figure 2-1. Figure 2-2 illustrates that the inflection point of the curve that results from calculating and plotting successive values of (X_t, X_{t+1}) occurs precisely at the point at which X_{t+1} equals the value of *a* divided by 4 (i.e., 2.707/4 = 0.67675) and X_t is 0.5. This observation is not unique to these values; the inflection point is so defined regardless of the value of *a*. The interval over which the values of X_{t+1} are greater than zero is $0 < X_t < 1$. If X_t exceeds 1, subsequent iterations diverge toward infinity.[24] This illustrates the limits of the data: values of X_t should range between 0 and 1 or be transformed to adhere to

[24] May, "Simple Mathematical Models with Very Complicated Dynamics."

these limits, and the value of the tuning parameter can be expected to range between 1 and 4 to observe what May described as "nontrivial dynamical behaviour."[25]

The graph shown in Figure 2-2 also has a line drawn at 45 degrees from the origin. This line intersects the curve on the downward slope where the value of X_t equals 1-(1/*a*). May (1976) described this point as an equilibrium value or "fixed point" of X in the equation; in population studies, this is zero population growth.[26] A line is drawn tangentially through the point of intersection. In Figure 2-2, the angle of this line is less than 45 degrees; if it were exactly 45 degrees, it would be perpendicular to the other 45-degree line. May described such lines with slopes of less than 45 degrees as stable (at least locally).

The slope of the line drawn tangentially to the curve through the fixed point changes as the value of *a* changes, as shown in Figure 2-3. As *a* increases, the curved line becomes steeper and the corresponding slope of a line drawn tangentially to the curve through the fixed point becomes greater than 45 degrees and therefore, unstable. The effects of increasing values of the tuning parameter are illustrated in chapter 5, the methodology chapter.

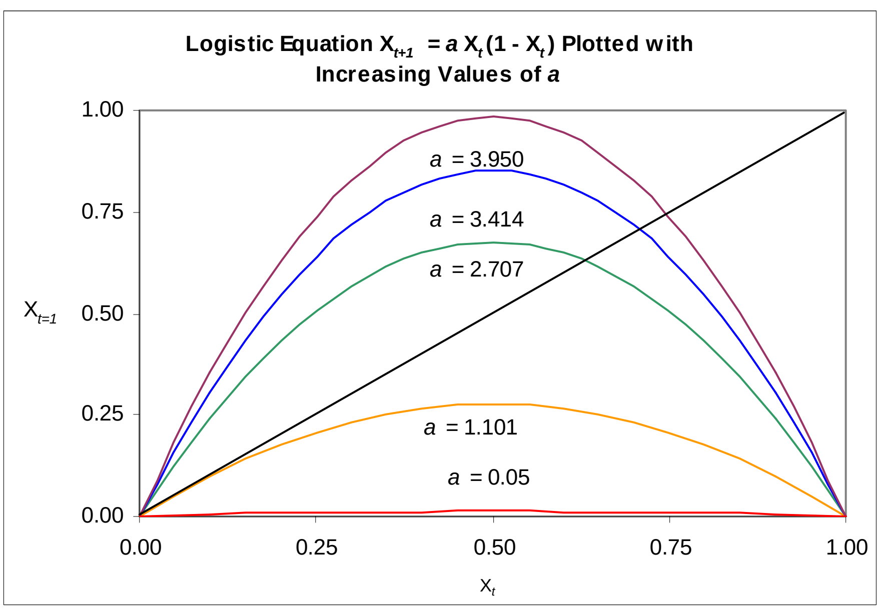

Figure 2-3

25 Ibid.: 460.
26 Ibid.

Logistic equations provide a way of mathematically describing nonlinear dynamic systems. Difficulties in determining which equation might best describe observed data, and in determining the value of the tuning parameter in that equation, are discussed further in chapter 5. The next section discusses a graphical way of describing nonlinear dynamic systems.

Phase planes and phase portraits

Plotting data that describe a nonlinear dynamic system on a phase plane provides a good way to visualize the behavior of the system. Examining the graphic representation of the temporal evolution of one or a pair of variables gives a sense of whether the system is stable or converging toward equilibrium, or if it is neither, the bounds within which the system is behaving. It provides a qualitative view of the whole system.

These plots are also known as phase plots or phase portraits. They show the data in a two-dimensional Cartesian plane with the coordinate 0,0 at the center, and provide a visual display of the behavior of the system. When connected, the data points that represent the state of the system at successive points in time form a trajectory that describes movement of the system through time. The phase plane graph describes the change over time of the values of one or a pair of variables by iteratively plotting the direction and amount of change in the values from the immediately preceding time, *t-1*, to the present time, *t*. Thus, the phase plane represents the marginal values or changes in the variable rather than the value of the variable at each point in time.

The trajectory may move in various directions, create strange patterns, or even come to a stop by "zeroing in" on one location.[27, 28, 29, 30] The center of the phase plane (0,0) represents no change from the previous time period. Quadrants of the phase plane are labeled counterclockwise per standard notation, starting in the upper right quadrant. In the upper right quadrant (Q1) both *t* and *t-1* are increasing. In the upper left quadrant (Q2) *t* is increasing and *t-1*is decreasing. In the

[27] Gleick, *Chaos: Making a New Science*.
[28] Roger Lewin, *Complexity: Life at the Edge of Chaos* (New York: Macmillan Publishing Co., 1992).
[29] Russ Marion, *The Edge of Organization* (Thousand Oaks, CA: Sage Publications, 1999).
[30] Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos*.

lower left quadrant (Q3) both *t* and *t-1* are decreasing. In the lower right quadrant (Q4) *t* is decreasing while *t-1* is increasing.

Phase planes offer one of the few means by which changes in variables over time and with respect to other variables can be easily visualized. They can be created from time series data without any tools other than spreadsheet software, and they allow the researcher to closely examine the morphology of the graphical representation of the system. The pattern and structure revealed by the graphical analysis may reveal the underlying order known as an attractor.

Attractors

The tendency of a deterministic nonlinear system to follow patterns, and to return to these patterns if disturbed, is explained by invoking the term "attractor." The term "derives from the observation that if a system in phase space is near an attractor, it tends to evolve towards the state represented by that attractor."[31] Cohen and Stewart (1994) described an attractor as "a region of phase space that 'attracts'all nearby points as time passes."[32] The larger area of phase space around an attractor is its basin of attraction. Attractors do not imply goal orientation: system states do not end up on the attractor due to any advance knowledge that they should be there. Rather, the dynamics of the system "push" the system, causing points to flow through phase space and create a phase portrait of the dynamical system.

An attractor is a preferred position for the system; i.e., the system will evolve until it arrives at the attractor, and will stay there unless otherwise disturbed. An attractor can be a

- Point, representing a steady state
- Regular path or periodic attractor, representing repeating processes; also called 2-cycle, 4-cycle, etc. depending on the number of possible states or values
- Strange attractor, an infinite nonrepeating sequence

Graphical examples of each of these are provided in chapter 5. Recalling the earlier discussion of the effect of the value of the tuning parameter, *a*, on the pattern of the data that are generated

[31] Çambel, *Applied Chaos Theory: A Paradigm for Complexity* 59.

from the equation, it should be clear that the values of *a* increase as the attractor moves from a point to a two-period and four-period cycle to a strange attractor.

Systems described by strange attractors exhibit patterned order and boundaries. Dubbed "strange attractors" by physicist David Ruelle, these attractors were identified during study of the onset of turbulence in gas and liquid systems. Traced in phase space, strange attractors represent the shape of unpredictability within a boundary and provide a picture of the system's interactions as a whole. An attractor in a nonlinear dynamic system may be "strange" because it has a recognizable shape and boundaries, but how or where the shape will form cannot be predicted.[33] Stacey (2000) described the strange attractor as "paradoxically stable and unstable, regular and irregular, predictable and unpredictable, at the same time."[34] Each attractor occupies a relatively small area of overall phase space, and a system may be expected to contain multiple alternative attractors, providing several different possible behaviors for the same system. Which behavior actually occurs depends upon both the initial configuration of the system and subsequent perturbations (i.e., the system's history).

Kiel and Elliott (1996) emphasized the conceptual nature of attractors by explaining that an attractor "functions as an abstract representation of the flow, or motion, of the system." As such, an attractor in a nonlinear system can be used as a model of the structure of underlying order because it "stores information about a system's behavior over time."[35] Jaditz (1997) described an attractor as "a parsimonious description of the long-run behavior of the system."[36]

Because the patterns of attractors reveal long-term trends, they give form and structure to behavior we would otherwise call random. Once the attractor is constructed from (or more

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[32] Jack Cohen and Ian Stewart, *The Collapse of Chaos: Discovering Simplicity in a Complex World* (New York: Penguin, 1994) 205.
[33] B. Zimmerman, "A Complexity Science Primer: What Is Complexity Science and Why Should I Learn About It?," in *Edgeware: Complexity Resources for Health Care Leaders*, ed. B. Zimmerman, C. Lindberg, and P. Plsek (Irving, TX: Voluntary Hospitals of America, 1998).
[34] Stacey, *Strategic Management and Organisational Dynamics* 262.
[35] Douglas L. Kiel and Euel Elliott, "Exploring Nonlinear Dynamics with a Spreadsheet: A Graphical View of Chaos for Beginners," in *Chaos Theory in the Social Sciences*, ed. Douglas L. Kiel and Euel Elliott (Ann Arbor: The University of Michigan Press, 1997), 26-27.
[36] Ted Jaditz, "The Prediction Test for Nonlinear Determinism," in *Chaos Theory in the Social Sciences: Foundations and Applications*, ed. Douglas L. Kiel and Euel Elliott (Ann Arbor: The University of Michigan Press, 1997), 69.

accurately, revealed by) the data, the relative amount of time a system spends on various portions of the attractor constitutes a probability distribution, which is useful in a number of ways. For example, we know that when a system is perturbed, the system trajectory is likely to return to the boundaries of the attractor. Knowledge about the probability distribution of past behavior provides us an idea of the area of the attractor to which the system is most likely to return. Images of attractors can also help us identify features of system transitions, the presence of multiple attractors, and the possibility of strategic options.[37]

Cohen and Stewart (1994) described attractors as emergent phenomena in dynamical systems that can be identified and interpreted only after the researcher observes the system's progression from an initial state; an attractor's characteristics are not easily predicted from looking at the equation that describes the dynamics.[38] This is due in part to the nature of the nonlinear dynamic system, in which the trajectory of the system is determined by the value of the first data point. This sensitive dependence on initial conditions is another key characteristic of complex systems.

Sensitive dependence on initial conditions

Nonlinear dynamic systems are deterministic, but they are nevertheless unpredictable over the long term because any two trajectories that start at different values (i.e., locations) will separate as they move forward in time. A small initial separation will grow to a multiple of itself at the first iteration in time, and, depending on the rules governing the dynamics, will typically grow by a similar multiple at the next iteration. Small differences in input can quickly become large differences in output. Such systems are said to be sensitively dependent on initial conditions.[39,40] Kauffman (1995) noted that tiny differences in initial conditions make vast differences in the subsequent behavior of the system.[41]

This was the property that Lorenz discovered in his weather prediction calculations, when in 1961 he noticed that a tiny variation in initial conditions—an inadvertent rounding of a

[37] Glenn E. James, *Chaos Theory: The Essentials for Military Applications* (Newport: Naval War College, 1996).
[38] Cohen and Stewart, *The Collapse of Chaos: Discovering Simplicity in a Complex World* 207.
[39] John L. Casti, *Complexification: Explaining a Paradoxical World through the Science of Surprise* (New York: Harper Perennial, 1995).
[40] Briggs and Peat, *Turbulent Mirror: An Illustrated Guide to Chaos Theory and the Science of Wholeness*.
[41] Kauffman, *At Home in the Universe*.

number—had huge downstream effects. This came to be known as the butterfly effect.[42] The butterfly effect encompassed the notion that a butterfly stirring the air in Hong Kong could transform weather systems in New York the following month. Lorenz (1993) chose sensitive dependence as an acceptable definition of chaos.[43]

Mathematically, sensitive dependence on initial conditions can be demonstrated by calculating iterations of a logistic equation using two different initial values of X_t. Such an example is shown in Figure 2-4, in which the logistic equation had a value of *a* near the upper limit (3.95) and the initial values of X_t were 0.15 and 0.50. The results of calculating the value of X_{t+1} for 30 iterations illustrate the effect of the two different initial conditions, as the two graphed lines start out with a similar pattern but quickly diverge.

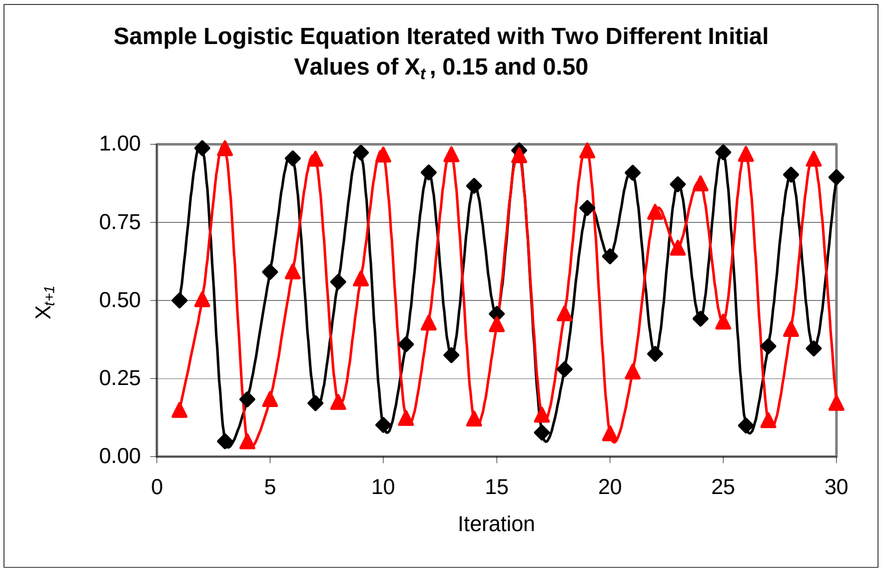

Figure 2-4

Complex adaptive systems

Complexity science is not a single theory; it is the study of complex adaptive systems. Of particular interest are the patterns of relationships within the system, how they are created and sustained, how they self-organize, and how outcomes emerge. Complex adaptive systems seem to be everywhere—stock markets, human brains, forest ecosystems, manufacturing businesses,

[42] Gleick, *Chaos: Making a New Science*.

and hospitals are all examples. Complex adaptive systems can also be found at all levels within a single system—the organization of neurons in the brain, symbols in the human mind, minds assembled in an organization, organizations within a society, and so on. All are complex adaptive systems, one fitting into another; an entire complex adaptive system can be a single node or agent in another complex adaptive system.[44,45]

A brief analysis of the term, "complex adaptive systems," is useful in helping us to understand these systems—"complex" implies diversity of elements and connections; "adaptive" implies the ability to change and learn from experience; and a system is a group of interacting parts that function as a whole. In a complex adaptive system, the interacting parts are often described as agents. These agents interact with each other according to sets of local rules that allow each to operate in its own best interests. The agents examine and respond to each other's behavior; their interactions become incorporated into the system through feedback processes, thereby changing both the agents' behavior and the system in which they act.[46]

In the past several years, social science, management, and organization researchers have shown an increasing interest in the subject of complex adaptive systems.[47,48,49,50,51] These authors have argued that both complex adaptive systems and organizations are:

- Nonlinear, such that there is no proportionality between cause and effect
- Sensitively dependent upon initial conditions, such that system outcomes are difficult to predict but are shaped by the system's history
- Replete with feedback loops that exhibit both negative and positive feedback

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[43] Edward N. Lorenz, *The Essence of Chaos* (Seattle: The University of Washington Press, 1993).
[44] Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos*.
[45] Kauffman, *At Home in the Universe*.
[46] Holland, *Hidden Order*.
[47] Goldstein, *The Unshackled Organization: Facing the Challenge of Unpredictability Through Spontaneous Reorganization*.
[48] Steven E. Phelan, "From Chaos to Complexity in Strategic Planning" (paper presented at the 55th Annual Meeting of the Academy of Management, Vancouver, British Columbia, Canada, August 6-9, 1995 1995).
[49] E. Overman, "The New Science of Management, Chaos and Quantum Theory and Method," *Journal of Public Administration Research and Theory* 6, no. 1 (1996).
[50] Stacey, *Strategic Management and Organizational Dynamics*.
[51] Marion, *The Edge of Organization*.

- Capable of self-organization, such that new structures, patterns, or properties can arise without central direction
- Subject to emergence, such that characteristics of the system are not predictable by examining the individual components of the system (i.e., the whole is greater than the sum of the parts)

Complex adaptive systems and self-organization are of particular interest to researchers who want to understand organizational adaptation through the lens of complexity science. The perspective of complex adaptive systems attempts to account for the nonlinear aspects of organizations and their environments. For practical purposes, a manager in an organization might choose to provide resources and general guidelines to support self-organization as an alternative to a centralized command-and-control approach to organizational change.

Self-organization

The concept of self-organization is fundamental to the perspective of complexity science. Self-organization is a "process or series of processes, in a complex system whereby new emergent structures, patterns, behaviors, directions, and properties arise without being externally imposed on the system."[52] In physical systems, one of the most commonly cited examples is the Bénard system, in which a liquid in a shallow, covered dish is heated from the bottom.[53,54,55,56] At a certain temperature, the liquid spontaneously restructures from a smooth-surfaced liquid to a turbulent mixture with hexagonal cells that are stable as long as heat is applied.

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[52] F. Stephen Larned, "Complexity Science and Leadership of Academic Health Centers," in *Creating the Future: Innovative Programs and Structures in Academic Health Centers*, ed. Clyde H. Evans and Elaine R. Rubin (Washington, D.C.: Association of Academic Health Centers, 1999), 20.
[53] Ilya Prigogine, *The End of Certainty: Time, Chaos, and the New Laws of Nature* (New York: The Free Press, 1997).
[54] Fritjof Capra, *The Web of Life: A New Scientific Understanding of Living Systems* (New York: Anchor Books, 1996).
[55] Briggs and Peat, *Turbulent Mirror: An Illustrated Guide to Chaos Theory and the Science of Wholeness*.
[56] Peter Coveney and Roger Highfield, *Frontiers of Complexity: The Search for Order in a Chaotic World* (New York: Fawcett Columbine, 1995).

Kauffman based his work concerning the origin of life on self-organization, or "order for free," which he saw as key to the emergence of life.[57,58] Kauffman (1995) noted, in his preface to *At Home in the Universe*, that

> Self-organization is the root source of order. The order of the biological world, I have come to believe, is not merely tinkered, but arises naturally and spontaneously because of these principles of self-organization—laws of complexity that we are just beginning to uncover and understand.

Self-organization has been seen as a prominent organizational characteristic.[59,60,61] Goldstein described self-organization in social systems as a discontinuous, qualitative change that is not hierarchically driven from the top; that realizes an innate potential to change; that takes advantage of unexpected events; and that represents system transformation in far-from-equilibrium conditions.[62] Stacey (1996) described system agents organizing themselves to produce a new pattern without any blueprint.[63]

While self-organization appears to occur in many kinds of systems (physical, biological, and social), complexity science literature does not assert that self-organization is a phenomenon that occurs in all systems and/or under most or all conditions. Rather, the phenomenon is reserved for a condition known as the "edge of chaos"—a critical point of the system where a small change can either push the system into chaotic behavior or lock the system into stable behavior.[64] Many organizations have both stable (locked in) subsystems, e.g., core processes for which standard operating procedures exist and work well, and less constrained, less stable, and perhaps even chaotic subsystems that are unpredictable and often unmanageable. This mixture can obscure the

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[57] Kauffman, *At Home in the Universe*.
[58] Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos*.
[59] Goldstein, *The Unshackled Organization: Facing the Challenge of Unpredictability Through Spontaneous Reorganization*.
[60] Ralph Stacey, "The Applicability of the Science of Complexity to Organisations," (Business School Centre for Complexity and Management, 1995).
[61] Ralph Stacey, *Complexity and Creativity in Organizations* (San Francisco: Berrett Koehler, 1996).
[62] Jeffrey Goldstein, "Using the Concept of Self-Organization to Understand Social System Change: Strengths and Limitations," in *Chaos and Society*, ed. Alain Albert (Amsterdam: IOS Press, 1995).
[63] Stacey, *Strategic Management and Organizational Dynamics*.
[64] Lewin, *Complexity: Life at the Edge of Chaos*.

presence of nonlinear dynamic systems within a social system, but it also helps explain why organizations and other social systems function as well as they do.

Very complicated behaviors or structures can result from collections of simple components when a system undergoes spontaneous self-organization. For example, members of a society satisfy their material needs by organizing themselves into an economy through the exchange of goods and services. No one consciously plans the organization and emergence of a market economy; groups of participants somehow acquire collective properties that they may never have individually possessed, or that would have simply not made sense for individuals to possess. These behaviors and the resulting structures are characterized as "emergent"; self-organization is a way of understanding emergent, collective behavior in complex adaptive systems.

Emergence

Lewin (1992) described the notion of emergence—the tendency of systems to create order from chaos—as "the principal message of the science of Complexity and its role in illuminating patterns in nature."[65] Complexity theory attempts to identify the rules governing the emergence of system structure and order from the interactions of simple components.

Marion (1999) discussed the emergence of order as a key characteristic of complex adaptive systems.[66] According to Marion, "interacting entities—atoms, molecules, people, organizations—tend (a) to correlate with one another because of their interaction, and (b) to catalyze aggregation" (p. xii). Emergent behavior of the whole is more complex than the behavior of the parts, just as the whole is greater than the sum of its parts. New and unexpected structures, patterns, or processes originate as entities (products, people, institutions) interact.

Patterns emerge not because someone expends energy specifically for the purpose of creating them, but as a consequence of interaction. Kauffman's term "order for free" describes this process.[67] Emergent behaviors and structures are the result of self-organization of system components, but the resulting behaviors and structures may have their own rules, patterns, and

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[65] Ibid. 191.
[66] Marion, *The Edge of Organization*.
[67] Kauffman, *At Home in the Universe*.

potential for outcomes not present in any or all of the system components.[68] Patterns of self-organization and emergence can be seen in the economy, the nervous system, ecosystems, and the behavior of individuals in the face of a natural disaster.

Stacey (1996) noted the following examples of emergence:[69]

- A single water molecule is inert; when billions are aggregated, however, gurgling, turbulence, and splashing can emerge. Add temperature shifts and wind, and waveforms and rainstorms emerge. With falling temperatures, ice or the fractal elegance of snowflakes, emerge.
- Multiple vehicles aggregate, and traffic jams emerge
- Individuals come together in groups as crowds, teams, or mobs, each with a different emergent character
- Consciousness emerges from aggregate neuronal activity
- Swarm behavior emerges from a bee colony
- In cartoons, humor is an emergent phenomenon. The cartoonist brings together two or more previously incompatible ideas, and their juxtaposition causes us to chuckle

Emergent phenomena have been described as the most enigmatic aspect of complex adaptive systems.[70] When individual agents interact on the basis of relatively simple rules, they self-organize at a higher systems level with collective properties that are different from those of the individual agents. One example of emergence is the synchronized flight of a flock of birds, which emerges from the interactions of individual birds without centralized or external control mechanisms. Flocking is a particularly evocative example of emergence, illustrating that complex global behavior can arise from the interaction of simple local rules. Flocking behavior has been modeled on a computer with a relatively simple set of rules based on separation, alignment, and cohesion.[71]

[68] Cohen and Stewart, *The Collapse of Chaos: Discovering Simplicity in a Complex World*.
[69] Stacey, *Strategic Management and Organizational Dynamics*.
[70] Holland, *Hidden Order*.
[71] Craig W. Reynolds, "Flocks, Herds, and Schools: A Distributed Behavioral Model, in Computer Graphics" (paper presented at the ACM SIGGRAPH '87 Conference, Anaheim, CA, 1987).

Prediction in deterministic nonlinear systems

Understanding how complex, nonlinear systems work is the goal of researchers using the complexity framework, but the very nature of nonlinear dynamic systems makes prediction problematic. The long tradition of analysis based on linear assumptions, as well as the practical matter of working within social system structures for which long-term policy making is a central strategic problem, leads us to expect and even demand the ability to predict what will happen next. There is no shortcut to learning the fate of a complex system; it has to play out in real time. According to Briggs and Peat (1989), it is common to hear scientists speak of "perspective" reality rather than objective reality, of "creative possibilities" rather than causality, of "likely scenarios" rather than specific outcomes, and of "useful models" rather than the truth.[72]

A dynamical system is "one whose state at any instant determines the state a short time into the future without any ambiguity."[73] In other words, a dynamical system is deterministic. In the strictest sense, the system is totally predictable: If one knows exactly the current state, one can determine the entire future behavior. Unfortunately, there are two loopholes—the difficulty in exactly specifying the state of the system, and the difficulty in working out the calculation needed to predict the future state. Unless the system is quite simple, predictions are usually confounded by small measurement errors in the specification of the initial state, and by the system's sensitive dependence on initial conditions. That is, in a nonlinear system, even a small error in specifying the initial state of the system may lead to large differences between what is observed and what is expected.

Yet researchers interested in the behavior of social systems and managers and others who work in social systems are faced with the need to understand what is likely to happen in the future. Recognizing the nonlinear components or characteristics of a system also means recognizing that while exact prediction may not be achievable, a more general kind of prediction may be possible. Short-term prediction is also likely to be easier and somewhat more accurate than long-term prediction. Although deterministic nonlinear systems may not repeat specific behaviors over the long term, the "families" of behavior they exhibit bear some resemblance to each other. System

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[72] Briggs and Peat, *Turbulent Mirror: An Illustrated Guide to Chaos Theory and the Science of Wholeness* 201.
[73] Cohen and Stewart, *The Collapse of Chaos: Discovering Simplicity in a Complex World* 188.

behavior has an overall qualitative pattern that tends to stay within certain bounds and which might be classified into identifiable categories. As Stacey (2000) suggested, organizational decision-making should use "qualitative patterns to reason by analogy and intuition" rather than "step-by-step reasoning from assumptions about the future."[74]

A Brief Look at Other Theoretical Perspectives

Collections of organizations have been the subject of analysis from a variety of theoretical perspectives. Population ecology, for example, is concerned with groups of similar organizations competing for resources. Organizations in a population may be characterized as having either symbiotic or competitive relations with each other, and organizational survival is determined by environmental selection.[75,76] Population ecology theory explicitly takes the environment into account. The level of analysis is populations of organizations; survival of populations of organizations is studied with respect to environmental conditions. The environment acts in a natural selection model and is seen as largely deterministic of organizational survival. Selection and retention of certain types of organizations are based on the appropriateness of fit between organizational form and characteristics of the environment. There is a focus on stability: whether an interorganizational network is retained, for example, depends on the role played by linking-pin organizations and the selection criteria that reinforce linkage stability. Stability, and therefore survival, is enhanced when there are multiple ties between boundary-spanners; loose coupling makes the linkages relatively independent. This model is most closely associated with Hannan and Freeman (1977) and Aldrich 1979.

Institutional theory is often closely identified with Selznick and DiMaggio and Powell.[77,78] DiMaggio and Powell (1991) considered the socially constructed beliefs about the world that infuse our thinking about organizations, and are embedded in standard operating procedures and legal requirements. In terms of institutional environment, organizational transactions with the

[74] Stacey, *Strategic Management and Organisational Dynamics* 267.
[75] Michael T. Hannan and John Freeman, "The Population Ecology of Organizations," *American Journal of Sociology* 82. (1977).
[76] Howard E. Aldrich, *Organizations and Environments* (Englewood Cliffs, N.J.: Prentice Hall, 1979).
[77] Philip Selzick, "Institutionalism 'Old' and 'New'," *Administrative Science Quarterly* 41. (1996).
[78] Paul J. DiMaggio and Walter W. Powell, " Introduction," in *The New Institutionalism in Organizational Analysis*, eds. W. W. Powell and P. J. DiMaggio (Chicago: The University of Chicago Press, 1991).

environment are viewed as a means of ensuring the organization's legitimacy.[79] In some respects, institutional theory is an extension of an open systems' perspective on the study of organizations. In terms of units of analysis, most studies of institutional effects have focused on specialized social structures that are associated with a subset of activities within a single society—either specific types of organizations or organizational fields. The emergence of the notion of organizational fields to identify for analysis sets of differentiated and interdependent organizations proved to be a valuable source of insights for organizational researchers, particularly in what Scott refers to as the "new institutionalism".[80] According to institutional theorists, societal forces serve to structure organizational fields, which develop their own governance systems and cultural norms; these systems then structure the individual organizations in the field. Institutional effects have also been examined at the level of the organizational population. Research has focused on the effects of legitimacy, defined in terms of prevalence, endorsement or certification, and legal sanction, and network linkages on organizational foundings and failures.[81,82] Some of the institutional concepts used by Scott to study a population of health care delivery organizations are discussed in the final paragraphs of this chapter.

Scott et al. (2000) took a longitudinal and multiple-indicators approach to analysis of changes in health care delivery systems within the context of institutional theory.[83] Scott et al. examined the emergence, transformation, and disappearance of health care organizations. This study provided a useful model for structuring my approach to gathering and organizing data for the research described in this dissertation.

Scott et al. (2000) conducted an empirical study of the half-century evolution of the organizational field's provision of medical care services in the nine-county San Francisco Bay Area.[84] The objective of the study was to increase understanding of the development of health

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[79] W. Richard Scott, *Institutions and Organizations* (Thousand Oaks, CA: Sage, 1995).
[80] Ibid.
[81] Michael T. Hannan and Glenn Carroll, *Dynamics of Organizational Populations: Density, Legitimation, and Competition* (New York: Oxford University Press, 1992).
[82] Joel A.C. Baum and Christine Oliver, "Institutional Linkages and Organizational Mortality," *Administrative Science Quarterly* 36, (1991).
[83] Scott et al., *Institutional Change and Health Care Organizations: From Professional Dominance to Managed Care*.
[84] Ibid.

care systems by examining how various organizations responded to both local and extended social forces.

Their research examined the effects of institutional change on five focal populations—hospitals, hospital systems, health maintenance organizations (HMOs), home health agencies, and end stage renal disease centers—through the lens of institutional theory and the methodology of case studies. A central focus of the quantitative analysis was change in the number and types of organizations in the organizational field. The authors' central objective was to account for changes in the characteristics of the populations of organizations, including density, ownership features, subtypes, and linkages, in response to changes in the material-resource and institutional environments, particularly the complexity of technology and cost effectiveness. Change was classified as occurring in one of two ways: adaptation—existing organizations doing new things or old things in new ways; and ecological change—the replacement of existing organizations by new types of organizations. Operationally, adaptive processes entailed changes in the structural features of existing organizations; ecological processes entailed the differential rates at which organizations formed or dissolved.

The use by Scott et al. of multiple types and sources of information emphasized that activities in social systems are situated in historical time and institutional space. Their use of diverse types of data also recognized that observations from different sources and of varied types might, in combination, provide a more accurate depiction of the events they described. I adopted a similar approach in this dissertation.

There were two major concepts that Scott et al. applied to their research: the processes of structuration/destructuration/restructuration, and profound institutional change. "Structuration" refers to the extent to which the behavior of organizations in a field constitutes (i.e., creates) a coherent structure or pattern of interactions as revealed by interaction rates, amount of shared information, mutual awareness, and shared governance arrangements. "Destructuration" refers to processes that undermine coherence and unity. It is the breakdown of traditional organizational forms and patterns of behavior, the dislodging of belief systems, and the dismantling of governance structures that had been dominant in an earlier period. "Restructuration" refers to attempts to put into place new organizational players, new logics, and new systems of governance.

The second major concept Scott et al. applied to their research was profound institutional change. They defined this as "change [that] has occurred, often abruptly, in the fundamental constitutive logics and governance structures that undergird the field."[85] Profound institutional change was identified as involving the combination of destructuration processes—in which previously existing, stable organizational fields were disrupted—and restructuration processes, in which new types of actors competed to create a new order.

Scott et al.'s identification of three institutional eras—professional dominance, federal involvement, and managerial control and market mechanisms—was based primarily on changes in governance structures, with the selection of dates denoting significant legislation affecting the health care field. Periodization assumed the presence of discontinuous change; Scott et al. constructed longitudinal measures of primary institutional logics in the U.S. health care field, and compared whether long-term transformation in health care organizations was better explained by a continuous, linear trend or by discontinuous time markers. The authors used confirmatory factor analysis, and multiple indicators were used to model the existence of the factors and to estimate their magnitude over time. They found evidence of the transformation of a relatively mature sector into a field that experienced destructuration, including the breakdown of forms, dislodging of belief systems, and dismantling of governance structures.

Scott et al. noted that it was difficult to precisely identify the causal structure responsible for determining the direction and nature of change in field structuration processes. This difficulty suggests the presence of nonlinear relationships among the dimensions and policy system elements examined by the authors, who did not look for or consider the existence of such nonlinearities in their analyses. I do not disagree with the arguments and findings of the Scott et al. study, but I do suggest that an examination of the health care delivery system for the presence of nonlinear dynamic behavior, and incorporation of that perspective into the research would have resulted in a more complete picture of the system they studied.

[85] Ibid. 312.

There are several parallels between the theoretical concepts of the Scott et al. (2000) study and elements of complexity science. For example, destructuration and restructuration appear to describe processes similar to self-organization and emergence, in which new emergent structures, patterns, and properties arise in complex systems without being externally imposed. In both emergence and restructuration, old structures and states are replaced with new ones.

In addition, Scott et al. (2000) described some of the changes observed in their study as discontinuous. They noted that the presence of definable institutional eras suggested the presence of profound and discontinuous change. The nature of change in complex systems is also discontinuous; the iterated results of logistic equations show qualitative, discontinuous changes in the output of the equation, as values of the tuning parameter, *a*, increase. Feedback processes in nonlinear dynamic systems can lead to sudden jumps in system properties.

Scott et al. employed adaptive and ecological processes to explain changes observed among populations of health care organizations. Despite their use of the term "adaptive," ecological processes appear to act more like complex adaptive systems than adaptive processes. Ecological processes resulted in the replacement of existing organizations by new types of organizations, through the dissolution of existing organizations and the subsequent formation of new types of organizations. Emergent behaviors and structures are the result of self-organization of system components; the resulting behaviors and structures may present new forms because they may have their own rules and patterns, not present in any of the system components.

Scott et al. also noted that organizational features exhibited an order that made some core characteristics more resistant to change than others. Moreover, these core characteristics were more likely to be modified by ecological than by adaptive processes. This phenomenon is explained in chaos theory by the concept of attractors. A system will evolve until it arrives at an attractor and will then stay there unless otherwise disturbed. A nonlinear dynamic system resists perturbations to its preference for an attractor—much like core characteristics that are resistant to change. However, both core characteristics and attractors may be qualitatively changed by environmental changes.

In summary, Scott et al. (2000) offered a detailed study of a health care delivery system from the perspective of institutional theory, which emphasizes the stabilizing effects of institutional environments.[86] Their use of longitudinal data and multiple indicators served as a useful model for the research study described in this dissertation. The nonlinear dynamic systems perspective might have assisted Scott et al. in understanding their observations in the health care delivery organizations they studied, particularly where the authors found it difficult to identify the causal structures responsible for determining the direction and nature of change in field structuration processes. This dissertation offers an example of an approach that provides a way of understanding social and policy systems as nonlinear dynamic systems.

[86] Ibid.

Chapter 3. Complexity Science Metaphors and Methodological Tools

In this research study, I applied the tools of nonlinear system dynamics and complexity science to help formulate an understanding of changes in academic medical centers that were concurrent with major changes in the health care delivery sector. In contrast, the application of chaos and complexity as a metaphor has more often dominated the literature. While the concepts and approaches of complexity science have been useful in describing and interpreting the behavior of social systems in a qualitative manner, discussions of the associated mathematics have typically been illustrative. One of the major contributions of this dissertation is the extension of the application of complexity science from metaphor toward the use of methodological tools: model specification, data collection, and nonlinear analysis.

Recent literature has argued for conceptualizing social systems as complex, self-organizing systems. The way in which these concepts have been applied to social systems ranges albeit unevenly, along a continuum with the metaphors of chaos and complexity on one end and a set of mathematical tools and models on the other. This literature has contributed to the introduction and use of novel approaches by researchers and practitioners studying and working in organizations and management. The use of the complexity perspective as a metaphor is abundantly suggestive but usually stops short of identifying the underlying mechanisms that generate emergence or self-organization, and therefore fails to fully realize the nonlinear implications of the approach. The challenge of using metaphorical extensions lies in the translation of the language of chaos and complexity to the language of social systems. The danger lies in the restatement in a different language of insights already offered by other theoretical approaches, without the addition of new knowledge.

In this dissertation, I acknowledge the value of the metaphorical application of complexity to analysis of social systems. The translation of observations about large-scale network systems into the language of complexity is a valuable first step toward exploring the potential of this new theoretical approach. I take the position, however, that regardless of the richness of the metaphors of complexity, it is preferable to now begin to move up the operational hierarchy toward model specification, empirical collection of data on the key variables in the model, and tests of the predictions of the computational models. The building of plausible models, the accumulation of good data over time, and the identification and interpretation of attractors—these are precisely the challenges of using quantitative analysis and mathematical tools. Kellert summed up the problem as the need to apply "the techniques of nonlinear dynamical system theory to bounded, aperiodic, unstable deterministic systems."[1] Kellert argued that the challenge is not impossible, despite the difficulty of using more rigorous methodological tools. Although Kellert does not specifically address it, I argue that this challenge must begin with the task of identifying whether the system being studied is bounded, and what the nature of those bounds might be: whether its periodicity can be identified and characterized; whether it is, in fact, a deterministic system; and whether the system is stable or unstable. I would argue that the mathematical techniques of nonlinear dynamic systems are required to help characterize the system as well as to analyze its characteristics.

When working within the framework of complexity theory, the problem of quantification of information about social systems is no greater than it is for any other theoretical framework. Likewise, the collection of high quality time series data is difficult to accomplish regardless of the theoretical framework of the study. Kellert suggested the research standard of applying the fairly rigorous criterion of identifying "a convincing reconstruction of a strange attractor" in order to rule out alternative explanations or models.[2] The usefulness of the application of the tools of nonlinear dynamic systems lies, therefore, in the identification of the bounds of the system (i.e., what values might reasonably be observed in the near future?) and in the apparent degree of chaos that the system might be exhibiting (e.g., the periodicity of data over time). Once identified, changes over time, studied either prospectively or retrospectively through the collection and analysis of past longitudinal data, may be associated with or attributed to changes in the system or the system's environment. The ability of a manager to recognize the presence of nonlinear dynamics or chaos in an organization or policy system presents a strategic advantage in adapting behavior to that chaos. For students of social systems, the acknowledgement of chaos in

[1] Stephen H. Kellert, "When Is the Economy Not Like the Weather? The Problem of Extending Chaos Theory to the Social Sciences," in *Chaos and Society*, ed. Alain Albert (Amsterdam: IOS Press, 1995), 37.
[2] Ibid., 36.

a system leads to very different predictions and interpretations than if the system under study is assumed to behave only in a linear manner.

The next section of this chapter describes some of the contributions to the literature that has used the sciences of chaos and complexity, and, more specifically, nonlinear dynamics and self-organizing systems, as metaphors. After this section, I discuss the literature that presented methodological tools that might help move forward the application of nonlinear dynamics to social systems.

Metaphorical Use of Complexity

The metaphorical use of chaos and complexity is becoming increasingly common. Kellert (1995) explored use of the metaphorical extension of nonlinear dynamics as a conceptual resource in science and social science.[3] The argument that because we can never precisely know the initial conditions of human history we can never correctly explain an historical situation (due to sensitive dependence on initial conditions) is an example of a metaphorical extension of chaos theory to the discipline of history. Kellert wrote:

> Because we can never obtain statements of precise initial conditions of human history, any attempted explanation of a chaotic historical situation will be wildly inaccurate, due to sensitive dependence on initial conditions. Instead of deductions from laws, the understanding of human history must rely on a narrative account of when history was constrained by broad factors and when it was brought to highly unstable situations where small causes could have great effects. This argument represents a metaphorical extension of chaos theory because it does not attempt a straightforward application of the techniques of nonlinear dynamics.

Kellert added that the metaphorical application of chaos theory served as a useful antidote to the application of linear dynamics, but he also criticized “illegitimate” metaphorical extensions of

[3] Ibid., 39.

chaos theory. He noted that not everything that is hard to understand is chaotic: competing and interacting influences are not a basis for declaring the existence of dynamical chaos, simple instability at a particular point does not denote sensitive dependence on initial conditions, and patterns are not necessarily attractors. In the end, Kellert concluded that a careful application of chaos models to social systems may provide useful insights into human behavior.

Goldstein built on the work of Prigogine and Kauffman to examine the relevance and application of self-organization to the dynamics of social change in businesses and other organizations.[4,5] Noting that traditional models of social change did not account for the primary elements of self-organization—nonlinearity, far-from-equilibrium conditions, redundancy, reliability, systemic correlation, social system noise, and system containment—Goldstein offered an alternative conceptual framework for explaining organizational change. Like Kellert, Goldstein warned that the incautious borrowing of the concept of self-organization from the physical sciences is merely speculative without an adequate measurement of appropriate variables in a social system.

Another well-articulated expression of the value of studying social systems (in this case, organizations) from the perspective of the self-organizing systems' metaphor is Morgan's *Images of Organization* (1997).[6] He proposed to understand organizations as flux and transformation by examining the logics of change. Four such logics discussed by Morgan include

- Organizations as self-producing systems, following the approach to systems theory developed by Maturana and Varela, who coined the term autopoiesis to refer to the capacity for self-creation and self-renewal through a closed system of relations. According to Morgan, "organization and environment are part of the same broad pattern...in evolution, it is pattern that evolves."[7]
- Chaos and complexity, drawing primarily on the concept of attractors. Morgan interpreted organizations and their relationships with the environment as part of an attractor pattern,

[4] Jeffrey Goldstein, *The Unshackled Organization: Facing the Challenge of Unpredictability through Spontaneous Reorganization* (Portland, Oregan: Productivity Press, 1994).
[5] Jeffrey Goldstein, "Using the Concept of Self-Organization to Understand Social System Change: Strengths and Limitations," in *Chaos and Society*, ed. Alain Albert (Amsterdam: IOS Press, 1995).
[6] Gareth Morgan, *Images of Organization*, 2nd ed. (Thousand Oaks, CA: Sage Publications, 1997).
[7] Ibid. 298-99.

created through key organizing rules that hold organization-environment relations in a particular configuration. He also suggested that managers can “nudge” systems into “desired trajectories by initiating small changes that can produce large effects.”

- Mutual causality, incorporating the concepts of negative and positive feedback to map fields of organizational relations with loops rather than lines. According to Morgan, the “logic of the whole is embedded in the nature of the deviation amplifying or stabilizing loops.”
- Dialectical analysis, emphasizing the paradoxes and contradictions that are generated when systems change.

Morgan extended the metaphorical use of nonlinear dynamics to a prescription for managers wishing to manage change in organizations. While it is evident that small changes can produce large effects, the flaw in Morgan’s advice lies in the assumption that the manager can predict the nature of the effect (large or small) on the system trajectory that might result from a nudge.

In *The Fifth Discipline*, Senge (1990) offered eleven laws that are reminiscent of nonlinear system dynamics:[8]

- Today’s problems come from yesterday’s “solutions”—solutions may shift problems from one part of the system to another
- The harder you push, the harder the system pushes back—well-intentioned actions may result in compensating feedback
- Behavior grows better before it grows worse—cause and effect are not obvious in complex systems; interventions may only work in the short term
- The easy way out usually leads back in—familiar solutions to problems are often the wrong solutions
- The cure can be worse than the disease—solutions that shift the burden do not strengthen the ability or strength of the system
- Faster is slower—natural systems have an optimal rate of growth; complex social systems do too

[8] Peter M. Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization* (New York: Currency Doubleday, 1990).

- Cause and effect are not closely related in time and space—thinking that they are closely related blinds us to the nature of reality in complex systems
- Small changes can produce big results, but the areas of highest leverage are often the least obvious—systems thinking, learning to see underlying structures, and thinking in terms of processes of change can help identify high-leverage changes
- You can have your cake and eat it too, but not at once—either-or choices may be an artifact of looking only at a fixed point in time rather than the process or the system
- Dividing an elephant in half does not produce two small elephants—both living systems and organizations have integrity; sometimes the entire system must be considered and other times only part of the system, but the relevant portions are not usually divided by existing organizational boundaries
- There is no blame—in the sense that blame is assigned to outside circumstances or factors; there is no outside if everything is part of a single system

Senge (1990) proposed a model of organization as a nonlinear system, thereby introducing nonlinear concepts to organizational researchers. However, he emphasized the role of a strong leader who can control the system from the top down—a leader who can identify leverage points at which interventions can be applied. This prescription is similar to Morgan's nudges, with the same potential problems.Wheatley (1992) was another early and enthusiastic adopter of the concepts of nonlinear dynamic systems for understanding organizations.[9] Interpreting organizations as self-organizing systems, she noted that the "new way of thinking" developed in the natural sciences offered "new images and metaphors for thinking about our own organizational experiences." Wheatley acknowledged, "Some believe that there is a danger in playing with science and abstracting its metaphors because, after a certain amount of stretch, the metaphors lose their relationship to the tight scientific theories that gave rise to them." But she also noted, "others would argue that all of science is a metaphor—a hopeful description of how to think of a reality we can never fully know."

[9] Margaret J. Wheatley, *Leadership and the New Science: Learning About Organization from an Orderly Universe* (San Francisco: Berrett-Koehler Publishers, Inc., 1992) 7-13.

Wheatley translated “sensitivity to initial conditions” to organizations by noting that one or a few creative individuals can have an enormous impact on the organization. The ability of an organization to amplify a small change was seen as a creative lever; if the disturbance created by a new idea is not quelled, it becomes lodged in the system and begins an iterative process which can change the trajectory of the organization. Wheatley also notes that the best organizations have a fractal quality; i.e., an observer could determine the organization’s values by watching anyone in the organization.

Kronenberg (1995) has applied chaos theory to the public policy process by suggesting a cloud metaphor.[10] He focused on issue transformation in the policy making process, arguing that understanding the transformational aspects of policy processes will improve public policy, and that insights from the New Sciences of Transformation (i.e., chaos, complexity and autopoiesis) can supplement more traditional metaphors and models. He noted that machine metaphors do not account for goal development or unstable or unpredictable environments, and that organism metaphors fail to explain issues related to system boundaries and system change, and are subject to the additional criticism of the incommensurability of natural law and constructivism.

Kronenberg chose the cloud metaphor because clouds are characterized by fuzzy boundaries, mutable shapes, and patterns that can be characterized in a general sense, and by their relationships with other complex systems—all characteristics of the policy process. Among the policy process phases described by Dunn (agenda setting, policy formulation, policy adoption, policy implementation, and policy assessment), Kronenberg suggested that the cloud metaphor best described agenda-setting and a new phase of the policy process—issue transformation.[11] As described by Kronenberg, issue transformation closes the loop between policy assessment and agenda setting; as such, it can help explain policy advocacy, the emergence of new policy arguments, and problem definition as they occur, as another scholar put it, “at the edge of chaos.” The application of the concept of the edge of chaos is not fully justified in Kronenberg’s development of the cloud metaphor. He did not explain either metaphorically or mathematically how one identifies when the policy process is at the edge of chaos.

[10] Philip S. Kronenberg, "Chaos and Re-Thinking the Public Policy Process," in *Chaos and Society*, ed. Alain Albert (Amsterdam: ISO Press, 1995).
[11] William N. Dunn, *Public Policy Analysis*, Second ed. (Englewood Cliffs, New Jersey: Prentice Hall, 1994).

Kronenberg did however describe how policy analysts would move from metaphors to action strategies. As a practical strategic tool, the cloud metaphor suggests "the need to engage stakeholders in dialogue" about the definition and interpretation of policy issues; it could be a tool for coalition and conflict management. Kronenberg also cautioned that the discovery of nonlinearity in social and policy systems should not blind us to the order that still exists in these systems. He correctly noted that most systems combine a mixture of stability and chaos, and overall system equilibrium may be achieved while subsystems may be simultaneously or sequentially chaotic.

The following section describes the literature that presents the application of methodological tools that might help move forward the more rigorous application of nonlinear dynamics to social systems.

Use of Methodological Tools

The application of quantitative nonlinear techniques of chaos theory to the study of social systems requires the ability to identify and quantify the relevant variables in the system, the availability of time series data of sufficient duration and quality, and the plausibility of using a simple model that does not change over time.[12] Researchers have devised and applied an array of tools to observe the behavior of nonlinear systems. Two of the most common are graphical analysis and application of a simple logistic equation.

James (1996) surveyed military systems and technologies that were susceptible to chaotic dynamics and provided suggestions for applying the "universal properties" of chaotic systems to strategic thinking and decision-making. James emphasized the types of events, behaviors, and transitions that were common across unrelated systems, and presented some practical approaches for using these insights in real-world situations.[13] According to James, the difference between

[12] Kellert, "When Is the Economy Not Like the Weather? The Problem of Extending Chaos Theory to the Social Sciences."
[13] Glenn E. James, *Chaos Theory: The Essentials for Military Applications* (Newport: Naval War College, 1996) 39-42.

chaos and random behavior is "the presence of an attractor that outlines the dynamics towards which a system will evolve." James' use of the tools was not to merely observe, but to recreate the system's rules of motion, to predict motion over the short run, and to control motion. The two most basic tools for depicting data in dynamical systems used by James were time series plots and phase diagrams; each was used to show raw data and give a qualitative picture of the system's boundaries and trends. James' application of the methodological tools of complexity was limited to technical systems; he concluded by suggesting that there was great potential for applying chaos theory to human systems. Evidence of chaotic behavior in human systems cited by James included the following indicators: a well-defined system; a clear list of observables to measure; aperiodic changes in those observables; bounded output; sensitivity to small disturbances; evidence or knowledge of nonlinear forces or interactions; attractors with fractal dimension; and small non-integer information dimension.

Kiel (1994) applied nonlinearity and chaos theory to government performance issues.[14] Kiel advocated the use of activity-related and performance-related time series data to analyze and change work processes. He described three types of nonlinear dynamic systems: equilibrium systems, which have stable output over time; rhythmic or oscillatory systems, which have repeating cycles over time (influenced by budget cycles, for example); and chaotic behavior, which appears random and disorderly, but which occurs within definable parameters. Each of these systems experienced different types of change, from incremental to erratic. Another type of change—"symmetry breaking," or wholesale transformational change—was discontinuous and could result from both planned and unplanned changes in methods or work processes, and could result in a period of confusion and instability.[15]

Sharp and Priesmeyer (1995) applied phase plane analysis to graphically assess administrative and clinical data, seeking ways in which chaos theory might contribute to quality management in

[14] L. Douglas Kiel, *Managing Chaos and Complexity in Government: A New Paradigm for Managing Change, Innovation and Organizational Renewal* (San Francisco: Jossey-Bass Publishers, 1994).
[15] The term "symmetry breaking" derives from the work of Prigogine on dissipative structures. Fluctuations from both inside and outside the structure were hypothesized to constantly test the stability of the dissipative structure. Occasionally, a novel fluctuation forces the structure to a critical stage, triggering unstable, nonlinear behavior and resulting in loss of the old form (the symmetry break) followed by a period of chaos and disorder and a reformation of the dissipative structure into entirely new and qualitatively different structures.

health care.[16] They were looking for previously unnoticed patterns in accounts receivable and cash flow. Priesmeyer and Sharp (1995) used phase plane analysis to “reveal otherwise unknown structure in common health care administration data.” [17] Positions of data points on the phase plane were related to specific interpretations and were used to generate action recommendations. Priesmeyer et al. (1996) explored ways in which chaos theory could be applied in health care by looking at case management and clinical pathways as nonlinear, evolving systems.[18] By creating phase plane plots of measures of pain and range of motion following total knee arthroplasty, the authors identified conditions that occur during recovery that required intervention.

McBurnett (1997) took a different approach, applying spectral analysis to time series data.[19] He demonstrated the application of spectral analysis to series representing noise and periodicity, known chaotic time series, and empirical data constructed from surveys conducted during the 1984 Democratic presidential nomination race. The problems of this approach center on the inability of spectral analysis to clearly discern cycles, either because the time series is too short or the signal-to-noise ratio is too high. McBurnett found that no two time series have identical spectra and there is no signature spectrum that identifies chaotic dynamics. In another application of complexity tools to public opinion data, McBurnett (1997) used three methods to analyze complex dynamical time series data.[20] These included phase portraits, the correlation integral, and Lyapunov exponents; the latter was used to illustrate the divergent properties inherent in complex dynamics. McBurnett’s analysis ruled out a linear model to explain changes in public opinion during the 1984 Democratic primary elections and confirmed the presence of nonlinear dynamics through use of the combination of tools.

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[16] Lawrence F. Sharp and H. Richard Priesmeyer, "Tutorial: Chaos Theory—a Primer for Health Care," *Quality Management in Health Care* 3, no. 4 (1995).
[17] H. Richard Priesmeyer and Lawrence F. Sharp, "Phase Plane Analysis: Applying Chaos Theory in Health Care," *Quality Management in Health Care* 4, no. 1 (1995): 70.
[18] H. Richard Priesmeyer et al., "Chaos Theory and Clinical Pathways: A Practical Application," *Quality Management in Health Care* 4, no. 4 (1996).
[19] Michael McBurnett, "Probing the Underlying Structure in Dynamical Systems: An Introduction to Spectral Analysis," in *Chaos Theory in The Social Sciences: Foundations and Applications*, ed. L. Douglas Keil and Euel Elliott (Ann Arbor, Michigan: The University of Michigan Press, 1997).
[20] Michael McBurnett, "Complexity in the Evolution of Public Opinion," in *Chaos Theory in the Social Sciences: Foundations and Applications*, ed. Douglas L. Kiel and Euel Elliott (Ann Arbor, Michigan: The University of Michigan Press, 1997).

Brown (1997) used the Lyapunov exponent, λ, an unambiguous measure of the existence of chaos in a dynamical system or time series.[21] Chaos exists when λ is positive. The exponent measures the average rate at which close or nearby trajectories diverge in phase space after small changes in initial conditions. The simplest way to think of the exponent is as a measure of error amplifying and accumulating over time; larger values indicate that the system is sensitive to initial conditions, one of the defining characteristics of chaotic systems. A negative value indicates a stable system. As a rule, chaotic systems contain at least one positive Lyapunov exponent.

Summary

Like all theories, complexity theory has its own language, its own way of describing the world. The problem is how to apply the concepts of complexity theory to very large-scale complex systems. Metaphors are a "basic structural form of experience, through which human beings engage, organize, and understand their world."[22] Morgan (1997) used as his basic premise the belief that "all theory is metaphor" and, as such, "we have to accept that any theory or perspective that we bring to the study of organization and management, while capable of creating valuable insights, is also incomplete, biased, and potentially misleading."[23]

The application of methodological tools, particularly nonlinear mathematics and graphical analysis, can help us understand how to tell if social systems are behaving in a nonlinear fashion and can help us see attractors—bounds within which the system is likely to move. The use of complexity metaphors to understand organizations as nonlinear dynamic systems runs the risk of applying new names to well-known phenomena without adding new understanding. The use of more rigorous methodological tools requires the development of models that can be operationalized, i.e., linked to specific data variables that can be explicitly defined and for which data can be collected and analyzed. The benefit derived from this not inconsiderable effort is a

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[21] Thad Brown, "Measuring Chaos Using the Lyapunov Exponent," in *Chaos Theory in the Social Sciences: Foundations and Applications*, ed. Douglas L. Kiel and Euel Elliott (Ann Arbor, Michigan: The University of Michigan Press, 1997).
[22] Gareth Morgan, "More on Metaphor: Why We Cannot Control Tropes in Administrative Science," *Administrative Science Quarterly* 28 (1983).
[23] Morgan, *Images of Organization* 5.

significant addition to the toolkit researchers use to understand the complexity dynamics of policy systems.

Chapter 4. U.S. Medical Schools

Medical School Literature

The closest offering to a “dedicated” literature on medical schools and academic medical centers (AMCs) is *Academic Medicine*, a publication of the AAMC. This peer-reviewed journal routinely presents articles describing best practices in medical education, the effects of outside influences such as the economy, federal policy, and managed care on medical education and the functioning of AMCs, and news items that track relevant legislation, issues, and positions of the AAMC on such matters. The *Journal of the American Medical Association* (JAMA) publishes articles on such effects on managed care, and on other “threats” to medical education, and devotes one issue each year to medical education. Other journals, such as *Science*, publish policy-related pieces and provide news items that focus primarily on research activities and on the funding of biomedical research.

Other primary sources of published information include reports commissioned by the National Academy of Sciences, by the Commonwealth Fund, by the Kaiser Family Foundation, by the Association of Academic Health Centers, and by other similar nonprofit organizations and foundations. The broad topics of these reports included the management of the three missions of medical schools’ financing of AMC activities, and strategic planning for the new environment of medical schools and teaching hospitals.

This chapter presents a brief history of three distinct eras of academic medicine since the end of World War II: the scientific era (1945-1964); the clinical era (1965-1981); and the era of market mechanisms (1982-present). Throughout the entire period, AMCs have assumed three interrelated missions: education, research, and patient care. A discussion of the activities undertaken in support of each mission is presented. The chapter closes with a discussion of legislation and policy affecting AMC activities and revenues.

Background

Among the most important factors in the achievements of American medicine have been the country's medical schools and teaching hospitals. The modern AMC was created over ninety years ago, largely following recommendations contained in the Flexner report.[1,2] Published in 1910, the report called for medical schools to be university-based rather than proprietary, for faculty to be engaged in original research, and for students to learn by participating in laboratory and clinical work. Implementation of the report's recommendations transformed the structure and focus of American medical education. Medical schools and their affiliated institutions served the public and were judged on the quality of their academic work and their adherence to and encouragement of professional standards of medical practice.

Academic medical centers have undergone three eras since the end of World War II. These eras are characterized by distinctive, but not necessarily mutually exclusive, institutional activities, actors, belief systems, and governance structures. [3,4] The research study described in this dissertation focuses on the most recent of these eras; however, a brief description of the earlier eras is provided as an aid to understanding the historical context of AMCs and to set the stage for the research problem. I have chosen to name these three periods the Scientific Era, the Clinical Era, and the Era of Market Mechanisms. These designations reflect both the characteristics used by Ludmerer (1999) and Scott et al. (2000) to classify the history of academic medicine and health care delivery, and the primary sources of funding of the medical education enterprise at different times during the last century.

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[1] Academic medical centers, also referred to as academic health centers, generally include a medical school, an affiliated teaching hospital, and a faculty practice plan. Except for freestanding medical schools, there is also a parent university; there may also be allied health schools (e.g., nursing, pharmacy) or research institutes as well as other affiliated clinical facilities.

[2] Abraham Flexner, *Medical Education in the United States and Canada.* (New York: Carnegie Foundation for the Advancement of Teaching, 1910).

[3] Kenneth M. Ludmerer, *Time to Heal: American Medical Education from the Turn of the Century to the Era of Managed Care* (New York: Oxford University Press, 1999). Ludmerer, writing about medical schools, identified the Age of Federal Beneficence and the Era of Cost Containment and Managed Care.

[4] W. Richard Scott et al., *Institutional Change and Health care Organizations: From Professional Dominance to Managed Care* (Chicago: The University of Chicago Press, 2000). Scott identified three time periods that defined

The scientific era: 1945–1964

From the end of World War II through the mid-1960s, medical schools were intensely academic, focusing on teaching and research. Research became the predominant activity as a result of a broad, federally funded expansion of science and higher education. Medical school faculties were influential in establishing an emphasis on quality of care, an ethos of voluntarism, and the characterization of medical schools as a public trust serving the public interest. The result was greater homogenization of medical schools (as nearly all of them became, to a greater or lesser extent, engaged in research), increased independence from universities (as most research grants were awarded to principal investigators [PIs] in the medical school rather than to the parent university), and greater dependence on soft money (as research grant and contract revenues increased relative to revenue from other sources). Federal funds were used to support research, train new investigators, and develop the research infrastructure. Increasingly, hospital diagnostic laboratories were inadequate for clinical research, and new research laboratories that rivaled those in university basic science departments were constructed in teaching hospitals. Increased specialization in clinical practice and research was accompanied by an increase in the number of medical specialty and sub-specialty boards. The scientific era was characterized by a general persistence of academic values, even as research activities began to supplant teaching activities.[5]

The clinical era: 1965–1981

The clinical era was introduced with the passage in 1965 of Medicare legislation [Public Law (P.L.) 89-97]. The new programs brought a significant infusion of federal funds and an increased reliance on public regulatory controls in health care delivery. The teaching hospitals' charity wards that existed during the first half of the twentieth century were suddenly filled with paying patients whose costs were covered by new federal benefits for the elderly (Medicare) and for those with low incomes (Medicaid).

Patient care became an important source of revenue, as the clinical enterprise outpaced the growth of the academic enterprise (research and teaching). Financial and organizational ties to

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health care delivery: the Era of Professional Dominance (1945-65); the Era of Federal Involvement (1966-82); and the Era of Managerial Control and Market Mechanisms (1983-present).

[5] Stephen Abrahamson, "When Is a School Not a School?," *Academic Medicine* 71, no. 1 (1996).

universities weakened further as the involvement of teaching hospitals in health care delivery increased and AMC revenues from faculty practice plans and hospital and medical school programs quickly outpaced support from the AMCs' parent institutions. The substantial and growing revenue from faculty practice plans benefited not only the clinical faculty but also research and teaching, because excess revenues were used to support these activities. The education of medical students, once the central mission of medical schools (and their only unique mission), was subsidized by faculty practice plan revenues.[6,7]

By 1980, concerns about containment of health care costs began to erode the nation's ability to provide both high quality medical care and broad access to that high quality care. The burden of attempting to provide the best health care for everyone regardless of cost was growing greater by the year.

The era of market mechanisms: 1982–present

The present era is characterized by the increasing influence of managerial logics, and by greater reliance on market controls for the delivery of health care, including the specialized patient care provided by teaching hospitals. Market mechanisms began to affect AMCs as governmental policies shifted toward deregulation and reliance on market forces for efficient health care delivery.[8] The rise of market mechanisms was a response to the increased cost of medical care as well as a consequence of the broader political and social context favoring deregulation and reliance on markets.

Various forms of health care delivery with the label "managed care" emerged to address longstanding concerns about the cost of the country's health care delivery system.[9,10] In this new

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[6] David Blumenthal, "The Research Mission of Academic Health Centers," in *Mission Management: A New Synthesis*, ed. Elaine R. Rubin (Washington, D.C.: Association of Academic Health Centers, 1998).
[7] Robert F. Jones and Susan C. Sanderson, "Clinical Revenues Used to Support the Academic Mission of Medical Schools, 1992-1993," *Academic Medicine* 71, no. 3 (1996).
[8] Susan U. Raymond, Henry M. Greenberg, and Rodney W. Nichols, "Medical Education and Clinical Research in the 21st Century," (New York: New York Academy of Sciences, 1999).
[9] The term "managed care" refers to a variety of health care delivery and reimbursement plans that typically involve three key components: oversight of the medical care given; contractual relationships and organization of the providers giving care; and linkage of covered benefits and managed care rules.
[10] Spencer Foreman, "Medical Education and Research: Financial Challenges and Institutional Responses" (paper presented at the Medical Education and Clinical Research in the 21st Century, New York, October 1999).

environment, AMCs, which have always had higher costs due to their educational, research, and specialized patient care activities, found their financial margins threatened.[11,12] Profitability and market share began to replace education and research as professional meeting topics and issues discussed in the community's literature.[13] As research and education missions increased operating costs and decreased cost competitiveness for patient care, financial pressures prompted changes in the management and organizational structure of AMCs.[14,15,16,17] Nonnemaker and Griner (2001) found that with changes in the organization, delivery, and financing of health care, the structures and policies that governed the relationship between parent universities and medical schools came to be viewed as inflexible and inadequate. Strategies for addressing these issues included "changes in governance, organization, and management of the medical school, such as unified authority for health affairs, reengineering administrative systems, and increased autonomy in decision making."[18]

Three Missions

American medical schools are grounded in three interrelated missions:

- Teaching—education of the nation's doctors
- Research—generation of new medical knowledge
- Patient care—development and delivery of specialized clinical care

[11] "Clinical Funding Cuts Threaten Academics," (Palo Alto, California: Stanford University School of Medicine, 1998).
[12] James E. Reuter, "The Financing of Academic Health Centers: A Chart Book," (New York: Georgetown University Medical School Institute for Health Care Research and Policy, 1997).
[13] Ludmerer, *Time to Heal: American Medical Education from the Turn of the Century to the Era of Managed Care*.
[14] Seth Allcorn and Daniel H. Winship, "Restructuring Medical Schools to Better Manage Their Three Missions in the Face of Financial Scarcity," *Academic Medicine* 71, no. 8 (1996).
[15] "Managing Academic Health Centers: Meeting the Challenges of the New Health Care World," (New York: The Commonwealth Fund, 2000).
[16] Stanley S. Bergen, *Academic Health Centers Respond to Managed Care* [Web page] (University of Medicine and Dentistry of New Jersey, 20 November 1996 [cited 3 December 2000]); available from http://www.umdnj/edu/planweb/envscan/9604.html.
[17] John K. Iglehart, "The American Health Care System - Teaching Hospitals," *The New England Journal of Medicine* 329, no. 14 (1993).
[18] Lynn Nonnemaker and Paul F. Griner, "The Effects of a Changing Environment on Relationships between Medical Schools and Their Parent Universities," *Academic Medicine* 76, no. 1 (2001).

These traditional missions are discussed in the next three sections of this chapter. Teaching undergraduate and graduate medical students is the only unique mission of AMCs. Research is also undertaken by universities, research institutes, and private firms such as pharmaceutical companies; patient care is also provided by community hospitals, the federal government, and many private health care providers. However, basic biological research, provision of care to indigent patients and other underserved groups (including assumption of the cost of charity care and bad-debt expense), and the assurance of quality standards in the training of physicians (e.g., through accreditation and licensing) are not effectively or efficiently provided or distributed by the private health care market.[19,20,21]

The Teaching Mission of Medical Schools

Issues related to the education of undergraduate and graduate medical students center on total physician supply and on the relative numbers of subspecialists, specialists, and generalists needed by the health care enterprise, on how to fund medical training, and on how best to train physicians to work in managed care environments. The pool of medical school applicants has varied somewhat over time, due primarily to changes in the employment market for college graduates, while physician production has remained remarkably constant.[22,23,24] The number of medical residents has increased, due in part to the increase in foreign medical graduates coming to the United States. Blumenthal and Thier (2002) reported that the total number of medical residents in U.S. clinical facilities increased from 37,562 in 1960 to 97,989 in 1999.[25] Data on medical school applicants, matriculants, graduates, and residents are published annually in the medical education issue of JAMA.

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[19] David Blumenthal, Eric G. Campbell, and Joel S. Weissman, "Understanding the Social Missions of Academic Health Centers," (New York: The Commonwealth Fund, 1997).
[20] Ludmerer, *Time to Heal: American Medical Education from the Turn of the Century to the Era of Managed Care*.
[21] Edmund D. Pellegrino, "Academic Health Centers and Society: An Ethical Reflection," *Academic Medicine* 74, no. 8, Supplement (1999).
[22] Donald G. Kassebaum and Philip L. Szenas, "The Decline and Rise of the Medical School Applicant Pool," *Academic Medicine* 70, no. 4 (1995).
[23] Barbara Barzansky, Harry S. Jonas, and Sylvia I. Etzel, "Educational Programs in US Medical Schools, 1998-1999," *Journal of the American Medical Association* 282, no. 9 (1999).
[24] Ludmerer, *Time to Heal: American Medical Education from the Turn of the Century to the Era of Managed Care*.
[25] David Blumenthal and Samuel O. Thier, "Training Tomorrow's Doctors: The Medical Education Mission of Academic Health Centers," (New York: The Commonwealth Fund, 2002).

Major studies of the medical workforce have generally concluded that the U.S. faces a physician surplus.[26,27,28] Increases in physician supply in relationship to the population have been documented by the Council on Graduate Medical Education (COGME): in 1970 there were about 150 active physicians per 100,000 population; by 1992 the ratio had increased to 245 per 100,000, and was projected to reach 298 per 100,000 by 2020.[29] The growth of managed care has decreased the requirement for physician services at a time when the number of residents in training has increased at about 4% annually.[30] As the physician workforce and market forces collide, the medical education enterprise finds itself faced with a dilemma: organized systems of managed care are demanding fewer physicians overall, fewer specialists and subspecialists in particular, and relatively more primary care physicians than in the past, while teaching hospitals, under pressure to control costs, are more dependent on using less expensive residents to meet patient care needs.[31]

Managed care market forces have tended to operate to reduce the proportion of specialists and subspecialists in relation to primary care physicians or generalists. Market pressures that encourage growth in the number of generalist physicians are in opposition to the forces that have driven the growth of specialism: new knowledge and technical advances that required special expertise; hospital appointments and other administrative requirements that required board certification; the view that subspecialty expertise is needed to manage serious or complex diseases; status considerations; and higher incomes earned by subspecialists. Valente et al. (1998) found that at managed care market penetration levels above 15%, there was an inverse relationship between the level of managed care and the decision of medical graduates to specialize. Although the effect of managed care penetration was small compared to individual characteristics such as age and gender, medical graduates who completed internal medicine training in markets with high HMO enrollments were significantly less likely to subspecialize.[32]

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[26] Neal A. Vanselow, "The Physician Workforce: Issues for Academic Medical Centers," (Washington, D.C.: Association of American Medical Colleges, 1997).
[27] Anne L. Schwartz, "Will Competition Change the Physician Workforce?," *Academic Medicine* 71, no. 1 (1996).
[28] Eli Ginzberg, "The Future Supply of Physicians," *Academic Medicine* 71, no. 11 (1996).
[29] Neal A. Vanselow, "Health Workforce Planning in the United States," in *NIH/US Health Workforce Planning 2000*, ed. Gary L. Filerman (American International Health Alliance, 1997).
[30] Vanselow, "The Physician Workforce: Issues for Academic Medical Centers."
[31] Schwartz, "Will Competition Change the Physician Workforce?."
[32] E. Valente et al., "Market Influences on Internal Medicine Residents' Decisions to Subspecialize," *Annals of Internal Medicine* 128, no. 11 (1998).

In internal medicine, the number of first-year fellows in nine traditional subspecialties declined by 21% between 1992 and 1998. Determinants of this decrease were identified as negative changes in the academic and clinical practice job markets, age, and gender. The AAMC, clinical literature, and federal policy were identified as emphasizing the importance of a shift back toward a more desirable generalist-to-specialist ratio in the workforce.[33]

Compared to hospitals with little or no teaching activity, AMCs incur additional expenses in part by providing for the education of students and residents. Teaching hospitals require additional income to cover the costs of activities that do not generate income, including medical education, care for indigent patients, investment in new equipment and facilities, and the maintenance of high-technology patient care services.[34] In 1995-1996, the average cost per case in hospitals with the greatest intensity of teaching was about twice that of nonteaching hospitals ($10,655 v. $5,034).[35] Blumenthal and Thier(2002) found a significant, positive relationship between overall cost per case in teaching hospitals, and the intensity of teaching, measured by the ratio of interns and residents to beds. After inclusion of variables designed to control for the influence of clinical research, of the provision of rare or high-technology services, and of case mix, educational involvement was estimated to account for a little more than half of the cost differential.

The financing of academic medicine evolved as a web of sources and means that were frequently not directly related to the academic functions they supported. Medical education is supported not by a dedicated source of revenue, but by income from patient care, payment for the direct and indirect costs of research, state and local appropriations, philanthropy, and tuition and fees. On average, only 10-20% of income that supports educational activities is derived from secure sources such as tuition and fees, endowment earnings, gifts, or state support.[36] Recently, the most significant of these sources of support has been revenue from clinical activities of medical school faculties and affiliated hospitals. Total revenue from clinical activities included income from faculty practice plans, the value of volunteer medical school faculty, and revenue from affiliated

[33] Jeremiah A. Barondess, "Specialization and the Physician Workforce: Drivers and Determinants," *Journal of the American Medical Association* 284, no. 10 (2000).
[34] Ernest Valente, "The Financial Health of Teaching Hospitals Continues to Decline," (Washington, D.C.: Association of American Medical Colleges, 2000).
[35] Blumenthal and Thier, "Training Tomorrow's Doctors: The Medical Education Mission of Academic Health Centers."

hospitals. Faculty practice plan revenues support education through direct transfers to the school and other transfers to departments; underwriting of faculty teaching time; direct support of residents and fellows; and direct support of other academic programs. Volunteer faculty members are able to contribute teaching services as a result of payments for clinical service. Hospitals support medical education by providing revenues to academic programs—primarily to graduate medical education—and by assuming academic program expenses.[37]

Teaching hospitals are experiencing greater difficulty in maintaining their educational mission because they must compete with nonteaching hospitals when negotiating with managed care contractors and federal programs. Only Medicare and, in most states, Medicaid, specifically recognize the increased costs incurred by teaching hospitals.
The cost-conscious market for health care delivery has rendered AMCs less able to compete with community hospitals and managed care organizations for patients. The resulting loss of hospital and faculty practice plan revenues has decreased the funds available for cross-subsidizing medical education.[38,39,40] Teaching is affected by the change in the health care delivery market because faculty have less time to teach and voluntary clinical faculty members are also busier and less inclined to contribute their time. Hadley and Gaskin (1995) reported that increased HMO penetration appeared to have decreased AMCs' ability to subsidize graduate medical education. From 1984 to 1991, the growth in the number of interns and residents was slower in high penetration areas, increasing by 0.9% compared to 6.9% at AMCs in low penetration areas.[41]

The changing environment of health care delivery has prompted efforts to move the education of physicians out of the traditional hospital setting and into ambulatory care environments, and to train physicians in alternative payment arrangements and information management in the

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[36] David D'Eramo, "Statement of David D'Eramo," (Washington, D.C.: U.S. House of Representatives, 1997).
[37] Jones and Sanderson, "Clinical Revenues Used to Support the Academic Mission of Medical Schools, 1992-1993."
[38] Alan M. Fogelman et al., "Preserving Medical Schools' Academic Mission in a Competitive Marketplace," *Academic Medicine* 71, no. 11 (1996).
[39] "Clinical Funding Cuts Threaten Academics."
[40] D'Eramo, "Statement of David D'Eramo."
[41] Darrell J. Gaskin and Jack Hadley, "The Impact of HMO Penetration on the Rate of Hospital Cost Inflation, 1984-1993," (Washington, D.C.: Georgetown University Medical Center, 1995).

practice setting.[42,43,44] Physicians have traditionally been taught to approach their medical duties in terms of individual patients rather than the populations and communities from which they come. Because the focus on managed care lies also on outcomes and population-based health, managers of managed care organizations estimate that physicians need an additional one to two years of post-residency training to practice in managed care settings.[45] Lurie (1996) identified eight domains of knowledge that could enable students to develop skills for work in managed care environments: epidemiologic thinking; human behavior; organizational behavior; information systems; quality measurement and improvement; health systems financing and delivery; ethics; and systems-based care.[46] To cite but one example of the response to the need to train new doctors to work in managed care settings, all third-year medical residents at New York-Presbyterian Hospital/Weill Cornell Medical Center are required to participate in a two-week block rotation in managed care and evolving health systems . This program was designed to educate residents about managed care and to teach critical thinking concerning the changing health care system.[47] Such curriculum changes are intended to respond to the changing context of medical practice and to teach managed care principles to residents.[48,49,50]

The growth of the research enterprise at AMCs, as well as dependence on income from clinical activities, may have contributed to a "devaluation of teaching."[51] As evidence that the education of medical students may no longer be the core activity of medical schools, Blumenthal and Thier (2002) cited the placement of day-to-day responsibility for the preclinical curricula, with assistant or associate deans rather than deans or department chairs; emphasis on research or

[42] Douglas L. Wood, "Educating Physicians for the 21st Century," *Academic Medicine* 73, no. 12 (1998).
[43] Brent C. Williams, James O. Woolliscroft, and Janet E. Heindel, "A Managed Care Curriculum Implemented across Four Academic Departments Using Mandated Evaluation Instruments," *Academic Medicine* 74, no. 5 (1999).
[44] Jaan Sidorov, "Retraining Specialist Physicians for Primary Care Practice," *Academic Medicine* 72, no. 4 (1997).
[45] Mark Callahan, Oliver Fein, and Michael Stocker, "Educating Residents About Managed Care," *Academic Medicine* 75, no. 5 (2000).
[46] Nicole Lurie, "Preparing Physicians for Practice in Managed Care Environments," *Academic Medicine* 71, no. 10 (1996).
[47] Callahan, Fein, and Stocker, "Educating Residents About Managed Care."
[48] Merwyn R. Greenlick, "Educating Physicians for the Twenty-First Century," *Academic Medicine* 70, no. 3 (1995).
[49] Robert M. Carey and Carolyn Long Engelhard, "Academic Medicine Meets Managed Care: A High-Impact Collision," *Academic Medicine* 71, no. 8 (1996).
[50] J.R. Maclean, W. Rahn, and W. Salazar, "Teaching Managed-Care Principles to Residents," *Academic Medicine* 74, no. 5 (1999).
[51] Ludmerer, *Time to Heal: American Medical Education from the Turn of the Century to the Era of Managed Care*.

clinical practice, rather than teaching excellence in tenure reviews; and the lack of a separate track for clinical educators.[52]

The Research Mission of Medical Schools

Medical schools and teaching hospitals are the locus of much of the clinical research performed in this country. Federal research and development (R&D) budget authority for health-related functions is second only to national defense, and most federal health-related R&D funding is targeted to NIH programs.[53] In a typical year, about half of all of National Institutes of Health (NIH) extramural funding is awarded to medical schools. In fiscal year (FY) 1994, for example, medical schools received 50% of NIH's extramural research budget, or $4.6 billion. These awards were concentrated in the top twenty medical schools, which received almost 49% of the total NIH support to medical schools that year.[54]

Within medical schools, full-time faculty who were PIs were more likely to have Ph.D.'s than M.D.'s (regardless of department), and were more likely to teach in a basic science department than a clinical department (regardless of degree).[55]

There are three types of clinical research conducted at AMCs:

- Translational research, in which basic biological research is conducted, using human subjects, with the goal of enhancing the medical applications of research
- Clinical trials, in which defined diagnostic or therapeutic technologies are evaluated for safety and efficacy
- Outcomes or health services research, in which research studies seek to develop better ways to measure the effects of treatment and improve the efficiency or quality of health services.[56]

[52] Blumenthal and Thier, "Training Tomorrow's Doctors: The Medical Education Mission of Academic Health Centers."
[53] Ronald L. Meeks, "Proposed FY 2003 Budget Would Complete Plan to Double Health R&D Funding, Considerably Expand Defense R&D," (Washington, D.C.: National Science Foundation, 2002).
[54] Andrea Pfeffer, "NIH Extramural Trends: FYs 1985-1994," (Bethesda, Maryland: National Institutes of Health, 1995).
[55] QRC, "Medical School Faculty: Principal Investigator Tables," (Bethesda, Maryland: National Institutes of Health, 1995).

Much of the translational research is conducted at teaching hospitals and other clinical settings and is funded by the NIH through programs such as the General Clinical Research Centers (GCRC) program. In addition, medical schools provide research training and perform research through other mechanisms such as cooperative agreements and R&D contracts. Through teaching hospitals and other clinical affiliations, AMCs are particularly well-suited to integrate basic research and training with patient-oriented research.[57,58] For this reason, they are the principal recipient of federal funding for basic and clinical biomedical research and training. However, translational research is also thought to be particularly dependent on cross-subsidies from patient care revenues. [59,60,61]

Clinical trials are less dependent on internal AMC funding because they are often supported by the pharmaceutical industry. Exceptions are studies of off-patent medicines and of surgical procedures that cannot be patented. Clinical investigations of health care quality, efficiency, and outcomes are a newer and smaller area of research at AMCs. Much of the funding for this research is provided by the Agency for Health care Research and Quality (AHRQ), formerly the Agency for Health Care Policy and Research (AHCPR). Market pressures have increased the importance of this type of research as the AMCs seek to improve their competitive positions.[62]

The significance of the amount of federally funded research performed at academic medical centers became apparent when Congress pledged to double the NIH budget in five years, between FYs 1998 and 2003. That pledge was fulfilled by the FY 2003 budget request of $27.3

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[56] W.F. Crowley, Jr. and Samuel O. Thier, "The Continuing Dilemma in Clinical Investigation and the Future of American Health Care: A System-Wide Problem Requiring Collaborative Solutions.," *Academic Medicine* 71, no. 1 (1996).
[57] David Blumenthal and Samuel O. Thier, "From Bench to Bedside: Preserving the Research Mission of Academic Health Centers," (The Commonwealth Fund, 1999).
[58] Stephen J. Heinig et al., "The Changing Landscape for Clinical Research," *Academic Medicine* 74, no. 6 (1999).
[59] AAAS, "NIH Budget Climbs $3.2 Billion or 15.7 Percent," (Washington, D.C.: American Association for the Advancement of Science, 2002).
[60] Pfeffer, "NIH Extramural Trends: FYs 1985-1994."
[61] Andrew Quon, "Changes in U.S. Medical Schools' NIH Rankings, 1991-2000," (Washington, D.C.: Association of American Medical Colleges, 2001).
[62] Crowley and Thier, "The Continuing Dilemma in Clinical Investigation and the Future of American Health Care: A System-Wide Problem Requiring Collaborative Solutions."

billion, an amount approximately double the FY 1998 appropriation of $13.6 billion.[63] In the four decades prior to this appropriation, the NIH budget had doubled about every ten years.[64] The increased funding has allowed academic medical centers, particularly those that are the most research intensive, to increase the number of its researchers, including the number of students and fellows working on research grants; in addition, increased funding has supported the development of the research infrastructure at medical schools and teaching hospitals.

Members of the AMC community expressed concern, during the period prior to the doubling of the NIH budget, about the effects of increased competition for patients on clinical care revenues, which, in turn, support research.[65,66] The NIH Associate Director of Science Policy summarized the interrelated effects of managed care on the research enterprise at AMCs as follows:[67]

- AMCs use clinical care revenues to underwrite academic activities
- Reimbursements to AMCs from managed care companies are typically lower than those paid by fee-for-service plans, and are sometimes less than the AMC's costs
- Managed care companies are reluctant to refer patients to AMCs because of their higher costs[68]
- Managed care companies are reluctant to cover the costs of clinical care when they are associated with a research protocol[69]

Internal funding of research has been a significant assistance to researchers at AMCs. Institutional support includes offsetting expenses that NIH or other sources of sponsored research do not support (e.g., the cost of capital and the portion of investigators' salaries that are above the federal cap), and supporting junior faculty who have not yet acquired the track record they need to compete for their own research grants. In 1992-1993, revenue from faculty practice plans

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[63] "Press Release for the FY 2003 President's Budget," (Bethesda, Maryland: National Institutes of Health, 2002).
[64] David Korn et al., "The NIH Budget in the "Postdoubling" Era," *Science* 296, no. 5572 (2002).
[65] Foreman, "Medical Education and Research: Financial Challenges and Institutional Responses".
[66] Iglehart, "The American Health Care System - Teaching Hospitals."
[67] Lana R. Skirboll, "The Impact of Managed Care on Research: The Changing Face of Medicine," *Academic Medicine* 72, no. 9 (1997).
[68] Robert Mechanic, Allen Dobson, and Sylvia Yu, "The Impact of Managed Care on Clinical Research: A Preliminary Investigation," (Bethesda, MD: National Center for Research Resources, 1996).
[69] Heinig et al., "The Changing Landscape for Clinical Research."

contributed $816 million toward research projects at medical schools.[70] This amount was about 20% of total NIH funding to medical schools in the same year.[71] In a separate study, Korn (2000) reported that in FY 1993, about 10% of revenues from faculty practice plans were estimated to support biomedical research. [72]Skirboll (1997) noted, however, that there was little empirical evidence to support the assertion that managed care was adversely affecting research at AMCs.[73]

While a clear cause-and-effect relationship between limits placed on AMC utilization by managed care organizations, and reduced funds available for research has not been presented in the literature, there have been some interesting correlational relationships reported.[74,75] Szabo (1997), for example, cited managed care's cost consciousness as limiting both AMC use and the length of hospital stays, and as reducing funds available for research.[76] Moy et al. (1997) reported that medical schools in all managed care markets had comparable rates of growth in NIH research funding from 1986 to 1990. Thereafter through 1995, schools in regions with high levels of managed care market penetration experienced slower growth in the size and number of NIH research awards. Much of the decrease in revenue growth was traced to slower growth of traditional investigator awards to clinical departments, but the authors stopped short of identifying a causal relationship between growth of NIH awards and managed care penetration.[77,78]

[70] Jones and Sanderson, "Clinical Revenues Used to Support the Academic Mission of Medical Schools, 1992-1993."
[71] Skirboll, "The Impact of Managed Care on Research: The Changing Face of Medicine."
[72] David Korn, "Conducting Basic and Clinical Research in the Managed Care Setting," in *Managed Care Systems and Emerging Infections: Challenges for Strengthening Surveillance, Research, and Prevention, Workshop Summary*, ed. Jonathan R. Davis (Washington, DC: National Academy Press, 2000).
[73] Skirboll, "The Impact of Managed Care on Research: The Changing Face of Medicine."
[74] J. Raloff, "Managed Care May Be Choking Clinical Research," (Washington, D.C.: American Association for the Advancement of Science, 1997).
[75] "Clinical Funding Cuts Threaten Academics."
[76] Joan Szabo, "Do Managed Care Practices Hamper Clinical Research?," *Managed Care*, August 1997.
[77] Ernest Moy et al., "Relationship between National Institutes of Health Research Awards to Us Medical Schools and Managed Care Market Penetration," *Journal of the American Medical Association* 278, no. 3 (1997).
[78] Ernest Moy, "Is Managed Care Affecting the Research Mission of Medical Schools?," (Washington, DC: Association of American Medical Colleges, 1997).

Campbell et al. (1997) reported similar results when they looked at the number of peer-reviewed research papers published.[79] In addition to their quantitative analysis of publications data, Campbell et al. found in a survey of attitudes that clinical investigators in the most cost-conscious AMCs were most likely to report tension among researchers, lack of cooperation from colleagues, and competition for resources. Weissman et al. (1999) surveyed a sample of research faculty in 117 medical schools to assess the amount and distribution of unsponsored research activities as a proportion of total direct costs of research, compared across stages of market competition. Results indicated that market pressures may be affecting the level of institutional funding available to faculty.[80]

The AAMC convened a task force on clinical research in 1998 to assess the opportunities and challenges facing clinical research in AMCs. They identified several challenges to clinical research, including regulations related specifically to data used in clinical research; increased uncertainty about reimbursements by insurers of routine care provided to patients participating in clinical trials; and the declining numbers of physician-scientists.[81] Griner et al. (2000) identified strategies designed to respond to the changing clinical research environment. These strategies included strengthening of clinical research leadership; reorganization of GCRC programs to better serve human subjects and clinical researchers; use of information technologies to improve efficiency; development of formal training paths for clinical researchers; creation of new businesses that served the sponsors of clinical trials; development of centralized offices for the management of industry-sponsored clinical trials; and creation of partnerships and alliances with contract research organizations and managed care organizations.[82]

Following the significant increase in NIH funding that began in 1998, concerns about support for research at AMCs have appeared less often in the literature and are based on data that precede or

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[79] Eric G. Campbell, Joel S. Weissman, and David Blumenthal, "Relationship between Market Competition and the Activities and Attitudes of Medical School Faculty," *Journal of the American Medical Association* 278, no. 3 (1997).
[80] Joel S. Weissman et al., "Market Forces and Unsponsored Research in Academic Health Centers," *Journal of the American Medical Association* 281, no. 12 (1999).
[81] Paul F. Griner et al., "Managing Change: Strategies from Case Studies of Medical Studies and Teaching Hospitals," (Washington, D.C.: Association of American Medical Colleges, 2000).
[82] Ibid., 21.

extend only a year or two into the budget-doubling period (see, for example, Korn, 2000).[83] However, there is some evidence that in areas with high managed care enrollments cross-subsidies for research are decreasing, potentially threatening the extended-term prospects of the AMC research mission. Moreover, as successful doubling of the NIH budget approaches, concerns about managing the "post-doubling" period are being raised.[84] More than half of NIH funding supports investigator-initiated research project grants. At the present time, these awards carry a funding commitment of just over four years. With the recent increase in the NIH-funded national research base, research activities at AMCs are particularly vulnerable to significantly reduced annual increases in NIH funding that are certain to begin in FY 2004.

The Patient Care Mission of Medical Schools

Patient care—the last of the three interrelated missions of AMCs—was transformed from a practical, hands-on method of training physicians, to a vital enterprise in its own right, with the passage of Medicare and Medicaid in 1965. This legislation provided a significant transfer of governmental funds to the AMCs for care of patients, many of who were previously charity cases, and for training residents. From the early 1980s through the mid-1990s, the financial health of most teaching hospitals progressively improved. Teaching hospitals generated enough revenue to provide support for teaching and research, with clinical service producing nearly 50% of aggregate annual revenue.[85,86]

The effect of the growth of the managed care model of health care delivery on the competitiveness and finances of AMCs was discussed earlier in this chapter, in the context of cross-subsidies for both education and research. Teaching hospitals experienced the dual effects of a more competitive health care market, and more restrictive reimbursement policies adopted by federal programs in health insurers. For example, revenue per faculty member in faculty practice plans did not change significantly between 1993 and 1998, although outpatient visits per

[83] Korn, "Conducting Basic and Clinical Research in the Managed Care Setting."
[84] Korn et al., "The NIH Budget in the "Postdoubling" Era."
[85] Griner et al., "Managing Change: Strategies from Case Studies of Medical Studies and Teaching Hospitals."
[86] D'Eramo, "Statement of David D'Eramo."

faculty increased and a higher percentage of faculty salaries were supported by practice revenue.[87]

Academic medical centers adopted a variety of organizational strategies in response to increased managed care market penetration and threats to clinical revenues. This occurred throughout the AMC community, but was most urgently addressed in areas where managed care plans were growing.[88] During the 1990s, AMCs attempted to strengthen their patient referral base and maintain or increase their market share, partly through expansion of the specialized services that historically differentiated teaching hospitals from other hospitals. Actions were generally aimed at securing an adequate patient base for teaching and research, and at generating sufficient income to cover costs of activities that did not generate revenues. Staff reductions, changes in the mix of staff, outsourcing services, quality improvement initiatives, reduction of uncompensated care costs, improved staff training and utilization management, increased use of automation, and practice guidelines were some of the strategies used to contain costs. [89] Considerable variety in responses was in evidence, including:

- Transformation from being part of a state system of higher education to being an independent public corporation—Oregon Health Sciences University.[90]
- Collaboration with a health maintenance organization (HMO) or managed care organization (MCO) in the form of a partnership, alliance, or formal affiliation—University of Massachusetts Medical Center and Fallon Health Care System;[91] University of Connecticut School of Medicine and several local managed care organizations;[92]

[87] Griner et al., "Managing Change: Strategies from Case Studies of Medical Studies and Teaching Hospitals."
[88] Iglehart, "The American Health Care System - Teaching Hospitals."
[89] Fogelman et al., "Preserving Medical Schools' Academic Mission in a Competitive Marketplace."
[90] Beth Alexander, Lois Davis, and Peter O. Kohler, "Changing Structure to Improve Function: One Academic Health Center's Experience," *Academic Medicine* 72, no. 4 (1997).
[91] Deirdre Carroll Donahue et al., "Research Collaboration between an Hmo and an Academic Medical Center: Lessons Learned," *Academic Medicine* 71, no. 2 (1996).
[92] Bruce Gould, "Partnerships for Education between Medical Schools and Managed Care Organizations: The Experience of the University of Connecticut School of Medicine," (Washington, D.C.: Association of American Medical Colleges, 1998).

Kimmel Cancer Center at Thomas Jefferson University and Aetna US Health care;[93] Case Western Reserve University School of Medicine and the Henry Ford Health System[94]

- Separation of education and research from clinical care in a nonprofit institute—Harvard Medical School and Beth Israel Hospital[95]
- Creation of an independent institute to educate physicians to function effectively in a managed care environment—Tufts University School of Medicine and Tufts Health Plan[96]
- Formation of a joint venture—Emory Health care (the clinical enterprise of Emory consisting of several teaching hospitals and two faculty practice plans of the Emory University School of Medicine) and Columbia/HCA, a for-profit HMO;[97] University of Michigan Health System and Ford Motor Company/General Motors[98]
- Sale of university assets to a for-profit system—Tulane University Hospital and Columbia/HCA[99]
- Mergers of teaching hospitals—Brigham and Women's Hospital and the Massachusetts General Hospital in Boston; Presbyterian Hospital and the New York Hospital, and Mount Sinai and New York University Medical Centers in New York; Barnes and Jewish Hospitals in St. Louis; and the hospitals of Stanford University and the University of California, San Francisco[100]
- Development of affiliations with rural hospitals and extensive subspecialty outreach services—University of Rochester School of Medicine and Dentistry, Oregon Health Sciences University, University of Iowa College of Medicine[101]

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[93] Ronald E. Myers, Neil Schlackman, and Arnold D. Kaluzny, "A Promising Process for Creating an AHC - Managed Care Organization Alliance for Research and Care," *Academic Medicine* 72, no. 5 (1997).
[94] David P. Stevens et al., "A Strategy for Coping with Change: An Affiliation between a Medical School and a Managed Care Health System," *Academic Medicine* 71, no. 2 (1996).
[95] Michael Rosenblatt, Mitchell T. Rabkin, and Daniel C. Tosteson, "How One Teaching Hospital System and One Medical School Are Jointly Affirming Their Academic Mission," *Academic Medicine* 72, no. 6 (1997).
[96] Rosalie R. Phillips et al., "The Tufts Partnership for Managed Care Education," *Academic Medicine* 72, no. 5 (1997).
[97] Sylvia Wrobel, "A Joint Venture to Address Strategic Objectives: Emory Health care and Columbia/HCA," (Washington, D.C.: Association of American Medical Colleges, 1998).
[98] Griner et al., "Managing Change: Strategies from Case Studies of Medical Studies and Teaching Hospitals."
[99] John C. LaRosa, "Tulane University and Columbia/HCA," in *Mission Management: A New Synthesis*, ed. Roger J. Bulger, Marian Osterweis, and Elaine R. Rubin (Washington, D.C.: Association of Academic Health Centers, 1999).
[100] Ludmerer, *Time to Heal: American Medical Education from the Turn of the Century to the Era of Managed Care*.
[101] Griner et al., "Managing Change: Strategies from Case Studies of Medical Studies and Teaching Hospitals."

- Expansion of primary care capacity—University of California, Los Angeles; UCLA School of Medicine; University of Rochester School of Medicine and Dentistry; Oregon Health Sciences University; University of Michigan Medical School; and University of Texas Southwestern Medical Center at Dallas Southwestern Medical School[102]
- Other internal consolidation and reorganization—Harvard Medical School assessed its five major teaching hospitals to identify and eliminate duplicative services and to compete for patients as a unified system.[103] The University of California, Los Angeles (UCLA) Medical Center formed a Medical Group that, while not a single practice plan, represented all of the physician providers and hospitals that were part of the UCLA Center for Health Sciences, in negotiations and contract execution, through a single signature process.[104]

A wide variety of organizational strategies were employed by AMCs in the 1990s as they navigated the emerging managed care environment. The particular actions of any individual AMC were taken in response to local market conditions and the organizational environment. There is also some evidence, however, that some AMCs are using "me-too" strategies in formulating their plans for accomplishing their missions in the new environment. Some AMCs are reacting to external pressures by copying from lower-cost, geographically better-positioned hospitals and health systems.[105] The organizational actions described in this chapter provide a qualitative underpinning to the analyses of quantitative data that are described in chapters 6 through 8. These analyses were designed to identify emerging patterns of behavior, derived from the cumulative measures taken by local actors at each AMC.

The following, and final section of this chapter, describes the public policy environment of AMCs, particularly with respect to policy effects on AMC revenues from patient care.

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[102] Ibid.
[103] Iglehart, "The American Health Care System - Teaching Hospitals."
[104] Michael Karpf, Raymond G. Schultze, and Gerald Levy, "The Decade of the Nineties at the UCLA Medical Center: Responses to Dramatic Marketplace Changes," *Academic Medicine* 75, no. 8 (2000).
[105] Kurt Krauss and John Smith, "Rejecting Conventional Wisdom: How Academic Medical Centers Can Regain Their Leadership Positions," *Academic Medicine* 72, no. 7 (1997).

Legislation and Policy Affecting Teaching Hospital Revenues

Medical schools establish affiliations with teaching hospitals to provide a source of patients and an environment for their clinical education and biomedical research activities. Teaching hospitals frequently offer the newest services and treatments, and attract patients that need specialized care; their facilities serve as the site of clinical research, particularly patient-oriented clinical research. Additional missions of teaching hospitals increase the cost of patient care, relative to community hospitals. Recognizing the legitimacy of these increased costs, the federal government has established several mechanisms to compensate teaching hospitals for the added costs of their health education programs.

When Congress established the Medicare program in 1965, it recognized that:

> Educational activities enhance the quality of care in an institution, and it is intended, until the community undertakes to bear such education costs in some other way, that a part of the net cost of such activities (including stipends of trainees, as well as compensation of teachers and other costs) should be borne to an appropriate extent by the hospital insurance program. [106]

Funds transferred to teaching hospitals through Medicare are in the form of direct graduate medical education (DGME) payments, indirect medical education (IME) payments, and disproportionate share hospital (DSH) payments.

The Medicare program makes direct payments to teaching hospitals for a share of the added costs associated with operating educational programs. DGME payments, including residents' stipends, teaching physicians' salaries, and the cost of office space and other overhead, are based on: a hospital-specific, per-resident amount that is calculated on an annual basis; the current number of full-time equivalent (FTE) residents; Medicare's share of inpatient days; and a locality

[106] House Report, Number 213, 89th Congress, 1st session 32 (1965) and Senate Report, Number 404 Pt. 1 89th Congress 1 Session 36 (1965). Reported on AAMC Government Affairs and Advocacy Web site. 4 September 2002 http://www.aamc.org/advocacy/library/gme/gme0001.htm.

adjustment. A facility may include in its FTE count residents who are being trained in the hospital and those who are in ambulatory settings, as long as the hospital pays for the training.[107] Differences in costs at teaching hospitals were found to be correlated with the intensity of the teaching program, as measured by the ratio of interns and residents to hospital beds.[108] The formula for DGME payments has changed several times since the mid-1980s. Notably, higher payments for primary care residents were instituted by the Omnibus Budget Reconciliation Act of 1993 (P.L. 103-66).

Medicare also pays most hospitals for their inpatient hospital services at a predetermined rate, for each discharge, under the prospective payment system (PPS). Psychiatric and rehabilitation hospitals and units, long-term care hospitals, children's hospitals, and cancer hospitals are excluded from PPS, and continue to be paid on a reasonable cost basis, subject to per discharge limits. Because teaching hospitals incur additional costs due to the presence of interns and residents and resulting higher staff levels, an IME adjustment to the PPS was allowed when Congress created the PPS in 1983. For every Medicare case paid under the prospective payment system (PPS), teaching hospitals receive an additional payment to help offset the indirect expenses of medical education.

The IME adjustment was justified at the time in a context broader than medical education:

> This adjustment is provided in light of doubts…about the ability of the Diagnosis-Related Group (DRG) case classification system to account fully for factors such as severity of illness of patients requiring specialized services and treatment programs provided by teaching institutions and the additional costs associated with the teaching of residents…The adjustment for indirect medical education

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Lynne Davis Boyle and Karen Fisher, "Medicare Direct Graduate Medical Education (DGME) Payments," (Washington, D.C.: Association of American Medical Colleges, 2002).

[107] "ACS Views on Legislative, Regulatory, and Other Issues," (Chicago: American College of Surgeons, 2002).

[108] Institute of Medicine, *On Implementing a National Graduate Medical Education Trust Fund* (Washington, D.C.: National Academy Press, 1997).

costs is only a proxy to account for a number of factors which may legitimately increase costs in teaching hospitals.[109]

IME payments are made through an adjustment tied to each teaching hospital's ratio of interns and residents-to-beds (IRB) plus any outlier payments for cases that are exceptionally costly relative to other cases in the same DRG.[110] Increases in the number of residents trained in teaching hospitals translate directly to increases in both DGME and IME payments.

The third source of federal payments, DSH, is also mediated through the Medicare program. Teaching hospitals, which already had a tradition of treating charity cases, have continued to serve large low-income populations. As the Medicare program transitioned from a cost-based reimbursement to a PPS, it added a special adjustment for hospitals that serve large populations of low-income patients. The original objective for the DSH payment adjustment was to compensate teaching hospitals the higher operating costs, including social workers and translators. Over time a second rationale emerged: DSH funds preserve access to medical care for Medicare and low-income populations, by financially assisting the hospitals that serve them. Like the DGME and IME, the DSH adjustment has been repeatedly modified, first increasing (P.L. 101-508) and then reducing (P.L. 105-33) the adjustment for specific categories of hospitals.[111]

In the last five years, Congress has passed three pieces of legislation that have made significant changes to Medicare provider payments (see Table 1). The Balanced Budget Act of 1997 (BBA) changed the IME payment add-on, capped the number of full-time equivalent (FTE) residents, and required residents to be counted on a three-year rolling average.[112] In 1999, as a result of an intense lobbying campaign by provider organizations and the AAMC, the realization that BBA

[109] House Ways and Means Committee Report, Number 98-25, 4 March 1983 and Senate Finance Committee Report, Number 98-23, 11 March 1983. Reported on AAMC Government Affairs and Advocacy Web site. 4 September 2002 http://www.aamc.org/advocacy/library/gme/gme0002.htm
Lynne Davis Boyle, "Medicare Indirect Medical Education (IME) Payments," (Washington, D.C.: Association of American Medical Colleges, 2002).
[110] Institute of Medicine, *On Implementing a National Graduate Medical Education Trust Fund*.
[111] Lynne Davis Boyle, "Medicare Disproportionate Share (DSH) Payments," (Washington, D.C.: Association of American Medical Colleges, 2002).
[112] Jennifer O'Sullivan et al., "Medicare: Changes to Balanced Budget Act of 1997 (BBA 97, P.L. 105-33) Provisions," (Washington, D.C.: Library of Congress, 1999).

provisions cut Medicare programs too deeply, and the presence of a large budget surplus, Congress enacted the Balanced Budget Refinement Act (BBRA). In addition to more IME payment changes, the BBRA changed DGME payments by imposing a new methodology based on a national average per resident amount adjusted by a factor that varied according to the physician fee schedule area in which a hospital is located (locality adjustment).[113] Finally, the Medicare, Medicaid, and SCHIP Benefits Improvement and Protection Act of 2000 (BIPA), which was passed in December 2000, provided an additional two-year freeze for IME payments and increased the per resident amount "floor" for DGME payments through 2002.

In addition to basic biomedical research, teaching hospitals conduct clinical trials research. Clinical trials test the safety and efficacy of drugs, medical devices, and new techniques, and are required by the U.S. Food and Drug Administration (FDA) for drug and device approval. Clinical trials are divided into four major phases:[114]

- Phase I trials determine whether a drug or product is safe for use on humans
- Phase II trials test for efficacy in a larger group of patients than Phase I trials (>100 patients)
- Phase III trials test safety and efficacy within the general population, and are typically large, multi-center, randomized control studies with thousands of participants
- Phase IV trials are post-market outcomes studies and may look at cost effectiveness

Phase I and II trials are traditionally funded by the federal government, but the NIH, for example, does not cover all associated patient costs. Much of the support for Phase III and IV clinical trials comes from biotechnology and pharmaceutical industries. Academic medical centers rely on the federal government and on third-party payers to reimburse them for ancillary test and procedures, including tests to ensure that the patient qualifies for the clinical trial, for basic medical care, and for other patient costs that are not directly part of the research.

[113] "Summary of the Medicare, Medicaid, and SCHIP Balanced Budget Refinement Act of 1999," (Washington, D.C.: Library of Congress, 1999).
[114] Myrna E. Watanabe, "Bottom Line, Culture Clash Impeding Cooperation of Managed-Care Organizations in Clinical Trials," *The Scientist* 10, no. 13 (1996).

Three challenges have reduced revenue streams that support clinical trials at teaching hospitals: managed care; the commercialization of clinical trials; and the Balanced Budget Act of 1997.[115] Price competition, and the mandate on managed care to hold down increases in medical costs have resulted in the diversion of patients away from teaching hospitals toward less costly community hospitals. Cost consciousness at academic medical centers has also reduced the time available for research. Pharmaceutical companies have turned to contract research organizations (CROs) that emphasize efficiency, and which are in direct competition with AMCs.

Although the effects of BBA have been ameliorated somewhat in subsequent legislation (as described in the preceding paragraphs), additional measures have also been introduced to ensure the availability of patients for clinical trials and the availability of support for clinical trials. Prior to 2000, Medicare did not pay for items and services related to clinical trials, due to their experimental nature. Several bills were introduced to remedy the situation, including H.R. 61—Medicare Clinical Trial Coverage Act of 1999; H.R. 2723—Bipartisan Managed Care Improvement Act; H.R. 2990—Quality Care for the Uninsured Act; S. 117 and H.R. 2769—Improved Patient Access to Clinical Trials Act; S. 784 and H.R. 1388—Medicare Cancer Clinical Trial Coverage Act of 1999; and S. 1344—Patient's Bill of Rights.[116] None of these progressed far in the legislative process. On 7 June 2000, the President of the United States issued an executive memorandum directing the Secretary of Health and Human Services to "explicitly authorize [Medicare] payment for routine patient care costs...and costs due to medical complications associated with participation in clinical trials." The final national coverage decision stated that effective for items and services furnished on or after 19 September 2000, Medicare would cover the routine costs of qualifying clinical trials, and of reasonable and necessary items and services used to diagnose and treat complications arising from participation in all clinical trials.[117,118]

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115 Heinig et al., "The Changing Landscape for Clinical Research."

116 "Office of Legislative Policy and Analysis Report: Access to Clinical Trials," (Bethesda, Maryland: National Institutes of Health, 1999).

117 "Medicare Coverage Routine Costs of Beneficiaries in Clinical Trials," (Washington, D.C.: Health Care Financing Administration, 2000).

118 "More Choices in Cancer Care: Information for Beneficiaries on Medicare Coverage of Cancer Clinical Trials," (Bethesda, Maryland: National Cancer Institute, 2002).

In summary, U.S. medical schools have entered a period in which their three primary functions—teaching, research, and patient care—have been influenced by the increasingly dominant managed health care delivery market. The education of physicians has been influenced by considerations of new practice environments, by increasing difficulty in funding medical education, and by changes in the relative need for specialists and general practitioners. Research conducted at medical schools, affiliated teaching hospitals, and other clinical settings has been conducted in an increasingly competitive environment—national competition for research funds, local competition for patients to participate in clinical trials and other patient-oriented research, and competition within the AMC for decreasing "spillover" funds from faculty practice plans and hospital revenue. AMCs have encountered direct competition from community hospitals and CROs in attracting patients whose costs are fully reimbursed, either by insurance companies or federal programs. The most notable unintended consequence of the challenges to faculty practice plan revenues is the decrease in cross-subsidies for teaching and research. In response to the market and regulatory environment, AMCs have employed a variety of organizational strategies in making long-term policy regarding resource allocation, organizational relationships, and market positioning.

Table 4-1. Federal Legislation Affecting Academic Medical Centers

Year	Legislation	Public Law	Academic Medical Center Related Provisions
1965	Social Security Act of 1965	P.L. 89-97	Medicare and Medicaid programs established (Title XVIII and Title XIX); the federal government pays proportionate share of direct costs of medical education in addition to reasonable operating and capital costs of Medicare patient treatment.
1982	Tax Equity and Fiscal Responsibility Act	P.L. 97-248	Hospital cost limits are extended to cover total operating costs per discharge; limit set on allowable rate of increase in costs. IME, first recognized as a concept in 1980, is increased to incorporate a differential based on the IRB in each teaching hospital. Methodology subsequently converted to a PPS payment; IME adjustment retained.
1983	Social Security Amendments	P.L. 98-21	Medicare implements the Prospective Payment System (PPS) using Diagnosis Related Groups (DRGs)
1986	Consolidated Omnibus Reconciliation Act	P.L. 99-272	DGME payment methodology changes to consider costs incurred and number of residents during a base year and limits the number of years of residency support.
1990	Omnibus Budget Reconciliation Act	P.L. 101-508	Congress adds money to the DSH adjustment for specific categories of hospitals; further reduces IME adjustment.
1993	Omnibus Budget Reconciliation Act	P.L. 103-66	Additional adjustments to the DGME payment methodology, including higher payments for primary care residents.
1997	Balanced Budget Act	P.L. 105-33	Scheduled $10.4 billion in cuts to state Medicaid DSH allotments over five years (FYs 1998 through 2002). Limits the number of FTE residents counted for DGME payments and introduces use of rolling 3-year average of number of residents. DGME payments can be made to entities other than hospitals. IME payments also to be gradually reduced.
1999	Medicare, Medicaid, and SCHIP Balanced Budget Refinement Act	P.L. 106-113	Delayed the BBA 1997 schedule for reducing IME and DSH payments.
2000	Beneficiary Improvement and Protection Act	P.L. 106-554	Extends many of the provisions introduced as part of the BBRA and restores some payments. IME and DSH payments frozen in FY 2003 and beyond; the “floor” in the methodology used to calculate DGME payments increased from 70% to 85%.

Chapter 5. Methodology

Research Methodology and Design

This dissertation describes a descriptive and explanatory research project that used a nonexperimental research design. In experimental and quasi-experimental research, inferences are drawn from causes (independent variables) to effects (dependent variables). In nonexperimental research, these inferences are typically made in the opposite direction; i.e., the researcher begins with the dependent variable and seeks to uncover the independent variables.[1] The hallmarks of experimental studies are manipulation of the independent variables by the researcher, and construction of study groups on the basis of randomized selection of subjects. Randomization is used to create groups that are "equal" in all respects except the independent variable. In a quasi-experiment, the researcher is able to manipulate the independent variables but randomization is typically absent. In a nonexperimental design, neither manipulation nor randomization is present. The research study described in this dissertation is based on a nonexperimental design.

In nonexperimental research, groups are often created on the basis of the dependent variable.[2] In this dissertation, the behavior of a population of institutions was of primary interest, but for some of the analyses the medical schools comprising the population were grouped on the basis of the penetration of managed care in their local health care delivery markets—the independent variable. Nonexperimental research can be thought of as passive-observational research. In this dissertation, the "observations" were most often published data; I did not directly observe the institutions of interest.

The primary research objective was explanatory rather than predictive in intent. Predictive research seeks to identify, define, and utilize information about predictors (independent variables) to create a system for predicting criteria (dependent variables) of interest. Explanatory

[1] Elazar J. Pedhazur and Liora Pedhazur Schmelkin, *Measurement, Design, and Analysis: An Integrated Approach* (Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1991).
[2] Ibid.

research often tests hypotheses that were developed to explain the phenomena of interest.[3] This research study was conceived as an attempt to explain the patterns of behavior in a population of institutions by attributing the variability to presumed causes (primarily managed care market penetration). The research described in this dissertation also had a descriptive component: the behavior of the academic medical centers and the market "behavior" of managed health care delivery were described and documented.

The time dimension of the data collected was retrospective. That is, I first collected observations of dependent variables in 2000 or 2001 and then compiled information on the dependent variables as well as the independent variable for past years to help explain current observations. The approach was similar to a longitudinal study but the time frame was retrospective rather than prospective. As a result, secondary analysis of existing data was an appropriate approach.

The research study observations included data for the entire population of accredited, U.S. medical schools. By studying the entire population of approximately 125 institutions, issues related to sampling statistics and generalizability of results to a population were avoided. This approach also eliminated concerns about threats to external validity, defined as the "generalizability of causal inferences outside the particular setting or area." [4] Because the entire population was included in the study, generalization was neither possible nor necessary.

The research study is focused on medical schools and their mission-related environments, i.e., the contexts of research, education, and patient care. A model was developed that identified dependent variables that described changes in the organizational characteristics and behavior of academic medical centers, and independent variables hypothesized to influence and mediate those changes. The context of the study and the study model are more fully described in the next section.

It is worth noting that while in some respects the dissertation study model resembled a multi-stage causal model, it was also different in some important ways. A causal model is a simplified

[3] Burke Johnson, "Toward a New Classification of Nonexperimental Quantitative Research," *Educational Researcher* 30, no. 2 (2001).
[4] William N. Dunn, *Public Policy Analysis*, Second ed. (Englewood Cliffs, New Jersey: Prentice Hall, 1994) 396.

representation designed to explain and predict the causes and consequences of the variables in the model. One of the statistical procedures often used in causal modeling is path analysis, a "specialized approach to linear regression that uses multiple (rather than single) independent variables." [5] Path analysis and causal modeling are usually designed to be predictive—forecasts are based on theoretical assumptions about causes and their effects. A fundamental assumption in developing causal models and conducting path analyses is that the relationships among the variables are linear.[6] Despite a resemblance between the dissertation study model and a more typical multi-stage causal model, this research design was developed to meet descriptive and explanatory objectives rather than predictive objectives. More importantly, the theoretical basis of the study did not assume linear relationships among the variables.

Explanatory nonexperimental research designs depend heavily on theory—perhaps even more than other types of research designs—to identify the variables that are relevant to the study. Whereas it is possible to select variables to use in a predictive study simply on the basis of practical considerations, in the absence of a theoretical framework for an explanatory study it is nearly impossible to determine which variables are relevant and should be included, and which are not relevant and should be excluded. Moreover, it can be very difficult to determine the role (e.g., independent, dependent) of the included variables.[7]

In this dissertation, the chosen framework of complexity science had a major influence on the study design and methodology. For example, the selection of the managed care market as a variable that directly and indirectly influenced the behavior of academic medical centers is consistent with the notion that nonlinear systems depend on feedback and that outside forces are often required for a nonlinear dynamic system to change. In the terminology of complexity, the system moves from one attractor to another. One of the most significant influences of the theoretical framework was on what was excluded from the research design and methodology; statistical approaches that relied on assumptions of linear relationships to predict system behavior and to draw conclusions about cause and effect were not consistent with a nonlinear systems dynamics approach.

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[5] Ibid. 230.
[6] Pedhazur and Schmelkin, *Measurement, Design, and Analysis: An Integrated Approach* 305.
[7] Ibid.

In summary, the research study is best described as follows:

- Nonexperimental—variables of interest were observed but not manipulated; “subjects” were not randomly assigned to groups.
- Explanatory—the purpose of the research study was to explain changes that had already occurred in academic medical centers’ components and activities related to core missions, using the variables in the study model; the research study did not seek to predict academic medical centers’ behavior.
- Descriptive—the research study described and documented the phenomena of interest with respect to academic medical centers and the managed care markets in which they were located.
- Retrospective—the research study began with observations on the present and moved backward in time to incorporate information on both the independent variable (to help explain current differences in the dependent variables), and the dependent variables, (which could be used to predict future system behavior)
- Population-based—the study included the entire population of academic medical centers rather than a statistical sample.
- Model-based—based on a study model that resembled a causal model such as might be used in a path analysis, but no assumptions were made about linear cause-and-effect relationships among the study variables.
- Theory-based—complexity science influenced the selection of variables and analytic tools.

The primary purpose of this dissertation was to examine the changes exhibited by a population of organizations—academic medical centers—concurrent with the market growth of a health care delivery model—managed care. The emergence of managed care as a dominant force in the delivery of health care challenged the financial well-being, core missions, and structures of academic medical centers. During the 1980s and 1990s, the same time period in which managed care significantly increased its health care delivery market share, academic medical centers were changing in a variety of ways. The rich description of these changes that was developed from multiple indicators represents a major contribution of this research study.

The research described in this dissertation was based on a representation of medical schools and their mission-related environments. This representation, shown in figure 5-1, provided the basis of the study model design. Figure 5-1 depicts key characteristics of the environments in which each of the three primary missions were situated. Each of the mission-related environments contained a financial component because each was a source of revenue. In addition to the functional (mission-related) environments, academic medical centers existed within a policy and legislative environment, in which they affected and were affected by, health care policy, legislation, and regulation. They also interacted with accrediting bodies and professional associations that served in a regulatory capacity as well as in an advocacy role.

Environmental Characteristics of Academic Medical Centers

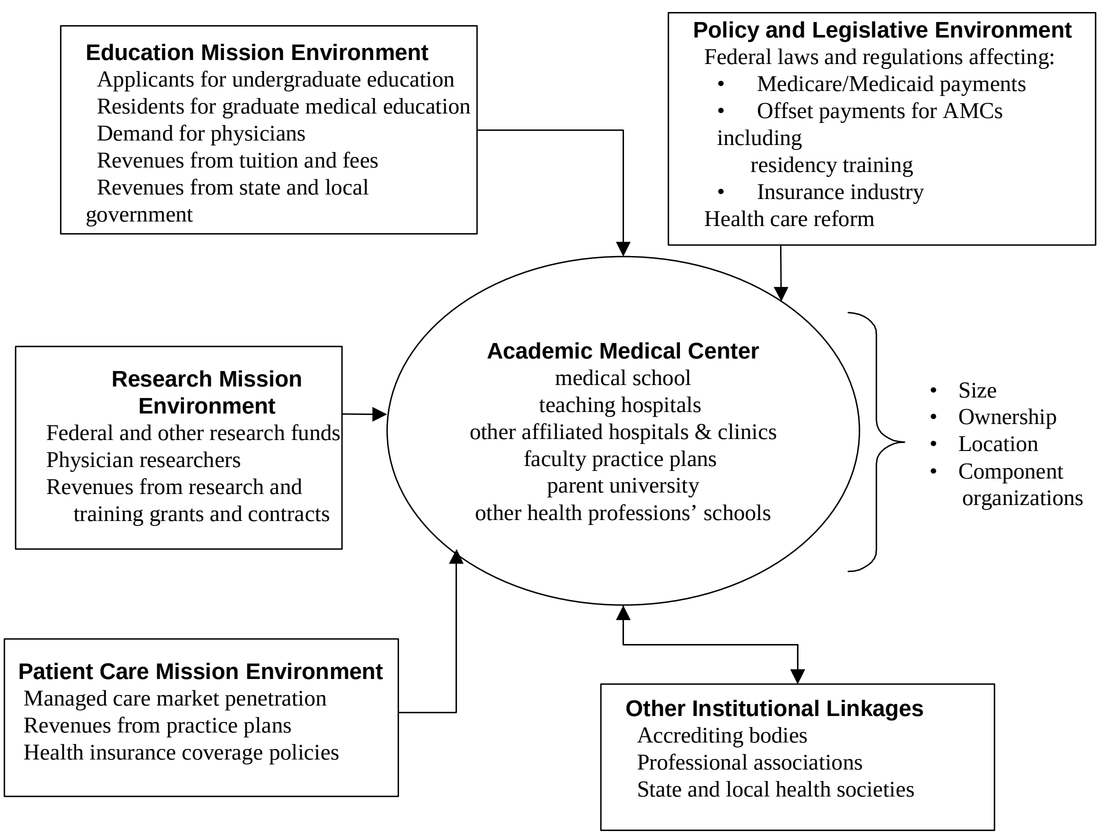

Figure 5-1

The bracketed text to the right of the AMC components lists several AMC organizational descriptors. This depiction represents only a selection of all possible characteristics and functions—those that are of interest to the dissertation research—and omits other factors that are present in the AMC environment or that may be of interest to other researchers

The dissertation research design was based on a study model that identified dependent variables that described changes in the organizational characteristics and behavior of academic medical centers, and independent variables hypothesized to influence and mediate those changes. This model, which guided the collection and analysis of data, is shown in Figure 5-2.

Model of Change in Academic Medical Centers

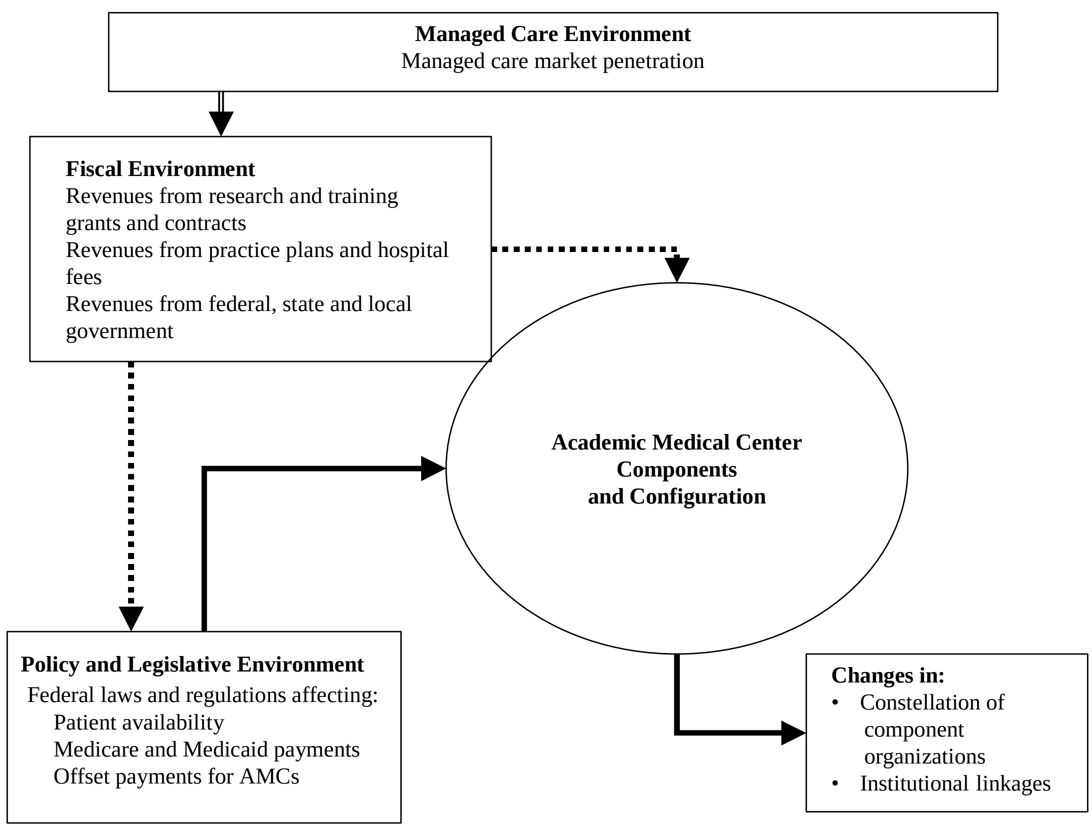

Figure 5-2

Figure 5-2 specifies the factors that were hypothesized to influence the activities and relationships of academic medical centers. The overarching independent variable in the model was the managed care environment, operationally defined as the percent market penetration of managed care plans. The managed care environment was hypothesized to directly influence the fiscal environment of the academic medical centers (as indicated by a solid line) and to indirectly influence their policy and legislative environment (as indicated by a broken line). That is, changes in the fiscal condition of academic medical centers were hypothesized to be among the factors that influenced federal policy and legislation. Changes in the policy and legislative environment were hypothesized to directly influence the organizational activities and relationships of academic medical centers.

The managed care environment was also hypothesized to indirectly influence the academic medical center activities and relationships through the mediating fiscal environment. Many of the effects of the managed care environment were hypothesized to be reflected in changes in the academic medical centers' fiscal environment, and these fiscal changes were hypothesized to influence organizational characteristics and mission-related activities of the AMCs.

The current state of activities and relationships presented by academic medical centers were described in terms of a limited set of variables: location, type of ownership, enrollment, graduates, faculty, total teaching responsibility, medical school administrative staff positions, faculty practice plan characteristics, clinical affiliations, and relationship to parent university.

Data collection and analysis focused on the trends and relationships among independent and dependent variables, as described in Figure 5-2. Viewing the population of academic medical centers as a complex adaptive system implies that, as a group, they would demonstrate both nonlinearity and the emergence of patterned behaviors. Therefore, I was particularly interested in identifying the presence of nonlinearity in system behavior and in identifying and characterizing patterns of system behavior.

The use of complexity theory had several implications for the research. First, patterns of group behavior—rather than the individual behaviors of medical schools or academic medical centers—would be the focus. Inspection of the data therefore centered on finding evidence of patterns exhibited by the entire group of academic medical centers, or by subgroups that were constructed on the basis of the centers' managed care market environment.

Second, the search for patterns conferred an exploratory element that might not otherwise have been present in the research. A large amount of data was compiled in order to examine as many of the relationships among variables and changes in variables and their relationships over time as possible. In the tradition of nonexperimental research, this thorough examination of the dependent variables was necessary to identify and explain the effects of the independent variables.

Third, this study's use of the entire population of academic medical centers, rather than a sample, ruled out the need for a sampling plan or for inferential statistical tests designed to draw conclusions about the population.

Where possible, therefore, I identified and compiled quantitative data for a period of twenty years—1981 through 2000. Graphing tools and data visualization were used extensively to expose the nature of the data. Specifically, phase planes were used to illustrate the changes in patterns and structure of the system over time. In addition mathematical tools were used in an exploratory manner to identify estimates of the tuning parameter (a constant) in a logistic equation. My approach to data collection and analysis is described in detail in the next sections of this chapter.

Data Collection and Coding Methodology

Types of Data

The study model provided guidance on the types of data that were collected and analyzed in this study. Accordingly, each of the components of the model suggested specific data variables: managed care market data; financial data that comprised the fiscal environment of academic medical centers; information on the policy and legislative environment of the academic medical centers; institutional characteristics of the medical schools; activities related to teaching, research, and patient care; and affiliations with clinical facilities that comprised some of the primary institutional linkages.

Data Sources

All data were collected from secondary sources, including published tables, publicly available databases, World Wide Web (WWW) sites, and nonpublic sources to which access was authorized for this research study. Some data were only available for the entire population of medical schools, but most data were available for each medical school in the study population.

Managed care market data. There were several sources of data on managed care, including managed care market penetration (i.e., the percent of individuals in a state or metropolitan statistical [MSA] who are enrolled in managed care plans). Sources included:

- The Centers for Medicare & Medicaid Services (CMS; formerly the Health Care Financing Administration [HCFA]). CMS provided public-use data files on Medicare and Medicaid enrollees by state and county, including the number and percent of enrollees who participated in managed care plans (http://cms.hhs.gov/). Over time, the data definitions of the statistics compiled by CMS/HCFA changed. For example, in some years beneficiaries who were enrolled in multiple plans were counted once for each plan enrollment, and in other years individuals were counted only once regardless of the number of plans in which they were enrolled.
- Managed Care On-Line, a Web site (http://www.mcol.com/) that described itself as "the Internet's business-to-business health management and managed care resource company since 1995." This site provided some information at no charge but was primarily a membership site. Its Knowledge Center pages provided Managed Care Fact Sheets with data such as national and state HMO market penetration rates. Data were reproduced from a number of sources, including CMS and the U.S. Census Bureau, which were identified with full citations.
- Managed Care–INFO, a Web site (http://www.managedcareinfo.com/) developed to be a managed care reference library, resource and information center. Managed Care-INFO was first published on the Internet in September 1998. Like Managed Care On-Line, this site

provided both free information and information available only to members. The latter included a large selection of managed care statistics, gleaned from cited sources. Links from this site led to additional WWW sites directed at hospital administrators, health care providers, and health plan managers.

Additional managed care-related data were available from foundations. These included the Robert Wood Johnson Foundation (http://rwjf.org/), which funds a Managed Care Industry Research Center and provides grants to study various aspects of managed care, and the Henry J. Kaiser Family Foundation (http://kff.org/), which funded the Kaiser Changing Health Care Marketplace Project and the publication in August 1998 of the report, *Trends and Indicators in the Changing Health Care Marketplace: Chartbook*.[8] One professional medical organization, the American Academy of Orthopaedic Surgeons, conducted its own survey of members in order to assess the percent of members' patients who were "in managed care."[9]

Financial data. Data on medical school revenues by source and expenditures by function were available in the annual medical education issues of the Journal of the American Medical Association (JAMA). The published data were derived from responses submitted by medical schools to the annual medical school questionnaire administered by the AAMC Liaison Committee on Medical Education (LCME). The data were published annually in aggregate form for all schools that reported data. Access to data for individual schools was restricted; for this study, I obtained school-level data for several selected years.

Data on National Institutes of Health (NIH) funding for research grants and contracts, training, and other activities provided to each medical school, were available on the NIH Office of Extramural Research WWW site.[10] Data on other federal funding for research at medical schools were available from the AAMC Institutional Profile System (IPS) and the annual Institutional Goals Ranking Reports. Summary data for all medical schools' revenue from grant and contract awards from federal and non-federal sources were available in the annual medical education issues of JAMA.

[8] Janet Lundy, Larry Levitt, and Jain Wang, "Trends and Indicators in the Changing Health Care Marketplace: Chartbook," (Menlo Park, California: The Kaiser Family Foundation, 1998).
[9] Details available at the Web site URL http://www.aaos.org/wordhtml/bulletin/apr00/fline7.htm.

Policy and legislative information. Information on federal legislation and policy changes were obtained from published articles, news items and press releases, and legislative analyses published by the AAMC and the Library of Congress.

Institutional characteristics of medical schools. Data on the location, type of ownership (i.e., public or private), annual enrollment, and medical school administrative staff positions were obtained from the annual issues of the Directory of American Medical Education published by the AAMC. The directories were available in the AAMC library in Washington, D.C., the library of the Uniformed Services University of the Health Sciences F. Edward Hebert School of Medicine in Bethesda, Maryland, and the National Library of Medicine on the campus of the NIH in Bethesda, Maryland.

Aggregate data describing the number of basic science and clinical faculty at all medical schools and per school data on the number of graduates and faculty members' total teaching responsibility were available in the annual medical education issues of JAMA. Enrollment refers to "undergraduate" enrollment, that is, those students studying for the Doctor of Medicine (M.D.) degree. "Graduates" refers to those students who are granted an M.D. degree. Total teaching responsibility included all of the students for which medical school faculty were responsible: medical students; residents, fellows, and others obtaining graduate medical education; and master's and doctoral students studying for a M.S. or Ph.D. degree in the basic sciences granted by the medical school or parent university. In addition to total faculty, the number of faculty in some years was subset into clinical science faculty, basic science faculty, and other faculty on the basis of departmental affiliation. Other faculty included those faculty members in administrative positions or in departments of dentistry, veterinary sciences, allied health, or social sciences.

Data on total full-time faculty by school were obtained from either the AAMC Faculty Roster System Annual publications or on the AAMC WWW site, http://www.aamc.org, depending on the year.

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[10] Data tables available at the Web site URL http://www.grants.nih.gov/grants/award/award.htm.

Data on the number and percentage of medical school graduates who trained in primary care specialties and who were presumed to be practicing primary care, or generalist medicine, were obtained from the AAMC WWW site.

Institutional linkages. Data on the relationship of a medical school to a parent university, on faculty practice plan organization, and on the operational type and legal structure of the faculty practice plan were obtained from data files available through the AAMC WWW site. Data describing clinical facilities with which medical schools had established affiliations were obtained from the annual issues of the Directory of American Medical Education published by the AAMC. These relationships have also been the subject of a number of studies, many of which have appeared in the AAMC-sponsored journal, *Academic Medicine,* and in JAMA.

Data Collection and Coding

Numeric and text data from the annual issues of the AAMC Directory of American Medical Education were entered into a Microsoft Access database. Other data were structured into a series of MS Excel (Excel) tables. Each medical school was assigned an identification (ID) number that was appended to each table or spreadsheet of school-level data and was used consistently throughout the study.

Managed care market data. Multiple sources of data describing managed care market penetration were available. Each was evaluated on the basis of completeness, consistency, and applicability to assessment of the managed care environment of each of the medical schools in this study. Managed care data were generally available at the state level and in many cases, MSA level. Data sets that expressed managed care market penetration in terms of participants as a percentage of the relevant population were selected and structured by state. Medical schools were then coded with their state location.

HMO market penetration data from a single source were available for the longest period of time (1995 through 2001, inclusive) by state. In this time series, data for the District of Columbia were available only for 2000 and 2001, and no HMO market penetration data were available for Puerto Rico.

The percentage of Medicare beneficiaries in managed care programs was available for 1997 through 2000, inclusive, and included data for the District of Columbia and Puerto Rico. The percentage of Medicaid beneficiaries in managed care programs was available for 1996 through 2000, inclusive, and also included data for the District of Columbia and Puerto Rico. MSA-level HMO market penetration data were available for metropolitan areas in which 82 of the 125 medical schools were located. These data were reported in 1999 and included the District of Columbia. The HMO market penetration trend data for 1995 through 2001 and the single year data for 1999 were published by different sources and were not comparable, even for the same year.

In order to understand possible effects of the managed care market environment, each school was assigned to one of three managed care market groups (low, medium, or high managed care market penetration in the school's state or metropolitan statistical area). The assignment process is described in Figure 5-4. Managed care market penetration is a continuous rather than discrete variable; the assignment of schools to discrete groups was introduced to assist with the analysis. The distribution of market penetration over all schools suggested that classifying the schools into three approximately equal clusters would create groups that differed on average, in their market environment (see Figure 5-3). There was not sufficient granularity in the data for two groups to discriminate well on the basis of managed care market penetration, nor did the variability in the data seem to justify the creation of four groups.

The average HMO market penetration rate for the period 1995 through 2001 was calculated for each state that contained an accredited medical school. For the 82 schools with MSA HMO market penetration data, MSA data for 1999 were compared to 1999 state data from the same source to determine whether the metropolitan area in which the school was located appeared to have a different market penetration rate than the entire state. Of the 82 schools with MSA data for 1999, 33 were located in MSAs that had a HMO market penetration rate that was at least 10% greater than the state in which they were located. One school was located in a MSA with a penetration rate more than 10% lower than the corresponding state rate. The median penetration rate for states for the period 1995 to 2001 was 27.3%, the same as the median penetration rate for states in 1999 (27.3%). Because 1999 appeared to be representative of the entire time period, MSA data for 1999 were used in place of the average HMO market penetration rate for the period 1995 through 2001 where the difference between the two was 10% or greater.

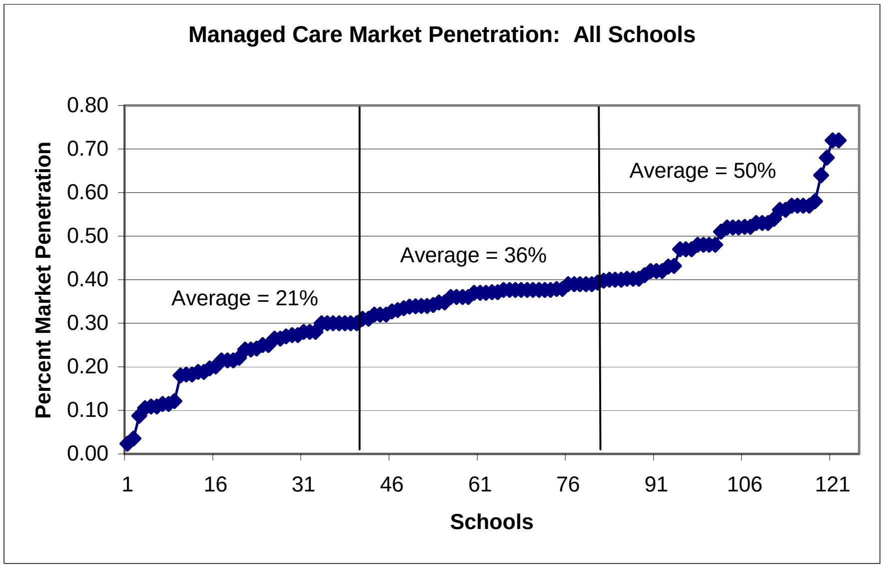

Figure 5-3

An examination of the cities for which MSA data were not available revealed a mix of smaller cities (e.g., Charlottesville, VA; Rootstown, OH; Grand Forks, ND; Sioux Falls, SD) and/or cities in less populated states (Honolulu, HI; Hanover, NH). These cities contained 43 accredited medical schools; each of these schools was assigned to a low, medium, or high market penetration group on the basis of state data.

Medical schools in Puerto Rico were assigned to a managed care market penetration group on the basis of the average number of Medicaid recipients participating in managed care plans for the period 1996 through 2000. The percentage of Medicaid participants using managed care was calculated for each state and year and the percentages were ranked. An average rank was calculated for each state. Puerto Rico, with an average of 77.8% Medicaid recipients participating in managed care plans, ranked twelfth among all states. On the basis of this relatively high rank, medical schools in Puerto Rico were assigned to the high market penetration group.

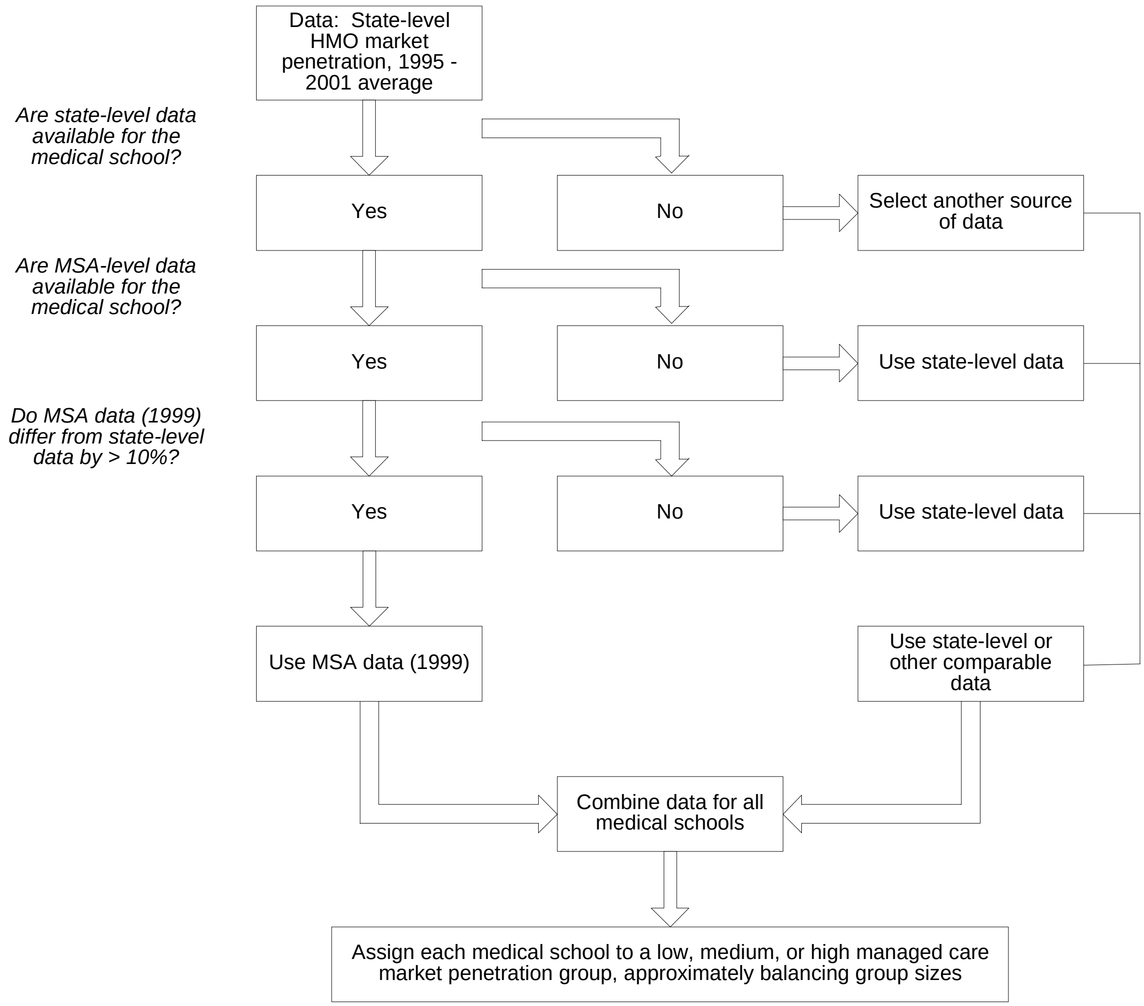

Figure 5-4

Using this process and roughly balancing group sizes, 44 schools with an average market penetration of 50% were assigned to the high managed care market penetration group; 41 schools with a market penetration of 36% were assigned to the medium managed care market penetration group; and 40 schools with a market penetration of 21% were assigned to the low managed care market penetration group (see Figure 5-3).

Financial data. Aggregate data on medical school revenues in current dollars were available by category for academic years 1981-1982 through 1998-1999. The categories included

- federal appropriations
- state and local government appropriations
- recovery of indirect costs (including facilities and administrative costs)
- tuition and fees
- restricted and unrestricted endowment
- gifts
- parent university support (also identified as general university funds)
- practice plans (including professional fee income and network affiliations and other medical service organization funds)
- hospitals and medical school programs (including reimbursements from hospitals and revenue from research and teaching/training programs at affiliated institutions)
- miscellaneous sources (including income from college services)
- grants and contracts (federal and other grants and contracts, including direct costs and the indirect costs of facilities and administration; also identified as sponsored research)

Not all categories were reported for every year. The most obvious discontinuity involved recovery of indirect costs. This category was reported for academic years 1981-1982 through 1987-1988. Facilities and administrative costs (indirect costs) were reported as a subcategory under federal and other grants and contracts for academic years 1993-1994 through 1998-1999. Indirect costs were not reported as a line item for the intervening years (1989-1990 through 1992-1993) although the trend of total revenues would suggest that the recovery of indirect costs was included in the total.

Revenue data for individual schools were available for academic years 1995-1996 through 1998-1999 for the categories of hospital revenues, federal support, state appropriations, tuition revenues, and expenditures for research grants. Hospital support consisted of total revenues from hospitals (medical school programs). Federal support revenues were those from federal appropriations, federal grants, and contracts (including facilities and administrative costs). State appropriations were self-explanatory. Tuition revenues included tuition and fees from M.D. and other programs. Data for research grants and contracts were reported as total expenditures (including transfers) for research grants and contracts. All data were as reported on AAMC Liaison Committee on Medical Education (LCME) annual survey, Part IA.

Data on NIH support for medical schools were available for FYs 1981 through 2001 for the categories of research grants, training grants, fellowships, R&D contracts, other activities, and total support. Both the number and the dollar value of grants and contracts were available. The Biomedical Research and Development Price Index (BRDPI) was used to convert current dollars to constant dollars. The BRDPI was developed and updated annually by the Bureau of Economic Analysis, Department of Commerce, under an interagency agreement with the NIH. The BRDPI measures changes in the weighted average of the prices of all the inputs (e.g., personnel services, supplies, and equipment) purchased with the NIH budget to conduct and support biomedical and behavioral research and development. The historical relationship between the BRDPI and the more commonly used Gross Domestic Product (GDP) price index is summarized by a statistically estimated linear equation that relates the annual percentage change in the BRDPI to the annual percentage change in the GDP price index.[11] The GDP is the market value of the goods and services produced by labor and property located in the United States. The GDP price deflator is a measure of the average price change for the whole GDP; it is the most comprehensive measure of price inflation for the total U.S. economy. Due to the nature of medical school finances and NIH support to medical schools as well as the linear relationship between the BRDPI and the GDP, the BRDPI was used throughout the study to calculate constant dollars.

Institutional characteristics of medical schools. Data describing the history, location, type of ownership, annual enrollment, and administrative staff positions of medical schools were collected from the annual issues of the AAMC Directory of American Medical Education for academic years 1981-1982 through 2000-2001. None of these data were available in electronic format. Data from the most currently available issue (academic year 2000-2001) were entered into an Access database. The database design consisted of one table for each type of data and

[11] James A. Schuttinga, "Biomedical Research and Development Price Index: FY 2001 Update and Projections for FY 2002-2007," (Bethesda, Maryland: National Institutes of Health, 2002).

year, linked by school ID number. Following entry of the 2000-2001 data, each table was printed and changes in the next-most-current year's data (academic year 1999-2000) were marked on the printed copy of the table and entered into the Access database. Data for each prior year, back to academic year 1981-1982, were collected in the same manner.

Medical school administrative staff position data were exported from the Access database to an Excel spreadsheet, with one row for each school and staff position, and one column for each year. For each school, a comparison of administrative staff position titles that were reported in one year, with those reported in the previous year, was automated by using an Excel function. Each year-to-year difference was visually inspected to determine if two position titles were similar enough to constitute the same position. For example, Assistant Dean, Admissions, and Assistant Dean for Admissions were considered to be the same administrative position. Acting Dean and Dean were not considered to be the same administrative position, since I wanted to capture the amount of change in medical school administration. The names of individuals holding each position were not collected; therefore, individual staff turnover was not included in the analysis. The number of medical school administrative staff positions, the number of staff position titles that were the same as or very similar to the previous year's, absolute change in the number compared to the previous year, and the percent of staff position titles that were the same as the previous year were summarized in a spreadsheet for each medical school and academic year, 1982-1983 through 2000-2001.

Aggregate data describing the number of faculty members at all medical schools, per-school data describing the number of graduates, and faculty members' total teaching responsibility at each school were available in the annual medical education issues of JAMA. None of these data were available in electronic format. The summary data for each academic year, 1981-1982 through 2000-2001, were entered into Excel spreadsheets.

The total number of full-time, part-time, and volunteer basic science faculty and full-time, part-time, and volunteer clinical faculty were collected separately for each academic year, 1981-1982 through 2000-2001, for all medical schools from the annual medical education issues of JAMA.

The data were entered into Excel spreadsheets and the total basic science, total clinical science, and grand total of faculty per year were calculated from the detailed data.

The number of total full-time faculty for each school was available for 1986 through 2001 from AAMC Faculty Roster System published reports. Beginning in 1990, these data were also separately available for basic science faculty and clinical science faculty. Beginning in 1998, there was also an "Other" category that included faculty members in administrative positions or in departments of dentistry, veterinary sciences, allied health, or social sciences. Data for 1998 and later were available electronically from the AAMC WWW site. Data for the earlier years were entered by hand into an Excel spreadsheet. The total numbers and the ratio of basic science to clinical science faculty were calculated for each school and year, 1990 through 2001.

Annual data for each school's total number of graduates were entered into an Excel spreadsheet for academic years 1981-1982 through 2000-2001.

Annual data for medical school graduates subsequently practicing generalist specialties in 1996 through 1999 were available electronically from the AAMC WWW site. Data for 1996 included 1989, 1990, and 1991 graduates who had completed a three-year residency program in pediatrics, family practice, or internal medicine and who did not participate in a subspecialty or non-generalist program through academic year 1995-1995. Data for 1997 included 1990, 1991, and 1992 graduates; data for 1998 and 1999 were both based on 1991, 1992, and 1993 graduates. The data were derived by the AAMC from the Graduate Medical Education Tracking Census (GMETC), which collected data annually from teaching hospitals and from the program directors of approved residency training programs.

The GMETC data were adjusted by the AAMC to estimate the number of graduates from each cohort who were likely to seek subspecialty training after the period for which data were collected, and the number who may have been excluded from the data collection. The annual adjustment was one half of one percent or less. The method of estimating generalists excluded individuals who trained in a subspecialty and then practiced mostly in primary care. This enumeration and estimate excludes individuals who did not complete training for any specialty after graduation from medical school (approximately 5% of 1991, 1992, 1993 graduates). Many of these graduates were presumed to be practicing primary care medicine, but were not included in the counts.

Total teaching responsibility of the medical school faculty was calculated for each school, academic years 1981-1982 through 2000-2001, by counting the total number of medical students; residents, postdoctoral fellows, and others obtaining graduate medical education; and master's and doctoral students studying for a M.S. or Ph.D. degree in the basic sciences granted by the medical school or parent university. Other students were included in the published tables for academic years 1981-1982 through 1986-1987. The composition of the Other category was not well-documented except to indicate that it did not contain continuing education course registrants. The proportion of students any school included in the Other category also varied widely, suggesting that this category was not well-defined. The data were structured in an Excel file so that residents, graduate students in the basic sciences, and total students (defined as the sum of medical students, residents, and master's and doctoral students) could be analyzed separately.

Institutional linkages. Information on the various forms of relationships among the medical schools, faculty practice plan, and the parent university (if any) was obtained from numerous published studies. Additional information on current types of medical school organization and governance and faculty practice plan organization was structured into an Excel spreadsheet for analysis.

Clinical facilities with which medical schools had established affiliations were entered by name for each school, for academic years 1981-1982 through 2000-2001. For each school, the number of clinical affiliations in each year and the number and percentage that were also affiliated (by name) in the prior year were calculated. Clinical facilities data were exported from the Access database to an Excel spreadsheet, with one row for each school and clinical facility, and one column for each year. For each school, a comparison of clinical facility names reported in one year with those reported in the previous year was automated by using an Excel function. Each year-to-year difference was visually inspected to determine if two names were similar enough to constitute the same clinical facility. For each school and year, the number of clinical facilities, the number that were determined to be the same as the prior year, and the percentage that were the same as the prior year were calculated.

Data on the relation of a medical school to a parent university, and faculty practice plan organization, operational type, and legal structure were available only for 2001. These data were downloaded into an Excel spreadsheet. Excel pivot tables were used to summarize data values for each of these variables for all schools, by managed care market penetration group, and for other categorical variables.

Data Analysis Methodology

The data were organized for analysis using the framework that guided data collection—the study model. Exploratory analysis of the variables identified in the study model began with the tabulation of totals, averages, percent increases or decreases from year to year, and other descriptive statistics for each of the variables. The most recent value of each variable in the study model was first examined individually to describe the state of the academic medical center system at a single point in time. Following the analysis of current data, data for all years was examined to illustrate and describe trends in each of the variables. The tabulations were performed using Excel, and each variable was graphed with year on the X-axis and the variable value (e.g., counts, dollars) on the Y-axis. One purpose of graphing was to obtain a visual sense of the change in the values of the individual variables over time, as well as of differences among the three groups of schools.

Social systems—and some of the more interesting research problems—often involve nonlinearity. A straight line can rarely describe the behavior exhibited by such systems over an extended period of time; eventually most events that involve human action exhibit nonlinearity. Graphing the data provided me with a way to assess the general trend of the time series data, including the degree of linearity or nonlinearity that described the course of change over time.

The type of graphical analysis used in this study was developed in response to researchers' efforts to examine and understand the motion of time series data generated by social systems.[12]

In addition to visual inspection, Excel was used to draw trend lines that best fit the data. I specified the type of trend line—linear, polynomial, logarithmic, or exponential—and Excel calculated the data points that resulted in the smallest total difference between the observed data points and the data points generated by Excel. The total difference was calculated as the sum of the squared differences between each observed data point and the corresponding calculated data point (i.e., the least squares value).[13] The data points generated by Excel were connected, creating a trend line that was drawn on the same axes as the observed data. Excel also calculated the R^2 value, where R^2 was 1 minus the sum of squares error (SSE) divided by the total sum of squares (SST). Therefore, $1-R^2$ was equal to the proportion of the sum of squares due to residuals, or errors. The closer the R^2 value was to 1.00, the smaller the error, and the better the fit of the trend line to the data. The better the fit, i.e., the smaller the least squares value, the better the Excel equation mathematically described the observed data. With this equation, values could be generated to predict future values of the variable.

After graphing the data values with time (years) on the X-axis and the variable value on the Y-axis, I constructed phase portraits of the individual data variables. Plotting the data in a phase space created a visual display of information about change in a system, as opposed to the discrete values of a system at a given point in time.

The phase portraits were created on a two-dimensional Cartesian plane, or phase space. The time series data points were plotted using the value for time period *t* on the Y-axis, and the difference between the value for time period *t* and the value for the preceding time period, *t-1*, on the X-axis. A line was drawn connecting the points in chronological order to create a trajectory. As a result, the trajectory of a study variable was plotted on the phase plane using the values for pairs

[12] L. Douglas Kiel and Euel Elliott, *Chaos Theory in the Social Sciences: Foundations and Applications* (Ann Arbor: The University of Michigan Press, 1997).

[13] The linear equation for calculating the least squares fit for a line was $y=mx+b$, where m is the slope and b is the intercept. The polynomial equation for calculating the least squares fit was $y=b+c_1x+c_2x^2+c_3x^3+\ldots+c_6x^6$, where b and c_1, c_2, $\ldots c_6$ are constants. The logarithmic equation for calculating the least squares fit was $y=c\ln x+b$, where c

of successive time periods. That is, the first data point on the phase plane represented the values of the variable at time period *t-1* (on the X-axis) and at time period *t* (on the Y-axis). The second data point represented the next pair of values, such that time period *t-1* for the second pair of values was time period *t* in the first pair of values, and so on. Connecting the points created a trajectory that showed both the direction and amount of change—compared to the previous state of the system—at each period of time examined. In this way, it was possible to identify structures or patterns in relationships that were not obvious when the data were examined in more traditional ways.[14]

The center of the phase plane was coordinate 0,0, and a data point at 0,0 represented no change from the previous time period. Quadrants of the phase plane were labeled counterclockwise using standard notation, starting in the upper right quadrant. In the upper right quadrant (Q1) both *t* and *t-1* are increasing. In the upper left quadrant (Q2) *t* is increasing and *t-1*is decreasing. In the lower left quadrant (Q3) both *t* and *t-1* are decreasing. In the lower right quadrant (Q4) *t* is decreasing while *t-1* is increasing.

Phase space can be thought of as a map that is used to visualize the dynamics of a system, i.e., the ways in which the system moves and transforms. Examining the graphic representation provided a sense of whether the system was stable, and, if not, of where and how the system changed; it provided a qualitative view of the whole system. Over time, the points represent the state of a system “flow” along the curves created by connecting the points. The trajectories of systems can move in various directions, cluster in a small area, oscillate, create repeating patterns that are similar but never exactly the same, or even come to a stop at a single point. The dynamic evolution of the system is captured in a way that static values such as means or totals could not capture.

In order to understand and interpret the phase portraits of the individual variables in the study, I created a set of seven standard phase portraits using data with known characteristics. Three of

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and b are constants and ln is the natural logarithm function. The exponential equation for calculating the least squares fit was $y=ce^{bx}$ where c and b are constants, and e is the base of the natural logarithm.

[14] Lawrence F. Sharp and H. Richard Priesmeyer, "Tutorial: Chaos Theory—a Primer for Health Care," *Quality Management in Health Care* 3, no. 4 (1995).

these showed exponential, curvilinear, and linear curves recreated as phase portraits. The remaining four were based on values generated and plotted using a simple logistic equation.

The first standard phase portrait illustrated an exponential curve. The XY line graph, shown in Figure 5-5, shows data plotted with iterations (time) on the X-axis and the value of the variable on the Y-axis. A trend line generated by the exponential equation $y = 9393.2e^{0.1262x}$ generates an R^2 value of 0.9957. The phase plane graph shows the phase portrait of the same data, shown in Figure 5-6. All of the points are in the upper right quadrant (Q1), indicating that the sequence of values was consistently increasing (i.e., every marginal value was positive).

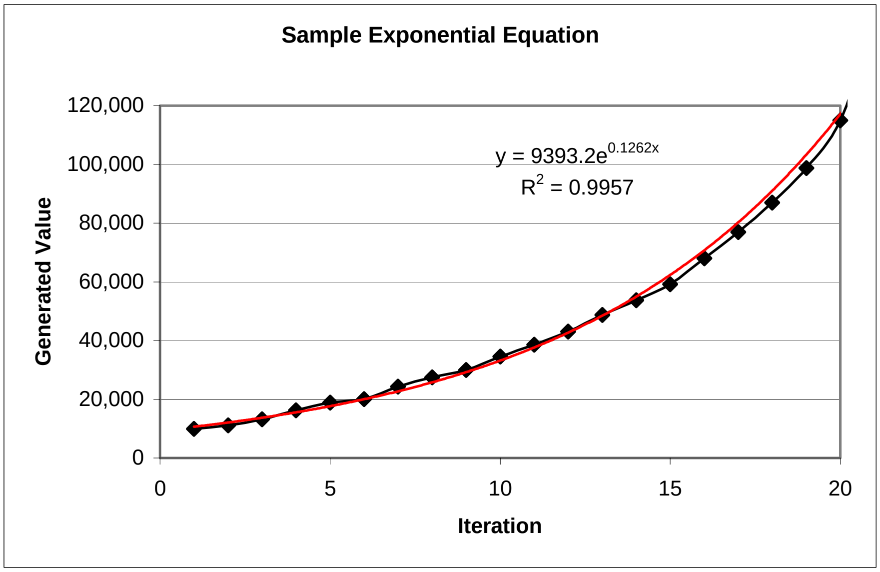

Figure 5-5

Although the trajectory remained in a single quadrant, it did not adhere to a single point attractor, as Sharp and Priesmeyer (1995) imply would likely be the case.[15] Instead, the data points cluster near the coordinates 0,0 early in the time period and, only later, sharply increase. It is clear in the XY line graph that the system is exponentially increasing, and in this simple case it is easier to interpret the trajectory of the data from the XY plot, than it is to interpret the phase portrait. However, it served to demonstrate what an exponentially increasing curve looks like when it is plotted on a phase plane.

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[15] Ibid.

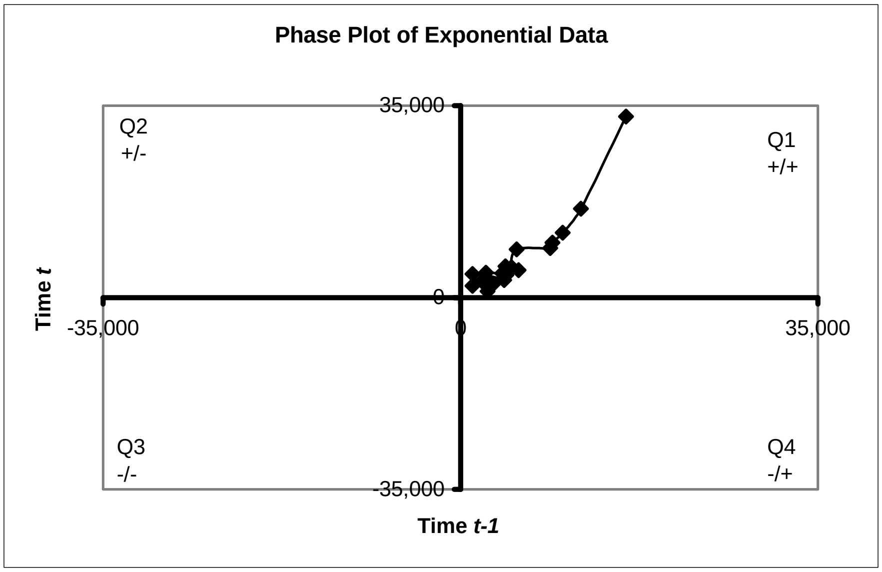

Figure 5-6

The second standard phase portrait illustrated curvilinear data. The XY line graph shows the plot of the data with iterations (time) on the X-axis and the value of the variable on the Y-axis, as shown in Figure 5-7. The trend line on this graph is based on a fourth-order polynomial equation,

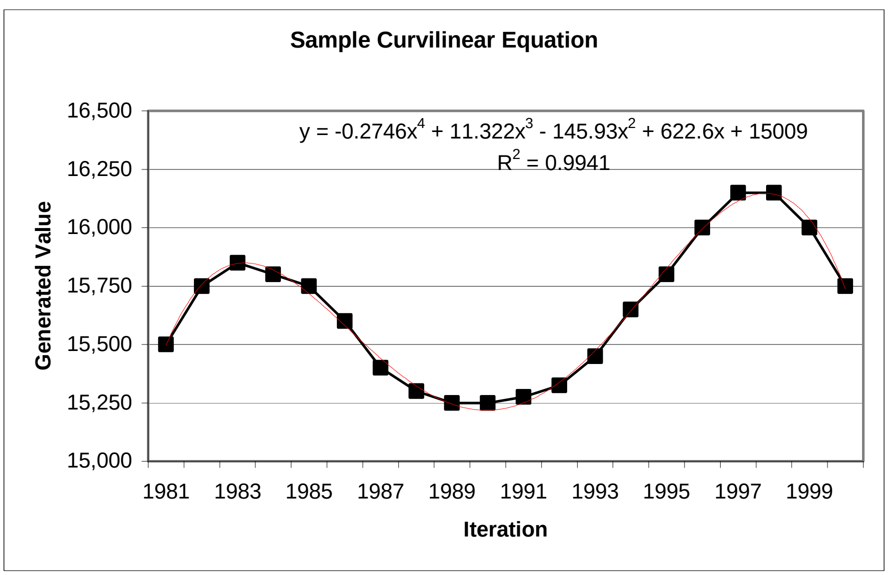

Figure 5-7

$y = -0.2746x^4 + 11.322x^3 – 145.93x^2 + 622.6x + 15009$, with an R^2 value of 0.9941. The curvilinear data show a slowing changing pattern of increases followed by decreases.

Accordingly, the phase portrait trajectory passes through Q1, Q4, Q3, and Q2, and again enters Q1 only to retrace its pattern through Q4 and Q3, as shown in Figure 5-8. It begins in Q1 because the curve is increasing in the beginning. The curve soon begins to turn downward in the XY graph, and this is manifested in a meandering trajectory on the phase plane that moves downward and to the left, through Q3 and Q4. As the curve begins to sharply increase on the XY graph, the trajectory moves upward and to the right, through Q2 and back into Q1. When the curve turns downward again on the XY graph, the trajectory repeats its visit to Q3 and Q4.

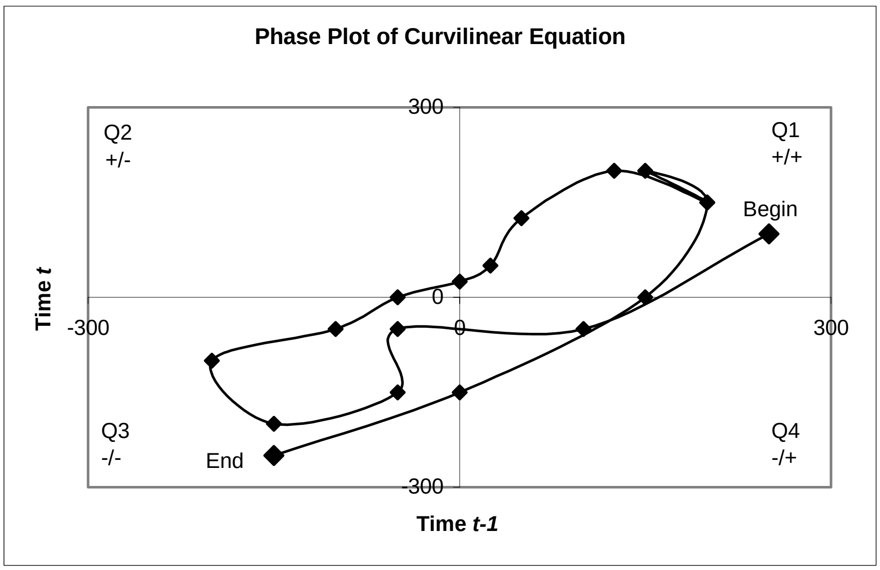

Figure 5-8

Because the trajectory, within its limited number of iterations, regularly visited all four quadrants, Sharp and Priesmeyer (1995) would suggest that this indicates the presence of an underlying period four attractor.[16] An XY graph of a system exhibiting period four behavior is characterized by an irregularly repeating pattern of four similar but not identical values; the system is moving or oscillating among four solutions. The number of iterations shown in this example is not enough to really determine graphically whether, over a longer period of time, the curve would reveal repetitions of four values or whether there would be repetitions at all. Nevertheless, the example demonstrates that a combination of increasing and decreasing system behavior, when translated to a phase plane plot, is characterized by loops that visit all four quadrants.

The third standard phase portrait illustrated a simple set of linearly increasing data. The XY line graph shows the plot of data that were generated with the equation y = 2.0109x-0.1739, as shown in Figure 5-9.

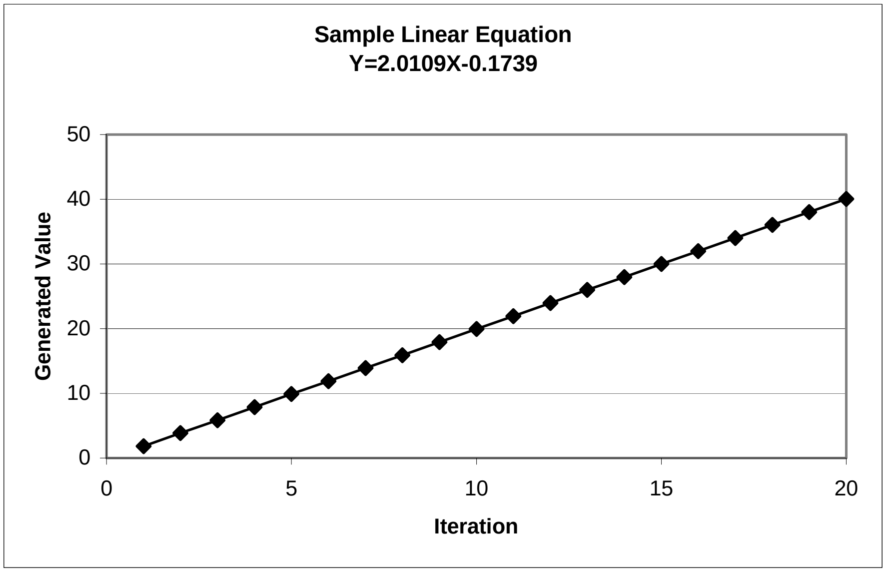

Figure 5-9

With each iteration, the generated value increased by 2.0109; that is, the marginal values are all equal. As a result, the phase portrait shown in the phase plane graph is a single point in Q1, as shown in Figure 5-10.

This standard phase portrait illustrated a stable, equilibrium system with a single point attractor. This example suggests that phase plots that show a tight cluster of data points are illustrating a stable system. Phase plot trajectories that begin or end in a single point or tight cluster of points are illustrating systems that either become unstable over time or move from a state of nonequilibrium to equilibrium, respectively.

[16] Ibid.

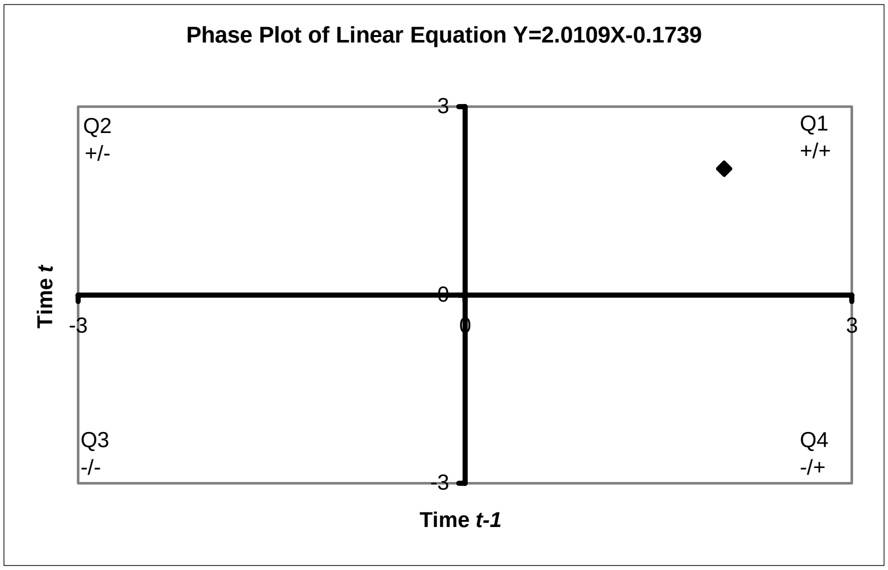

Figure 5-10

The remaining four standard phase portraits were generated from a logistic equation in which the constant, *a*, was varied. The logistic equation had the following form:

$$X_{t+1} = aX_t(1-X_t),$$

where a is a constant, X_t is an initial value for the variable at time t, and X_{t+1} is the value for the next time period, $t+1$. The value of X describes the current state of the system while the value of a describes "the whole of 'characteristics of the system' that cause that system to be either stable (period 1-type), oscillating (period 2-type), oscillating in a complex manner (period 4-type) or chaotic."[17] The system moves from equilibrium (period 1-type) to oscillating (period 2-type) when $a = 3$, and from period 2-type to period 4-type when $a = 3.45$.[18] The constant a can be viewed as a measure of the system environment, ranging from stable, when it is a low value, to "energetic" when the value is higher.[19] That is, the value of a is a parameter in the equation, but it also represents the value of a system regulator that influences the degree of nonlinearity as well as the rate at which increases and decreases occur.[20] This type of equation is often identified in

[17] H. Richard Priesmeyer, "Logistic Regression: A Method for Describing, Interpreting, and Forecasting Social Phenomenon with Nonlinear Equations," in *Chaos and Society*, ed. A. Albert (Amsterdam: IOS Press, 1995), 332.
[18] Edward N. Lorenz, *The Essence of Chaos* (Seattle: The University of Washington Press, 1993).
[19] Sharp and Priesmeyer, "Tutorial: Chaos Theory—a Primer for Health Care."
[20] A. B. Çambel, *Applied Chaos Theory: A Paradigm for Complexity* (Cambridge, MA: Academic Press, Inc., 1993).

complexity science literature as particularly useful and is also known as a first-order difference equation.[21,22]

The set of four standard phase portraits were generated from calculations derived from iterations of the logistic equation using the values *a* = 2.707, *a* = 3.414, *a* = 3.520, and *a* = 3.950. They describe systems with point, two-cycle, four-cycle, and chaotic or strange attractors, respectively. The first of these is shown in Figure 5-11, where *a* = 2.707 and $X_t = 0.5$. The points were plotted from a starting point of 0.5. The second point was calculated as $X_{t+1} = (2.707)(0.5) * (1 - 0.5)$. The third point was calculated by multiplying 2.707 by the previous value of X_{t+1} and then multiplying that product by 1 minus the previous value of X_{t+1}, and so on for each successive iteration of the equation. After several early fluctuations, the line quickly settled down to a stable series of points (a horizontal line).

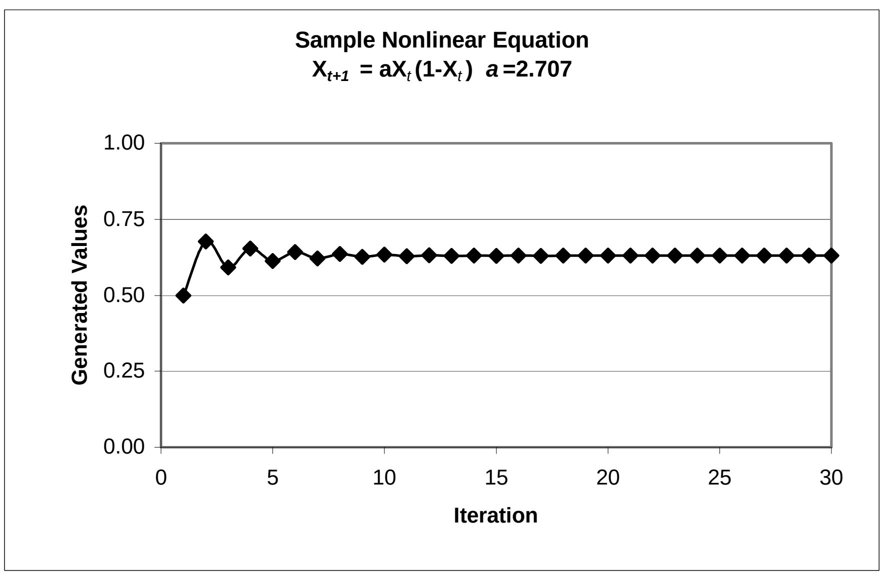

Figure 5-11

The phase plane graph shows the phase portrait, in which the initial fluctuations and the stability are both apparent, as shown in Figure 5-12. The trajectory first oscillates between Q2 and Q4 and then converges on a cluster of points at coordinate 0,0, in the center. For other initial values of

[21] Robert M. May, "Simple Mathematical Models with Very Complicated Dynamics," *Nature* 261, June 10 (1976).
[22] Priesmeyer, "Logistic Regression: A Method for Describing, Interpreting, and Forecasting Social Phenomenon with Nonlinear Equations."

X_t, the size of the fluctuations varied slightly but a stable point was quickly reached in every case. This example illustrates a system with a point attractor. Such systems with low values of *a* are resilient; they are not particularly sensitive to initial conditions.

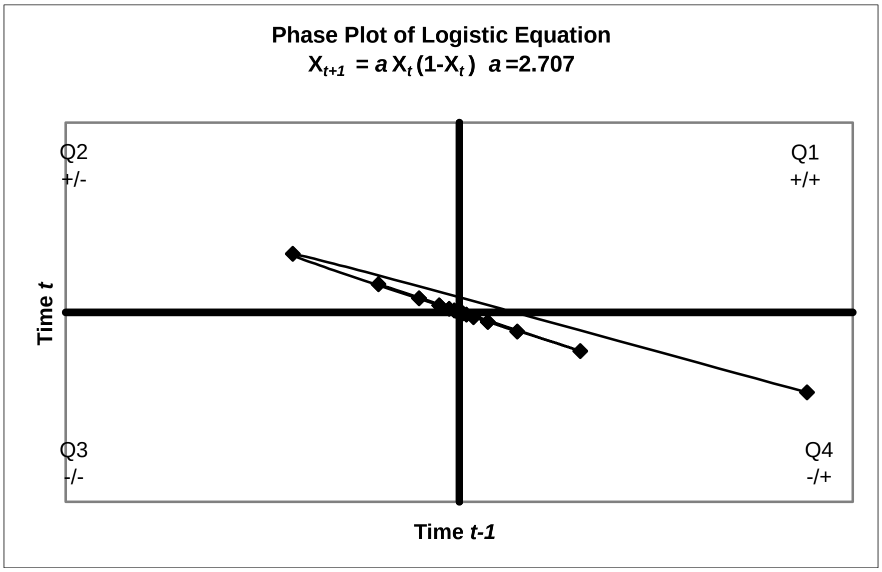

Figure 5-12

The second in the set of four standard phase portraits generated from the logistic equation used *a* = 3.414. At this value of *a*, the XY line graph shows a two period cycle, i.e., a regularly repeating pattern that oscillates between two values, as shown in Figure 5-13. The starting value of X_t is again 0.5. Other initial values behaved slightly differently in the first few iterations, but all settled quickly into regular oscillations, demonstrating stable periodic motion. The phase plane graph shows the phase portrait with alternating points in Q2 and Q4, as shown in Figure 5-14. Unlike the data generated with a lower value of *a*, iterations of this equation would never settle down to a stable solution; as such, the graphs illustrate a period 2 attractor. The phase portrait illustrates a system that is oscillating between two solutions.

The third in the set of four standard phase portraits was generated from the logistic equation where the value of *a* = 3.520, which placed the system in a four period cycle. In the XY line graph, X_t is initially set to 0.5, as shown in Figure 5-15. It can be readily seen that four values alternate

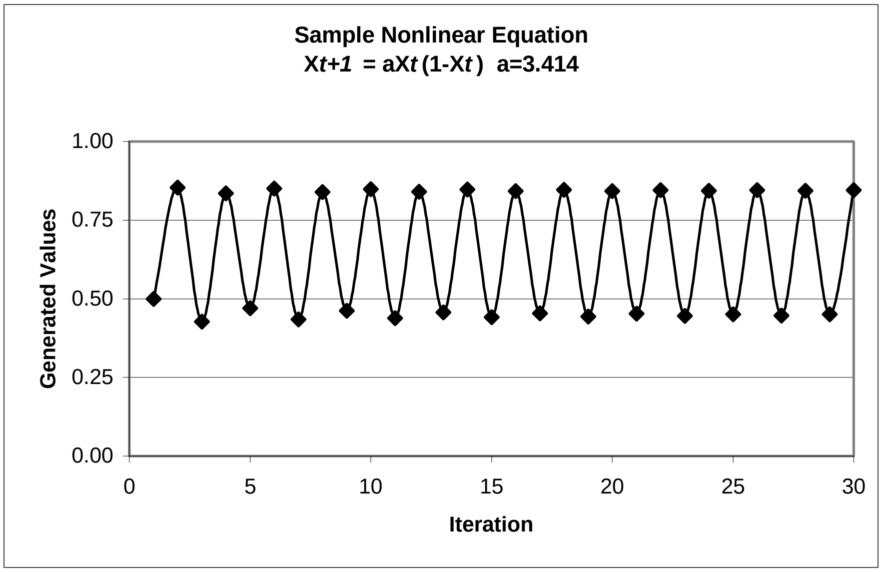

Figure 5-13

in a consistent pattern, demonstrating stable periodic motion that is slightly more complex than a two period cycle. The phase plane graph shows the phase portrait with points alternating in Q2 and Q4, but unlike the previous phase portrait, the points in Q2 and Q4 are not in exactly the same place, as shown in Figure 5-16. This example illustrates a system that is oscillating among four values.

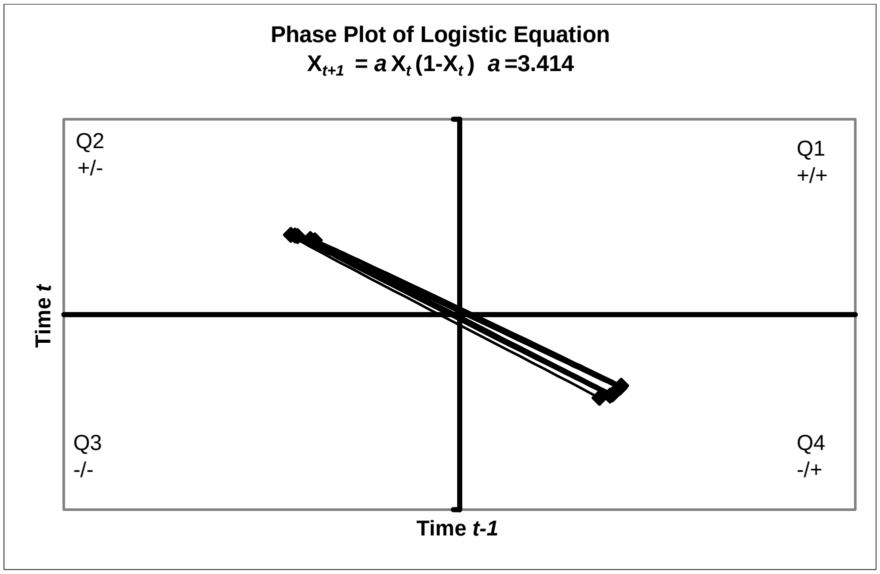

Figure 5-14

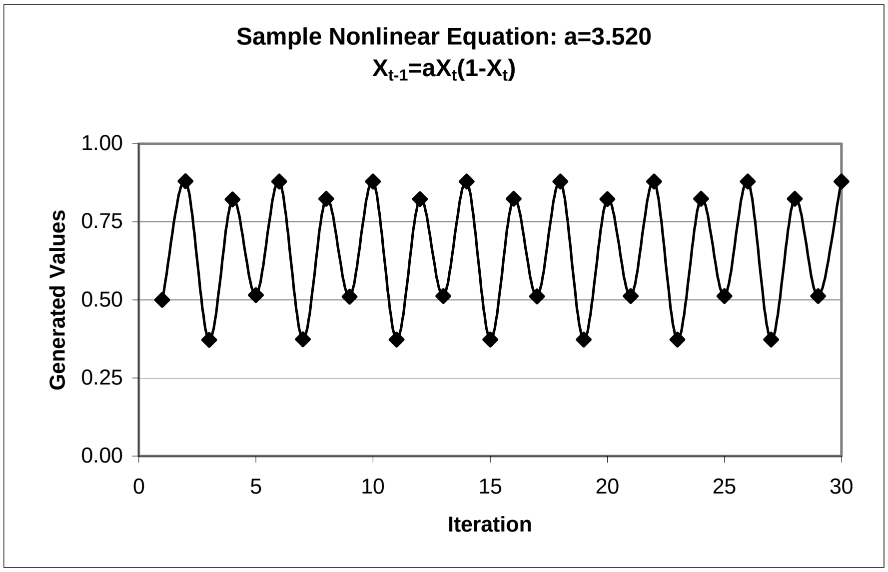

Figure 5-15

The last in the set of four standard phase portraits was generated from the logistic equation using the value of a = 3.950, which placed the system in the chaotic region and illustrates a chaotic, or strange, attractor. Between values of a = 3.8 and a = 4.0, Kiel and Elliott (1996) described a

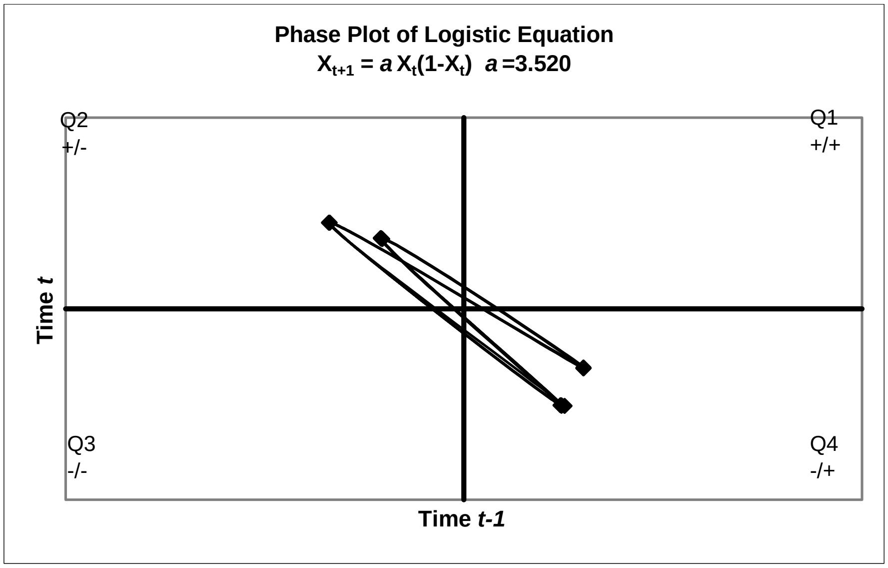

Figure 5-16

qualitative change in system behavior, in which there is no specific pattern in the system's longitudinal behavior.[23] In the XY line graph, X_t is initially set to 0.5, and while the generated values alternately increase and decrease, the pattern is not regular and does not repeat, as shown in Figure 5-17.

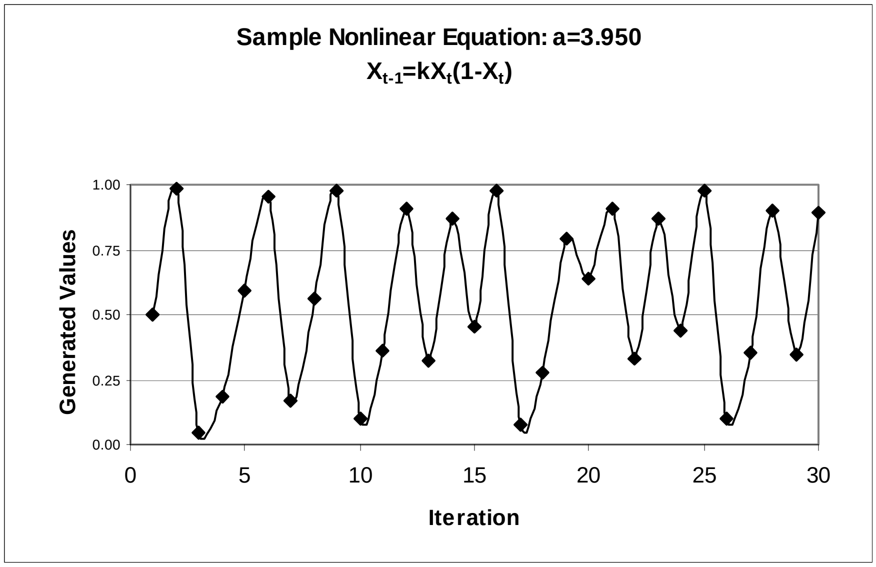

Figure 5-17

Although the values appear to be random, they are not. All of the values of X_t were computed directly by iterating the logistic equation. The values also remain within definable parameters—a large range in this case, between 0.049 and 0.988. These boundaries can be seen in the phase plane graph, where the phase portrait shows a trajectory that visits all four quadrants but is clearly circumscribed, as shown in Figure 5-18.

Construction of phase portraits was not limited to a single variable changing over time. I also looked at the relationship between pairs of variables, using the same approach as outlined above for single variables. As with a single variable, marginal rather than absolute values were used to capture the dynamics of the system. However, each data point in a phase portrait of two variables

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[23] Douglas L. Kiel and Euel Elliott, "Exploring Nonlinear Dynamics with a Spreadsheet: A Graphical View of Chaos for Beginners," in *Chaos Theory in the Social Sciences*, ed. Douglas L. Kiel and Euel Elliott (Ann Arbor: The University of Michigan Press, 1997).

represents two values (one for each variable) at the same point in time, rather than two points in time for one variable.

It was apparent, particularly from the example of the curvilinear data, that the nature of the underlying attractor could not always be interpreted from the phase portrait. The graphical analysis is relatively easy to do and is suggestive of the nature of the system graphed, but is not conclusive. In the case of the examples I generated using the logistic equation, I knew the value of the parameter, *a*, and therefore could infer from the value of *a* the nature of the underlying attractor. Identification of the nature of the underlying attractor in a social system therefore relies on knowing the value of the parameter, *a*, in a logistic equation that describes the observed data. In addition to graphical analysis, nonlinear mathematical analysis is needed to more fully understand the behavior of a nonlinear dynamic system. In particular, logistic equations have been usefully applied to describe the motion of a system in phase space.[24]

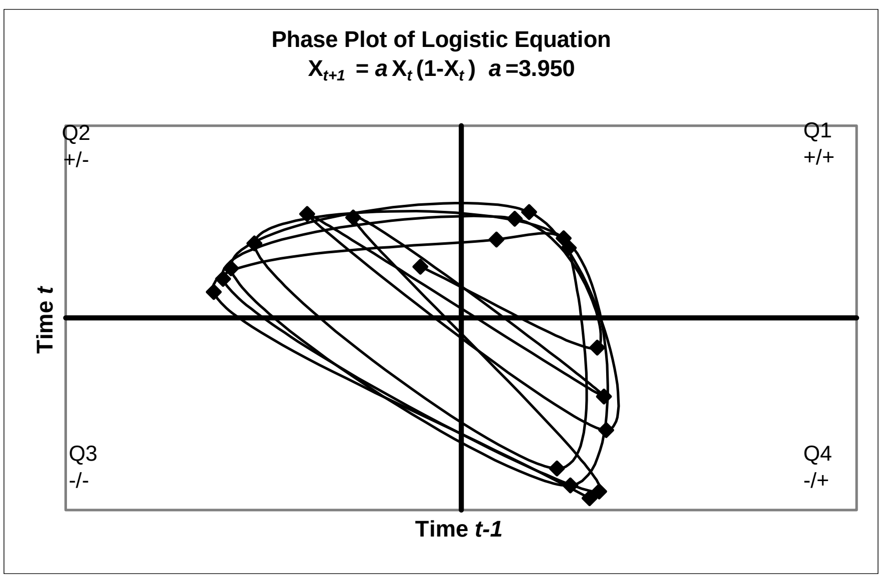

Figure 5-18

Until recently, there was a tendency to deal with the problem of nonlinearity by either treating it as a deviation and ignoring it, or transforming the data so a linear technique could be applied. Transformations such as taking the logarithm of a variable assume a continuous function with a

[24] J.M.T. Thompson and H.B. Stewart, *Nonlinear Dynamics and Chaos*, Second ed. (Chichester, England: John Wiley & Sons, Ltd., 2002).

slope that can be calculated at each point. This assumption is fundamental to calculus, another commonly used tool for understanding and predicting phenomena. Since nonlinear phenomena may have discontinuities and/or oscillations, the tools of calculus and linear regressions (even with transformed data) often cannot be used. Logistic equations provided a means of describing nonlinear behavior.

Logistic equations are available in various forms, and can be used to model the qualitative behavior of a nonlinear dynamic system.[25] There are two classes of logistic equation—continuous and discrete.[26] For this research study, a continuous form of logistic equation was chosen because the study variables were typically continuous in nature. Although measurements were taken at discrete intervals, the variables were free to vary between the points at which they were measured.

The primary challenge of applying a logistic equation to data lies in finding the value of the regulating constant or tuning parameter. The software package MATLAB was used to solve for the value of the tuning parameter by finding the value that, when inserted into the logistic equation, produced predicted values that were most similar to the observed values.[27] That is, the solution yielded the best least squares fit of the observed data. The analysis was conducted in the following manner:

1. A function, which I called logeqt, was defined to identify the parameters of a logistic equation: xp = logeqt(*r*,*t*,*p*,*q*), where
   r = the constant (or tuning parameter)
   t = the time value (year)
   p = the initial value (and for subsequent iterations, each value of X_t using prior notation)
   q = the carrying capacity of the system

2. The solution, or value of xp, was defined as: {[q*p]./[p + (q-p) * exp (-r*t)]}, where, in MATLAB notation, "." indicates that actions to the right of "/" should be performed for

[25] Ibid.
[26] Çambel, *Applied Chaos Theory: A Paradigm for Complexity*.
[27] MATLAB is a licensed product of MathWorks, Inc. http://www.mathworks.com

each value of the variable, function, or constant to the left of ".", and "exp" denotes the exponential function.

3. A second function, which I called fitlogeqt, was defined to calculate a least squares fit of the data: J=fitlogeqt (*r*,*t*,*p*,*q*,*d*), where the parameters were labeled the same as in the first function, and *d* was added as a placeholder for the data.

4. A MATLAB program was written to:
   a. Allow insertion of the observed data
   b. Allow insertion of the number of observed data points
   c. Normalize the data, if necessary, to values between 0 and 1 by finding the maximum value in the observed data and dividing each data element by that value; i.e., normalize the data with respect to the maximum observed value
   d. Set the initial value (*p*) to the value of the first observed data point
   e. Initialize the time value to $t = 0$ and specify that the time parameter should iterate through the correct number of observed data points
   f. Set a placeholder for the final value (*q*) to 1
   g. Find the value of *r* (related to but not the same as *a* in earlier discussions of logistic equations) that yields the minimum least squares value using the MATLAB's predefined function, *fminbnd*, a general function for nonlinear numerical methods that minimizes the function of one variable within a fixed interval. Put another way, the function *fminbnd* finds the value of the constant in the logistic equation that, when inserted into the equation and used to generate predicted data, the predicted data most closely match the observed data.
   h. Output data values generated by inserting *r* into the equation defined in step 1; the value of *q* was adjusted to a value of less than 1 if necessary.
   i. Observed and predicted data values (i.e., the output data values generated in step g) were plotted on the same axes, providing a visualization of the similarity between the two sets of values.

The result of the MATLAB analysis described above is an equation that best describes, mathematically, the observed data. The observed and predicted values were entered into an Excel spreadsheet, the square of the difference between each pair of data was calculated, and all of the squared differences were summed. This sum of squared differences was used to evaluate the goodness of fit between the two sets of data.

Chapter 6. Results of Analyses of Current Data

The annual data of interest to this study were organized for each school and year, in order to illustrate the presently existing medical schools as a group, and to assist in identifying patterned behaviors. This chapter presents the most recent data included in the study; these data described financial and institutional characteristics of all schools as a group and for each of the three managed care market groups of schools. The large number of variables presented here underscores the value of examining multiple indicators to fully understand the behavior of a complex social system. These data provide evidence for a detailed, rich description of the schools and their environment, as they currently exist. These data and the results of the trend analysis presented in chapter 7, were combined and further analyzed to identify emerging patterns of behavior. The full complement of indicators is presented to allow the reader to understand the breadth of indicators that were examined, and to see what indicators were not included in pattern identification, as well as those that were included.

U.S. Medical Schools

In the most recent year for which data were collected and analyzed (usually academic year 2000-2001) there were 125 accredited medical schools. As a quick reference for interested readers, I have created a profile of each school. These profiles can be found in appendix A. Each profile lists the name and location of the medical school, the type of ownership (public or private), data that describe its managed care market environment, institutional descriptors such as relationship to a parent university and faculty practice plan organization and legal structure, as well as current data showing enrollment, number of graduates and faculty, total teaching load, total revenue, NIH funding support, number of clinical affiliations, and a short narrative of the school's history. Each profile also includes the school's assigned ID number and managed care market penetration group number.

Sections 2 and 3 of this chapter describe and summarize the most currently available financial and institutional characteristics of all 125 accredited medical schools. Sections 4 and 5 summarize the same data for each of the three managed care market groups of schools. The final section (section 6) of this chapter provides a comparative summary of the current status of the three groups of schools.

Financial Data—All Medical Schools

Data describing the fiscal environment of medical schools by revenue source showed that in academic year 1998-1999 grants and contracts and faculty practice plans accounted for nearly two-thirds (63.7%) of medical schools' income. Reimbursements from hospitals, and revenue from research and teaching/training programs at affiliated institutions accounted for an additional 15.1% of total revenue. Federal, state, and local appropriations contributed 8.8%, tuition and fee revenue contributed approximately 3.8%, and other sources such as endowment and gifts contributed 8.6%. The distribution of revenue by source in 1998-1999 is illustrated in Figure 6-1.

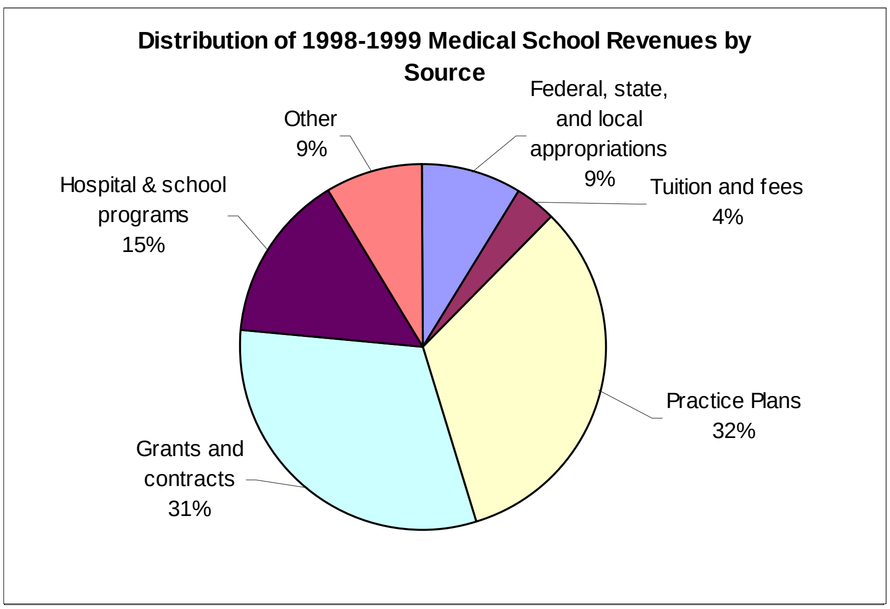

Figure 6-1

In current dollars, total revenue in 1998-1999 was $38,263 million, or an average of $311.1 million per school (2 schools were excluded due to changes in reporting practices). Faculty practice plans contributed $12,510 million of this total, followed by $11,845 million in revenue received from grants and contracts. This represented an average of $101.7 million in revenue from faculty practice plans and $96.3 million in grants and contracts per school in current dollars. Other revenue from federal sources and state and local appropriations totaled $3,363 million and tuition revenue was $1,460 million. Average revenue from federal, state, and local appropriations averaged $27.3 million and average revenue from tuition and fees represented $11.9 million per school.

The NIH is the largest single funder of biomedical research in the U.S., providing approximately half of its extramural support to medical schools. Total NIH support for medical schools in FY 1998 was $5,592 million, or an average of $44.7 million per school. The NIH provided more than half of the grant and contract revenue received by medical schools in 1998-1999.

Although funds were competitively provided for research training grants, individual fellowships, career development support, research and development contract work, construction, and other purposes, most of the funds were distributed by the NIH for support of traditional basic science and clinical research projects. In FY 2001, $7,850 million (or $ 62.8 million per school) was provided by the NIH to medical schools in the form of research grants; NIH support for all activities averaged $68.4 million in current dollars.

Institutional Characteristics—All Medical Schools

Location. U.S. medical schools were located in both large and small cities. Census Bureau data from the 2000 decennial census indicated that medical schools were located in areas with an average of approximately 1.7 million people.[1] The population in the areas in which the medical schools were located ranged from just over 5,000 to over 9.5 million.

Type of ownership. Of the 125 medical schools in the study, 74 were public institutions and 51 were private institutions.

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[1] *U.S. Census Bureau, Census 2000 Redistricting Data (P.L. 94-171) Summary File* [Web page] (U.S. Census Bureau, 2 April 2001 [cited 27 June 2002]); available from http://factfinder.census.gov/home. Census 2000 PHC-T-3. Ranking Tables for Metropolitan Areas: 1990 and 2000. Table1. Metropolitan Areas and their Geographic

Enrollment. Education is one of the three generally recognized missions of U.S. medical schools; the other two missions are research and provision of clinical care to patients. During the 2000-2001 academic year, medical schools reported an average of 539.7 students enrolled in an M.D. degree program.

Graduates. Nearly all students who attend medical school graduate. During the 2000-2001 academic year, schools reported an average of 128.2 students graduating with an M.D. degree.

Graduates practicing generalist medicine. In 1999, 30% of 1991, 1992, and 1993 medical school graduates had completed an approved, three-year residency training program in pediatrics, family practice, or internal medicine and had not participated in a subspecialty or non-generalist program through the 1996-1997 residency year.

Faculty. During the 2000-2001 academic year, medical schools employed an average of 765.6 faculty members per school; the average school had 1.45 faculty members for every medical student. When residents, master's, and doctoral students were included in the total teaching responsibility, the ratio was 0.54 faculty members per student.

Medical school faculty members can be divided into basic science and clinical faculty on the basis of their departmental affiliation. Clinical faculty members generally outnumber basic science faculty members. In 2001, the average number of basic science faculty was 120.2 while the average number of clinical faculty was 635.5 per school. The ratio of clinical to basic science faculty was therefore about 5.25 to 1 in 2001.

Total teaching responsibility. Medical school faculty members' teaching responsibilities extend beyond medical students. Residents, postdoctoral fellows, and others obtaining graduate medical education are also the responsibility of medical school faculty. Master's and doctoral students studying for advanced degrees granted by the medical school or the parent university also take courses taught by medical school faculty. In academic year 2000-2001, medical students

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Components in Alphabetic Sort, 1990 and 2000. Population, and Numeric and Percent Population Change: 1990 to 2000.

comprised only about 37% of the faculty's teaching load. The remainder of their teaching responsibilities were devoted to residents and postdoctoral students (43%) and master's and doctoral students (20%). The distribution of the 2000-2001 teaching load is shown in Figure 6-2.

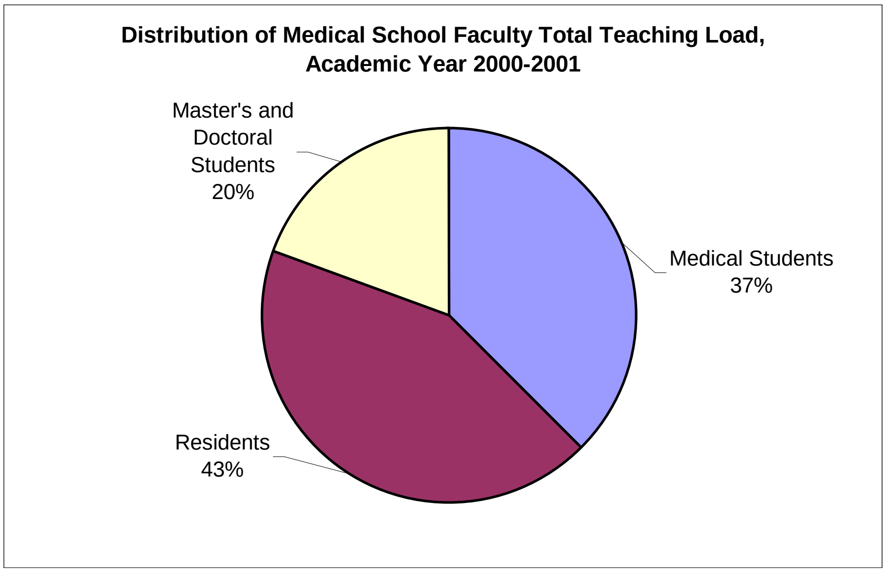

Figure 6-2

Medical school administrative staff. Medical school administrative staff positions include the Dean, various Associate and Assistant Deans and Directors, the Provost, the Registrar, and the Librarian; the position title Comptroller or Chief Financial Officer was also occasionally reported. During the years analyzed in this study, Chief Operating Officers and Chief Information Officers also appeared as new positions in some schools. In academic year 2000-2001, the average number of administrative staff positions was 18.8 per school.

Clinical facilities. Medical schools form affiliations with hospitals and clinics to gain access to patients and to train medical students and residents. The average number of clinical affiliations per school in academic year 2000-2001 was 11.5.

Types of faculty practice plan, organization, and governance. Faculty practice plans were established to arrange for billing, collection, and distribution of professional fee income on behalf of clinical faculty who provide clinical services. The practice plan organization and legal structure with respect to the medical school varied. In 2001, 119 medical schools reported information about faculty practice plan organization. Of these, 94 (79.0%) had medical school-based practice plans. An additional 15 (12.6%) were health system-based and the remaining were described as hospital-based.

The legal relationship between the practice plan and the medical school also varied. The most common relationships in 2001 were those in which the practice plan was part of the parent university (53 schools or 44.5%) or was established as a separate not-for-profit corporation (44 schools or 37.0%). The remaining faculty practice plans were some form of professional corporation (8 schools) or a mixed type (13 schools). The faculty practice plan at Duke University School of Medicine was the only for-profit corporation.

Operationally, faculty practice plans were most often federated. Federated practice plans have some measure of common governance and a central advisory committee to address issues of common management. A total of 57 practice plans (47.9%) were described as federated. The second most commonly occurring practice plan was multi-specialty. Multi-specialty practice plans have a high degree of common governance, a single governing board, a central administrative or management structure, and pooled income. A total of 49 practice plans (41.2%) were described as multi-specialty. In 13 medical schools (10.9%), the practice plans were department-based. In departmental practice plans, individual departments are autonomous; there is no common governance at the medical school level, and there is little or no common management.

Relationship to parent university. Although 28 medical schools were classified in 2001 as freestanding, most have a relationship with a parent university. The most common form of the relationship (72 schools) was related/proximate; that is, the medical school was part of a public or private university and was located in the same city as the parent university. The second most common form of the relationship (24 schools) was related/distant. As suggested by the classification, the medical school was part of a public or private university but was not located in the same city as the parent university; this classification included urban/suburban relationships. One medical school—Northeastern Ohio Universities College of Medicine, a community-based, state medical school—maintained cooperative relationships with several universities. It was classified as a consortium.

Most freestanding medical schools were entities that did not have any affiliation with a parent university. Both public and private freestanding medical schools existed. An additional 7 medical schools were classified as a freestanding/state system, and as the name suggests, these schools were affiliated with a state system of higher education. One medical school, the Uniformed Services University of the Health Sciences, was classified as federal government freestanding. It is a public medical school sponsored by the federal government.

When the variants of freestanding and parent-university related schools were combined, approximately 22% of medical schools were freestanding or unrelated to a parent university; about 78% of all medical schools had a relationship with a parent university.

Financial Data—Medical Schools by Managed Care Market Group

Data for individual schools' revenue by source was limited to academic years 1995-1996 through 1998-1999. While limited, these years represented a period of significant growth in managed care market penetration. The categories of revenue sources included hospital revenues, federal support, state appropriations, and tuition and fees. Data for expenditures for grants and contracts were also available. The amount of NIH support for each medical school by year and type of support was available for all study years. Forms of NIH support included research grants, training grants, fellowships, contracts, and other support.

Total medical school revenue. Schools in high (Group 3) managed care markets reported an average of $273.3 million in total revenue in academic year 1998-1999. This revenue was higher than average total revenue reported by schools in medium (Group 2) or low (Group 1) managed care markets. These two groups of schools averaged $221.1 and 138.6 million in current dollars, respectively.

Federal support. Federal support for all activities was the largest source of medical school revenue, averaging $67.3 million per school. Schools in high (Group 3) managed care markets received more revenue from the federal government in academic year 1998-1999 than did schools in medium (Group 2) or low (Group 1) managed care markets. Average federal support for schools in high managed care markets was $98.1 million in current dollars. Schools in medium (Group 2) managed care markets received an average of $68.1 million in 1998-1999. Schools in low (Group 1) managed care markets received the lowest average amount of federal support in 1998-1999 ($33.4 million).

Hospital fee revenue. Revenues from hospital fees averaged $46.8 million per school in academic year 1998-1999. Schools in medium (Group 2) managed care markets received the most revenue on average from hospital fees ($55.6 million). Average hospital fee revenue for schools in high (Group 3) managed care markets was $51.7 million in academic year 1998-1999. Schools in low (Group 1) managed care markets had the lowest average hospital fee revenue in academic year 1998-1999 ($32.3 million).

State appropriations. Public medical schools receive revenues from state appropriations; state funding is generally small or nonexistent for private medical schools. Schools in low (Group 1) managed care markets, a group in which public medical schools outnumber private schools 30 to 10, had the highest average amount of revenue from state appropriations in academic year 1998-1999 ($32.2 million). State appropriations for schools in medium (Group 2) managed care markets averaged $23.8 million. Public schools outnumbered private schools in the group, 23 to 18. Schools in the high (Group 3) managed care markets received the lowest average amount of state appropriations ($22.7 million); in this group, there were 21 public schools and 23 private schools. Average state appropriations for all schools were $26.1 million in academic year 1998-1999.

Tuition and fee revenue. Revenue from tuition and fees was the smallest major source of revenue for medical schools. Since tuition at private schools is over twice as high as tuition at public schools ($33,000 versus $14,350 in academic year 1998-1999), I expected to see a pattern among the three groups of schools that was the reverse of average state appropriations. Indeed, this was the case. Schools in high (Group 3) managed care markets received the highest average tuition and fee revenue ($13.9 million in current dollars). Schools in medium (Group 2) managed care markets received an intermediate amount of revenue from tuition and fees ($11.4 million in current dollars). Schools in low (Group 1) managed care markets received the lowest average amount of revenue from tuition and fees, $9.8 million in current dollars.

Grants and contracts. These data were reported as expenditures rather than revenues. Schools in high (Group 3) managed care markets expended the highest average amount from grants and contracts ($86.8 million in current dollars). Schools in medium (Group 2) managed care markets expended a smaller average amount from grants and contracts in 1998-1999 ($62.3 million in current dollars). Schools in low (Group 1) managed care markets expended the lowest average amount from grants and contracts (30.8 million in current dollars).

Total NIH support. Data on total extramural funding provided by the NIH to medical schools were available for FYs 1981 through 2001. In FY 2001, schools in high (Group 3) managed care markets received higher average funding from NIH than did schools in medium (Group 2) or low (Group 1) managed care markets. Average NIH funding for schools in high managed care markets was $92.1 million. This average was about $20 million higher than the average for schools in medium (Group 2) managed care markets, which was $71.4 million in current dollars. Schools in low (Group 1) managed care markets received a much lower average amount of total NIH funding in FY 2001 ($39.1 million in current dollars).

NIH support for research grants. Nearly all of NIH support provided to medical schools was in the form of research grant awards. In FY 2001, the proportion of total funding that supported research grants was about 92% (an average of $62.8 million per medical school). This proportion was the same for schools in all three managed care market groups.

Average NIH research funding provided to medical schools in high (Group 3) managed care markets was greater in FY 2001 than average funding provided to schools in either medium (Group 2) or low (Group 1) managed care markets. Average NIH research funding for schools in high (Group 3) managed care markets was $84.7 million in current dollars. Schools in medium

(Group 2) managed care markets received an average of $65.6 million in current research grant dollars from NIH. Schools in low (Group 1) managed care markets received the lowest average amount of NIH research grant funding in 2001 ($35.8 million in current dollars).

Institutional Characteristics—Medical Schools by Managed Care Market Group

Location. Medical schools in high and medium managed care market penetration groups were located, on average, in areas with 2.80 and 1.98 million persons, respectively. Medical schools in the low managed care market penetration group were located in relatively less populated areas, averaging about 1.06 million persons. That larger urban areas tended to have higher managed care market penetration rates was borne out by a comparison of the median state market penetration rate for all states in 1999 (27.3%) and the median market penetration rate for MSAs in 1999, which was 39%.

Type of ownership. Ownership of medical schools in high managed care markets was about evenly divided: 21 were public and 23 were private institutions. Of medical schools in medium managed care markets, 23 were public and 18 were private institutions. Public schools greatly outnumbered private schools in low managed care markets; 30 were public and only 10 were private institutions.

Enrollment. Schools in high (Group 3) and medium (Group 2) managed care markets enrolled slightly more students on average in academic year 2000-2001 (536.6 and 538.7, respectively), than schools in low (Group 1) managed care markets (506.2).

Graduates. Schools in high (Group 3) and medium (Group 2) managed care markets graduated slightly more students on average (128.4 and 133.2 graduates, respectively) in academic year 2000-2001 than schools in low (Group 1) managed care markets (123.1 graduates).

Graduates practicing generalist medicine. Schools in medium (Group 2) managed care markets had the lowest percentage (29.5%) of 1991 through 1993 graduates who had completed residency training in a primary care specialty. Schools in high (Group3) managed care markets produced a similar percentage of primary care physicians (30.5%). The highest percentage of graduates who had completed primary care specialty training came from schools in low (Group 1) managed care markets. Of these schools' graduates, 33.7% were presumed to be practicing generalist medicine.

Faculty. Schools in high (Group 3) and medium (Group 2) managed care markets had a similar number of full-time faculty members on average in 2001—886.5 and 865.8, respectively. Schools in low (Group 1) managed care markets had much smaller faculties on average in 2001 (530.0). The ratio of faculty members to medical students at schools in high and medium managed care markets was 1.65 to1 and 1.61 to1, respectively. The ratio of faculty to medical students at schools in low managed care markets in 2000-2001 was 1 to1.

Schools in high (Group 3) and medium (Group 2) managed care markets also had similar and larger average numbers of clinical faculty than schools in low (Group 1) managed care markets. Group 3 schools averaged 752.0 clinical faculty members; Group 2 schools averaged 718.6 clinical faculty members; and Group 1 schools averaged 422.2 faculty members per school in clinical science departments in 2001.

Although Group 3 schools had larger clinical faculties on average, Group 2 schools had larger basic science faculties in 2001. Schools in medium (Group 2) managed care markets averaged 137.8 basic science faculty members, compared to an average of 126.4 basic science faculty members per school in high (Group 3) managed care markets. Schools in low (Group 1) managed care markets had the fewest number of basic science faculty members on average (95.6).

The ratio of clinical to basic science faculty also differed by managed care market penetration group. Schools in low (Group 1) managed care markets had a clinical to basic science faculty ratio of about 4.5 to 1 in 2001. Schools in medium (Group 2) managed care markets had an intermediate clinical to basic science faculty ratio (about 5 to1). Schools in high (Group 3) managed care markets had the highest ratio of clinical to basic science faculty (about 6 to 1).

Total teaching responsibility. Faculty in medical schools in high (Group 3) and medium (Group 2) managed care markets had larger total teaching loads, on average, than faculty in schools in low (Group 1) managed care markets in 2001. Schools in medium (Group 2) managed care markets averaged the highest total teaching load (1,559.7 students). Total teaching responsibility averaged 1,528.0 students per medical school in high (Group 3) managed care markets. Total teaching responsibility was lowest at schools in low (Group 1) managed care markets; these schools averaged 1,124.5 students of various types.

In academic year 2000-2001, the percentage distribution of medical students, residents, and master's and doctoral students was similar for schools in high (Group 3) and medium (Group 2) managed care markets, as shown in Figure 6-3.

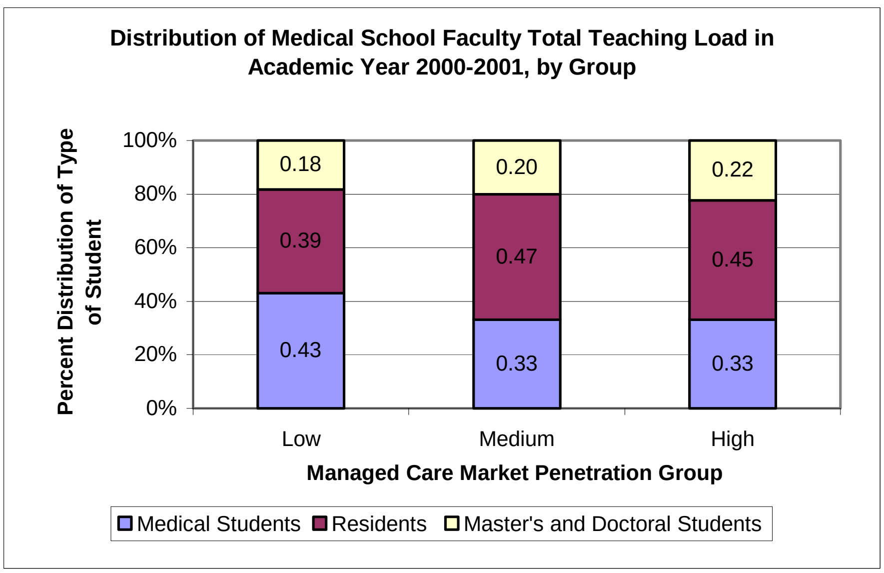

Figure 6-3

Medical students in both of these groups of schools accounted for 33.1% of the total teaching load. Residents and postdoctoral students also represented similar proportions—44.6% and 46.8% of the total teaching load in Group 3 and Group 2 schools, respectively. Master's and doctoral students comprised the remaining teaching load, with 22.3% and 20.1% in Group 3 and Group 2 schools, respectively. The teaching load at schools in low (Group 1) managed care markets was distributed slightly differently. Residents and postdoctoral students, and master's and doctoral students comprised a lower percentage of the teaching load (38.6% and 18.3%, respectively), while medical students accounted for a higher percentage of the teaching load (43.1%).

Medical school administrative staff positions. Schools in medium (Group 2) managed care markets reported the largest average number of administrative staff positions in academic year 2000-2001 (20.3 medical school administrators). The average size of administrative staffs in schools in high (Group 3) and low (Group 1) managed care markets was smaller (18.7 and 17.3 staff positions per medical school, respectively).

Clinical facilities. Schools in medium (Group 2) managed care markets had the highest average number of clinical affiliations (12.2) in 2000-2001. Schools in high (Group 3) managed care markets had established affiliations with an average of 11.4 clinical facilities in academic year 2000-2001. Schools in low (Group 1) managed care markets had the lowest average number of clinical affiliations (10.9).

Types of faculty practice plan, organization, and governance. Schools in the three managed care market groups were similar in 2001 with respect to the predominance of the type of organization of their faculty practice plans. Schools in high (Group 3) and medium (Group 2) managed care markets based 78.0% and 78.9% of their practice plans within the medical school, respectively. Schools in low (Group 1) managed care markets based 85% of their faculty practice plans within the medical school. Schools in high (Group 3) and medium (Group 2) managed care markets had a higher percentage of health system-based practice plans (14.6% and 15.8%, respectively) than did schools in low (Group 1) managed care markets (8.1%). Hospital-based practice plans accounted for less than 10% of the plans in any of the managed care market groups. The percentage of schools for which data were not applicable or not available was similar for schools in all three groups.

The legal relationship between the practice plans and the medical schools in the three managed care market groups varied in some respects. Schools in high (Group 3) and low (Group 1) managed care market groups had the highest percentages of practice plans that were part of a university (51.2% and 43.6%, respectively). Schools in medium (Group 2) managed care markets had fewer (38.5%) of their practice plans legally structured as part of their parent university. The second most common legal structure, a separate not-for-profit corporation, occurred most frequently among schools in low (Group 1) managed care markets (41.0%), followed by schools in high (Group 3) and medium (Group 2) managed care markets (36.6% and 33.3%, respectively). Multiple professional corporations accounted for 12.8% of the faculty practice plans in medium managed care market schools (Group 2), but only 5.1% of the practice plans in low managed care market schools had this practice plan legal structure. No schools in the high (Group 3) managed care market group structured their practice plan as a multiple professional corporation. The remainder of the practice plans were classified as mixed (12.2% in high, 12.8% in medium, and 7.7% in low managed care market schools), or as a for-profit corporation (one school in the low [Group 1] managed care market), or as a single professional corporation (one school in the medium [Group 2] managed care market).

Operationally, the majority of plans in schools in high (Group 3) and low (Group 1) managed care markets were federated plans, with some measure of common governance and management (56.1% and 51.3%, respectively). The second most frequently occurring operational type of practice plan in schools in high (Group 3) and low (Group 1) managed care markets was the multi-specialty plan (34.1% and 41.0%, respectively), with a high degree of common governance. Schools in the medium (Group 2) managed care market had more multi-specialty practice plans (48.7%) and slightly fewer that were described as federated (35.9%). Fewer than 10% of practice plans in high (Group 3) and low (Group 1) managed care markets were departmental plans (9.8% and 7.7%, respectively), while 15.4% of practice plans in schools in medium (Group 2) managed care markets were departmental plans, with little or no common governance. Schools with no reported practice plan were fairly evenly distributed across the managed care market groups.

Relationship to parent university. Overall, medical schools that were related to a parent university outnumbered freestanding medical schools by about 3.5 to 1. The ratio of university-related to freestanding schools for medical schools in high (Group 3) managed care markets was approximately 3.9 to 1. Most (26 of 44) of the medical schools in Group 3 were related and proximate to a parent university; an additional 9 were related to but distant from a parent university. Of the remaining 9 schools, 7 were freestanding with an additional one each classified as federal government/freestanding and state system/freestanding.

Medical schools in medium (Group 2) managed care markets consisted of 12 freestanding or state system/freestanding schools, and the remaining 29 were related to a parent university. Of those schools that were related to a parent university, 25 were located in the same city (proximate), and 4 were distant from the parent university. The ratio of university-related schools to freestanding schools in this group was about 2.4 to1.

Medical schools in low (Group 1) managed care markets had the highest ratio of university-related to freestanding schools—about 4.7 to 1. This group also had the highest number (and highest proportion) of schools classified as related/distant; 11 of the 40 schools in this managed care market penetration group were so classified. With another 21 schools classified as related/proximate and one as a consortium, this group had the highest percentage (82.5%) of schools related to a parent university. The remaining 7 schools in this group were freestanding (n = 6) or state system/freestanding (n = 1). One reason for the relatively high number of related/distant schools was that several of the lower population states in which these schools were located have placed the medical school in the state capital or in the largest city—not necessarily the location of the state's public university.

Comparative Characterization of the Current Status of Medical Schools

Following the study model, the evidence presented in the preceding sections can be grouped by the three missions of medical schools: teaching, research, and patient care. On this basis, schools in high (Group 3) managed care markets can be broadly characterized as research institutions; schools in medium (Group 2) managed care markets can be broadly characterized as "the educators"; and schools in low (Group 1) managed care markets can be characterized primarily as the smaller, multi-functional, public schools. Of course, all of the schools performed all three missions. Nevertheless, each of the three groups of medical schools differed in their emphasis of one or two of the missions.

I have already noted that high managed care markets tended to occur more often in urban areas. Schools in the high (Group 3) managed care market group were located in the most populated areas and were, by a small margin, more often private institutions. About 60% were related and proximate to a parent university, with the remainder evenly divided between related/distant and freestanding. These schools received the most federal support and had the highest average total revenues.

The most striking feature of schools in high managed care markets was their dominance as research institutions. These schools reported the highest average expenditures for grants and contracts, and received the highest average funding from the NIH for research projects, research training, and fellowships. These schools had the largest average number of full-time faculty, and educated the highest average number of master's and doctoral students who were being trained to conduct research.

Schools in the medium managed care market group (Group 2) were located in somewhat lower population areas than Group 3 schools, and over half of the schools were public institutions. These schools had the highest average medical student enrollment and number of graduates, and the greatest average total teaching responsibility. While average enrollment of medical students was only slightly higher than enrollment in Group 3 schools, the average number of residents in Group 2 schools was substantially higher than in schools in high managed care markets. Like medical students, residents were primarily trained to be clinicians, not researchers.

In addition to education, schools in medium managed care markets provided a significant amount of patient care. They received the highest average amount of hospital fee revenues, and were affiliated with the highest average number of clinical facilities—in which they accommodated the largest number of residents. These clinical facilities offered opportunities for educating medical students and residents, and provided a source of patients and revenue from caring for these patients. Medicare DGME payments also provided revenue to cover residents' stipends and teaching physicians' salaries. IME payments were also provided by Medicare on the basis of the ratio of interns and residents to the number of hospital beds. A higher number of residents at

Group 2 schools translated directly to increased revenue in the form of DGME and IME payments.

Schools in medium (Group 2) managed care markets also had the largest average number of administrative staff positions, and were most often related and proximate to a parent university. They were rarely related to but distant from a parent university; however, compared to schools in high managed care markets, a higher percentage were freestanding.

Schools in the low managed care market group (Group 1) were located in the lowest population areas and were, overwhelmingly, publicly owned. They also received the highest average amount of state appropriations, and had the highest percentage of schools that were related to but not located in the same city as a parent university. With one exception, these schools did not have the highest average for any of the study variables associated with teaching, research, or patient care activities. The exception was that medical students comprised a higher percentage of the average total teaching load in these schools than in either of the other two groups of schools. Other types of students contributed proportionately less to total teaching responsibility, suggesting that faculty at schools in low managed care markets focused primarily on teaching medical students.

Group 1 schools played an important role in producing physicians and providing specialized clinical care in lower population metropolitan areas and states. The average enrollment and number of graduates, and the average number of affiliated clinical facilities, are only slightly below the average for all schools. Their grant and contract revenue, and average number of full-time faculty, were much smaller than the national average.

In 2001, there were clear differences among the groups of schools that were located in high, medium, or low managed care markets. The next chapter of this study explores trends in key variables over a twenty-year period. These data provided evidence for characterizing changes in academic medical centers that were concurrent with the time period in which managed care was rapidly increasing its share of the health care delivery market.

This chapter has presented the most currently available data for the indicators comprising each of the variables in the study model. These data are used to begin to build a rich description of academic medical centers, one of the contributions of this research study. From among the many indicators, specific clusters of indicators were found to provide a basis for characterizing each of the managed care market groups of schools. Data for all of the indicators were included to offer the reader an appreciation of the source of the rich description of the academic medical centers and to introduce a degree of transparency into the analytic process by revealing information about the kinds of data that did not appear to be easily grouped into ordered patterns. The next chapter presents the results of the analyses of trend data.

Chapter 7. Results of Analyses of Trend Data

This chapter presents trends in managed care market and medical school data over time. In most cases, data (for variables) used to create the description of the three groups of schools as they were in 2001 were available for a twenty-year period. These trend data were used to track the patterns of behavior of the three groups of schools over this period. This chapter also presents a comparison between the current "snapshot" of medical schools, presented in chapter 6, and changes in academic medical centers that have occurred during the last 20 years.

Managed Care

"Managed care" covers a variety of organizational structures and functions which can generally be described as a group of interdependent systems designed to deliver integrated health care services to a specific population in a cost-controlled manner. Managed care health plans typically share certain characteristics, including the provision of a comprehensive set of health care services and financial incentives for members to use providers and services associated with the health plan. A managed care plan differs from a health insurance company by its active role in managing health care delivery. Health maintenance organizations (HMOs), preferred provider organizations (PPOs), point of service (POS) plans, and exclusive provider organizations (EPOs) were all considered managed care organizations (MCOs) for the purposes of this study.

HMOs represent a form of health insurance that combines a range of coverages on a group basis. A group of doctors and other medical professionals offer care through the HMO for a flat monthly rate with no deductibles. However, only visits to professionals within the HMO network are fully covered by the policy. The HMO must clear all visits, prescriptions, and other care in order for the patient to be covered. A primary physician within the HMO handles referrals. HMOs are the oldest form of managed care; they emerged in a recognizable form in the 1930s, in tandem with the indemnity model. The best known of the prepaid group practices that comprised the early form of managed care, was the Kaiser Foundation Health Plan. In the early 1970s, Congress passed the Health Maintenance Organization Act, providing specific grants to support the development of HMOs and attempting to set health care standards. By 1980, HMOs were well-established in the health care business, and the federal government, recognizing the cost containment value of HMOs, began setting up Medicare and Medicaid HMO programs.

Preferred Provider Organizations (PPOs) began to emerge in 1984 as an alternative to the established HMO. The PPO model reimburses its providers on a discounted fee-for-service basis, and can be described as a managed health care organization that contracts with specific providers of medical services at reduced or specifically negotiated rates. In exchange for reduced rates, service providers usually receive expedited claims payments and referrals from the PPO or employer groups. PPO plans usually offer greater freedom of choice of medical service providers, and may be owned by commercial insurance or pharmaceutical companies, physician or hospital organizations, foundations, or large employers.

Point of Service (POS) plans typically allow members to choose health care services from either participating or non-participating providers. The POS plans combine characteristics of the traditional HMO and PPO, and usually utilize existing HMO or PPO networks. The model was initially developed by HMOs to give enrollees greater freedom of choice, but utilization of health care providers who fall outside of the plan results in substantially higher costs for the patient.

Exclusive provider organizations (EPOs) consist of medical providers—usually a group of physicians and a hospital—which have joined to offer services to specific clients. The restrictions in an EPO are on the providers—medical service providers who join a PPO can treat any patient; EPO service providers cannot. EPOs are usually developed and implemented by employer groups that are trying to control health benefits costs.

In the 1990s, managed care became the dominant form of health insurance for privately insured individuals, and the mechanism by which an increasing number of Medicare and Medicaid enrollees received health care. The Medicare + Choice (M+C) program provided for the delivery of Medicare health benefits to elderly and disabled Americans through HMOs, PPOs, and provider-sponsored organizations (PSOs). Thus, a portion of Medicare beneficiaries has received services from MCOs. The Medicaid program provided health and long-term care coverage to low-income Americans. All states except Alaska and Wyoming (neither of which has an accredited medical school) enrolled some portion of their Medicaid population in managed care programs. Many states implemented mandatory managed care enrollment for Medicaid recipients.[1,2]

During the decade of the 1990s, enrollment in HMOs nearly tripled (from 37.5 million), and since 1986, enrollment nearly quadrupled (from 26.3 million). During the same period, national HMO market penetration increased 2.5 times, from 14.9% in 1990 to 37.9% in 1999.[3] In calendar year 1999, HMOs lost more than 400,000 enrollees—the first annual decrease in total HMO enrollment since 1973. As a percentage decrease, however, the drop was quite small—only 0.5%. During the same period, growth in HMO Medicare enrollment slowed to an annual rate of 1.1%, and growth in HMO Medicaid enrollment decreased to just 4.1% following annual growth rates of over 20% since 1993.[4] By the second half of 2000, total HMO enrollment stabilized; approximately 200,000 enrollees were added, resulting in a slight enrollment increase of 0.3%. At the same time, HMO Medicare enrollment began to decrease, losing 7.2% in 2000, partly due to the partial or complete withdrawal of managed care firms from M+C programs. HMO Medicaid enrollment continued to increase, but at a slower rate. HMO market penetration is shown in Figure 7-1. The average and the range of ± one standard deviation are shown.

U.S. Medical Schools

During the first academic year of the study (1981-1982), there were 123 accredited medical schools. In 1982-1983, Mercer University School of Medicine was fully accredited, and in 1994-1995 the Medical College of Pennsylvania and Hahnemann University School of Medicine joined to form MCP Hahnemann School of Medicine. This resulted in a total of 125 schools. The study population remained at this level for the remainder of the period examined in this study. Oral Roberts University School of Medicine was accredited from 1983-1984 to 1989-1990 but

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[1] "The Medicare Program," (Menlo Park, California: The Kaiser Family Foundation, 2002).
[2] "Medicaid and the Uninsured: Medicaid and Managed Care," (Menlo Park, California: The Kaiser Family Foundation, 2001).
[3] "Managed Care Trends Digest 2001," (Aventis Pharmaceuticals Inc., 2001).
[4] Heath Hickok, "HMOs Post First Ever Annual Decrease in Total HMO Enrollment," (St. Paul: InterStudy Publications, 2000).

was not included in any of the analyses. Separate data for the Medical College of Pennsylvania and Hahnemann University School of Medicine prior to 1995-1996 were also not included.

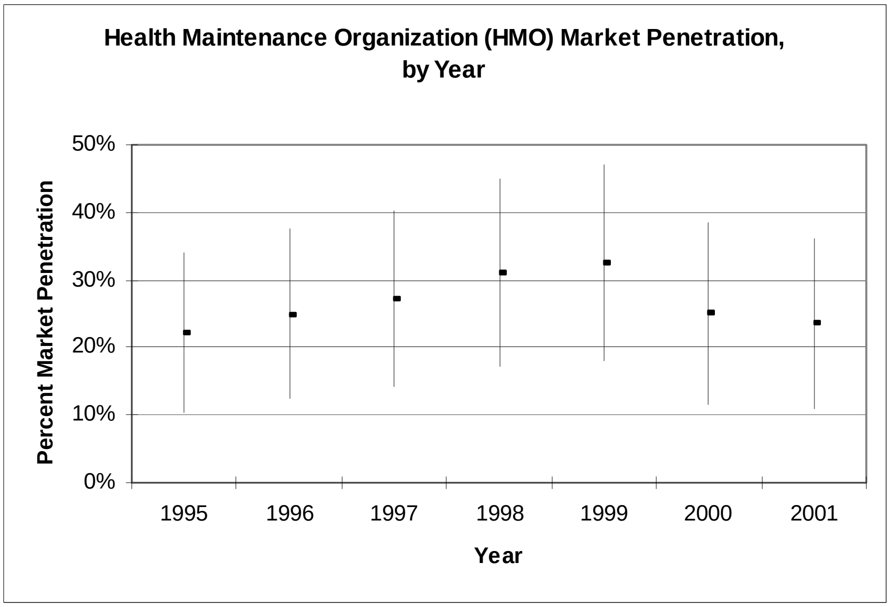

Figure 7-1

Financial Data—All Medical Schools

Total revenue for all schools increased substantially during academic years 1981-1982 through 1998-1999. Annual total revenue in millions of dollars was converted to constant 1990 dollars using the National Institutes of Health (NIH) Biomedical Research and Development Price Index (BRDPI). The change over time is shown in Figure 7-2; in 1981-1982, total revenue was $4,381 million; by 1998-1999, total revenue had increased over tenfold in constant dollars to $50,737 million.

Both an exponential trend line and a linear trend line were drawn using the Microsoft Excel trend line function. Visually, the exponential trend line appeared to fit the data slightly better than the linear trend line (R^2 = 0.9872), particularly during the early part of the period. The R^2 values are provided in this chapter for all of the trend lines that were fit to the data using the Excel trend line function. The closer the R^2 value was to 1.00, the smaller the error, and the better the fit of the trend line to the data. In some cases, the R^2 values for the nonlinear (e.g., exponential, logarithmic) lines were only slightly greater than the R^2 values for linear trend lines. This raises an interesting question regarding the meaning of linear and nonlinear, but this question entails a mathematical discussion that is beyond the scope of this dissertation. I have included the R^2 values for nonlinear trend lines because the fact that a similarly high (although not greater) R^2 value can be calculated for a linear trend line does not negate the observation that a nonlinear trend line does a very good job of describing the changes over time in much of the observed data in this study.

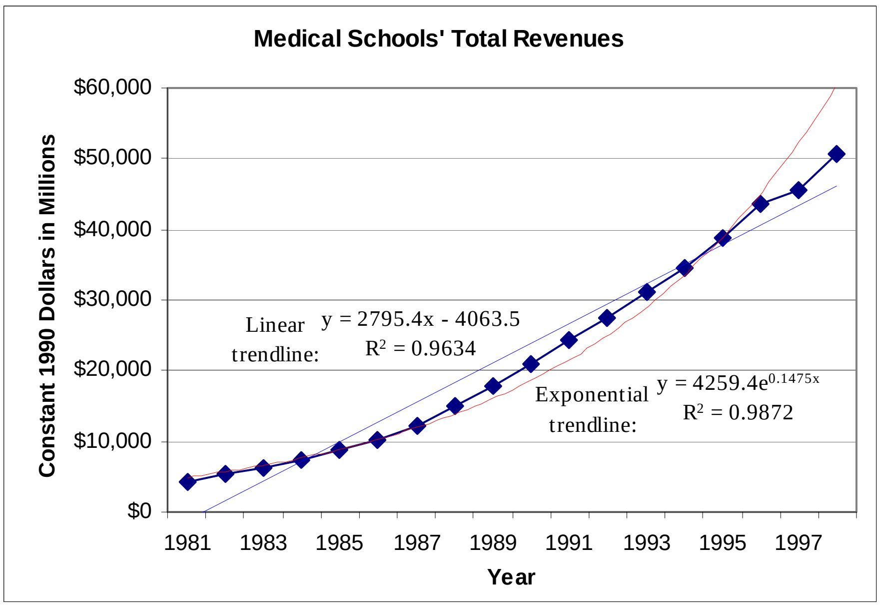

Figure 7-2

To simplify analysis, the revenue data from federal, state, and local appropriations were combined. Data from endowment, gifts, parent university support, and miscellaneous sources accounted for less than 9% of total revenue in academic year 1998-1999, and were not included in the graph. Data for all schools by major revenue category are shown in Figure 7-3. During academic years 1981-1982 through 1987-1988, the difference between the smallest single source of revenue (tuition and fees) and the largest source of revenue (grants and contracts) increased each successive year and ranged from $1,159 to $2,739 million. In academic year 1988-1989, the difference increased markedly to $4,032 million and increased steadily through 1998-1999. In academic year 1990-1991, faculty practice plan revenue replaced grants and contracts as the largest single source of revenue. By 1998-1999, the difference between tuition and fee revenue and practice plan revenue was $14,652 million in constant dollars. As the figure illustrates, the slopes of the increases in faculty practice plan and grant and contract revenue began to increase sharply in 1988-1989. In 1990-1991, hospital and medical school program revenue also began to increase at a greater rate. Other sources of revenue continued to increase at a fairly modest rate.

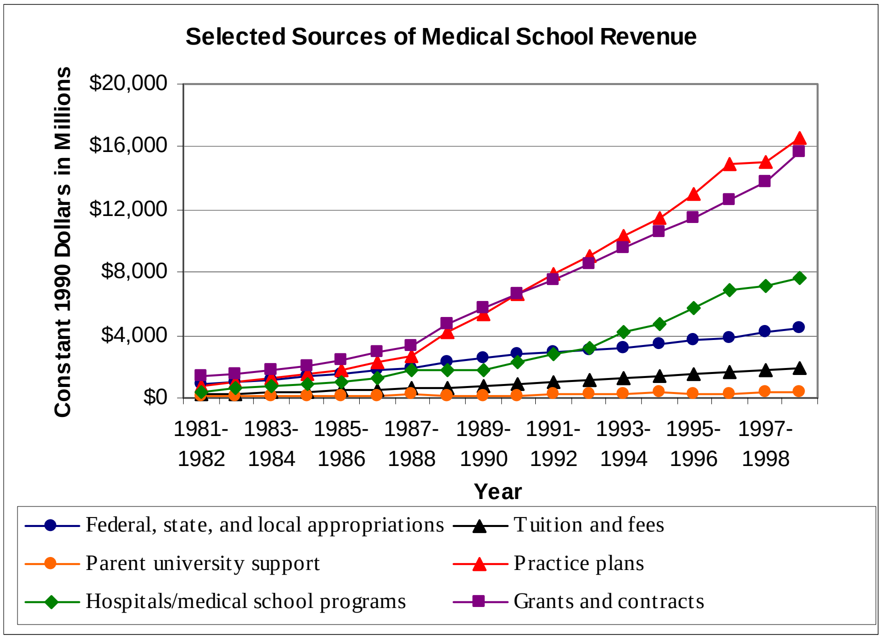

Figure 7-3

NIH support for medical schools between FYs 1981 and 2001 was converted to constant 1990 dollars using the BRDPI (see Figure 7-4); all dollar amounts are shown in thousands. Average total NIH funding for medical schools rose substantially in constant dollars during the period, from $8.2 million in 1981 to $102.2 million in 2001; increases were particularly sharp after 1995, reflecting a federal initiative to double the NIH budget. An exponential trend line fits these data with an R^2 value = 0.9875. As with total revenue for all schools (see Figure 7-2), there was very little difference between the R^2 value that resulted from drawing a linear trend line and the R^2 value that resulted from drawing an exponential trend line.

Because most NIH support was for research grants, these data (in constant dollars) closely tracked the total amount of NIH support between FYs 1981 and 2001 (see Figure 7-4). Research grant support also increased exponentially over time, as illustrated by the trend line.

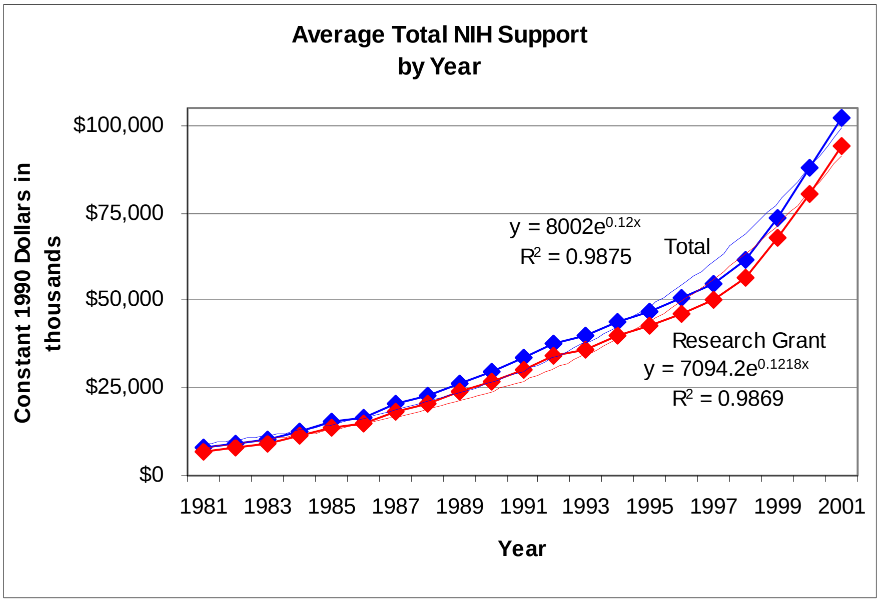

Figure 7-4

Institutional Characteristics—All Medical Schools

Enrollment. Enrollment of medical students was relatively stable for the twenty-year period, with total annual class size varying by only about 5%. During the period that was the focus of this study (academic years 1981-1982 through 2000-2001), minimum total enrollment occurred in 1989 (63,773 students) and maximum total enrollment occurred in 1994 (67,030 students). Rather than deviating irregularly each year from the average value, however, the data show rather regular peaks and troughs. The total number of students enrolled per year at all medical schools is shown in Figure 7-5.

Graduates. Because the number of students graduating closely followed the number of students enrolled, the number of medical school graduates was also relatively stable for the last twenty years, varying by only about 6.5%. During the period of this study, the minimum number of graduates occurred in 1989 (15,118 graduates) and the maximum number of graduates occurred in 1998 (16,140 graduates). Like enrollment, graduation data rose and fell with some regularity during the study period. The total number of graduates per year from all medical schools is shown in Figure 7-6.

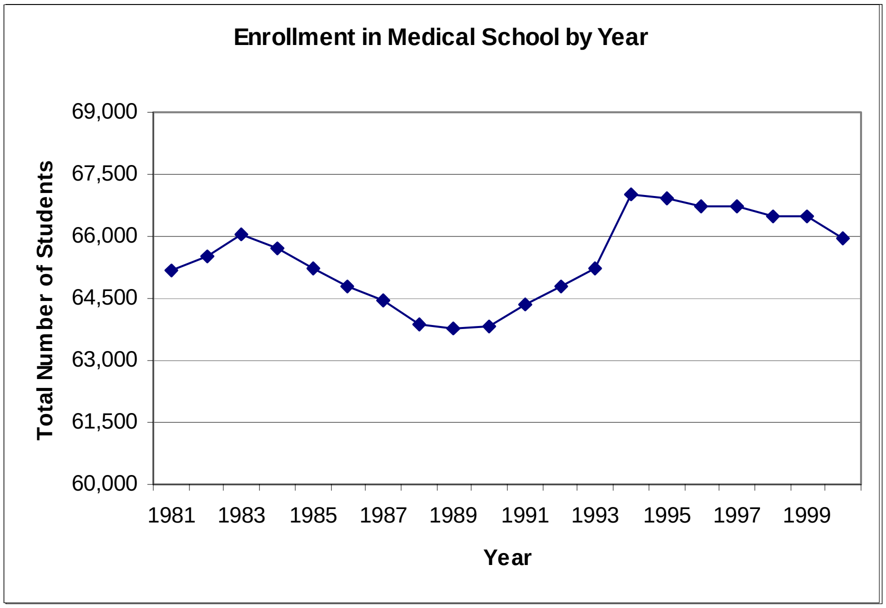

Figure 7-5

Faculty. Unlike the number of medical students, the number of faculty increased markedly after 1986. In 1986, medical schools had an average of 467.4 full time faculty members; by 2001, that number had increased to an average of 765.6 faculty members. The total number of

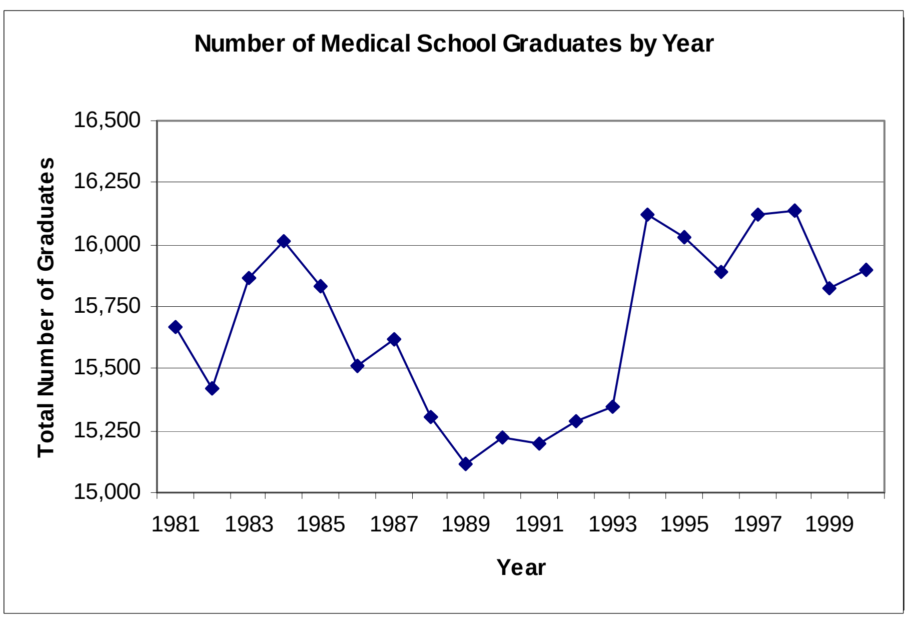

Figure 7-6

full-time medical school faculty per year is shown in Figure 7-7. An exponential trend line that resulted in an $R^2 = 0.9788$ was drawn to the data. As a result of the increase in faculty, the ratio of faculty members to medical students increased from 0.88 to 1 to 1.45 to 1 over the study period.

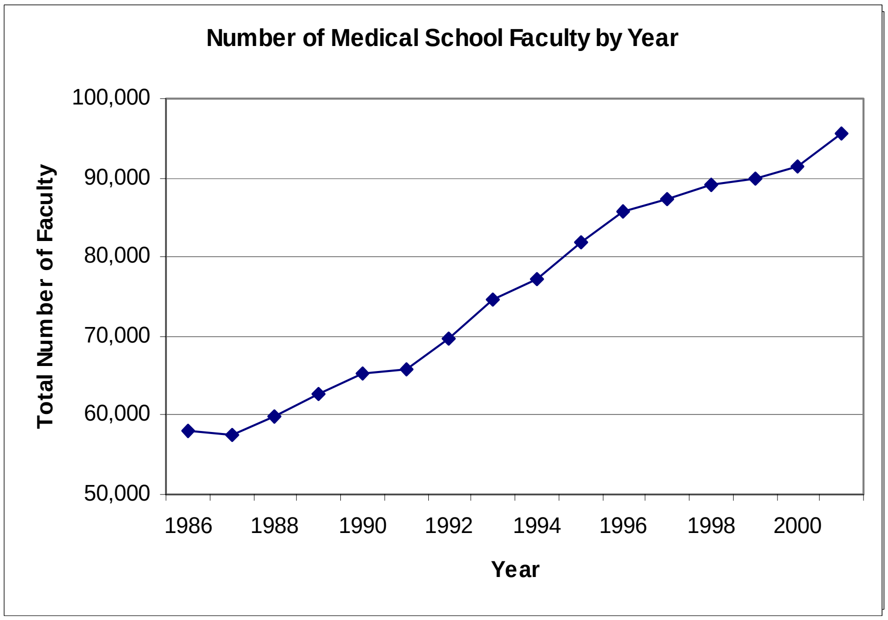

Figure 7-7

Clinical faculty outnumbered basic science faculty in every year of the study, and their numbers increased more rapidly. Between 1990 and 2001, the average number of basic science faculty per school increased from 99.8 to 120.2, while the average number of clinical faculty increased from 407.2 to 635.5. The total number of clinical and basic science faculty per year are shown in Figures 7-8 and 7-9, respectively. Because the number of clinical faculty grew more quickly than the number of basic science faculty, the ratio of clinical to basic science faculty increased from about 4 to 1 to over 5 to 1 during the 1990s.

Total teaching responsibility. During academic years 1981-1982 through 2000-2001, the total teaching load increased from less than 130,000 students to nearly 180,000 students per year (see Figure 7-10). An exponential trend line with an $R^2 = .9510$ provided a good fit to the data. During this period, the number of master's and doctoral students nearly doubled, from 16,555 in 1981-1982 to 34,423 in 2000-2001 (see Figure 7-11). An exponential trend line was fit to

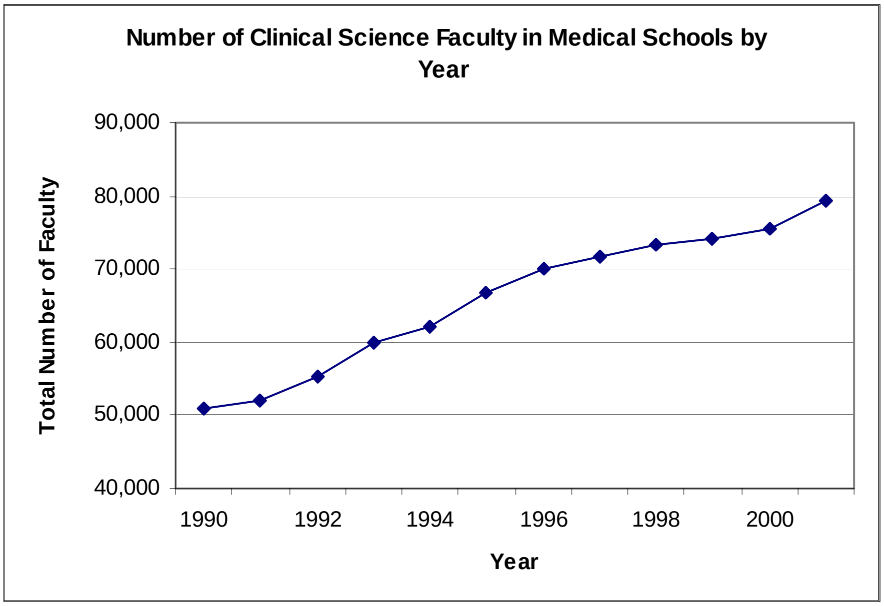

Figure 7-8

these data (R^2 = 0.9853). The number of residents and postdoctoral students increased about 60% over the same time period, but not as smoothly, as shown in Figure 7-12; there were 46,952 residents in academic year 1981-1982 and 75,791 in academic year 2000-2001. An exponential trend line with an R^2 = 0.8738 was fit to the data.

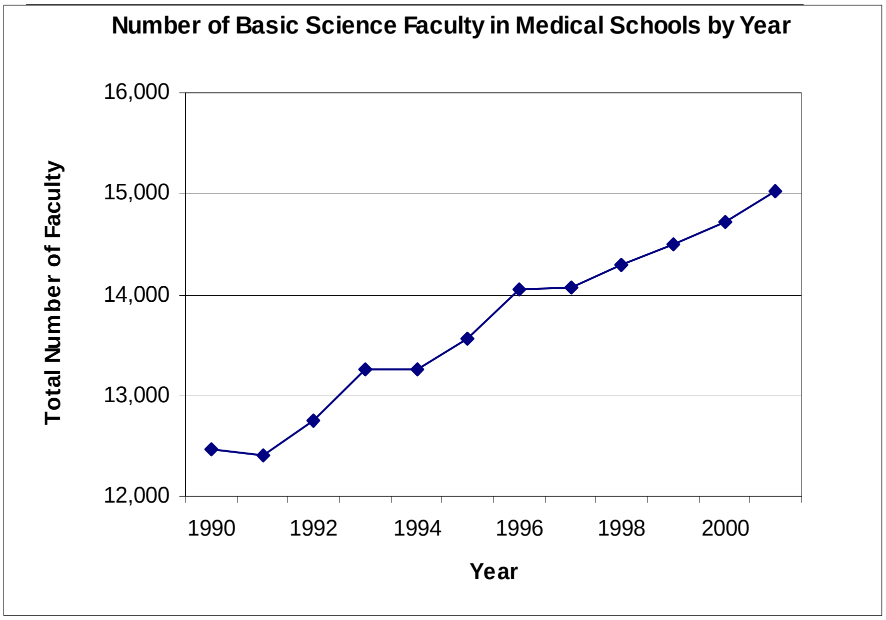

Figure 7-9

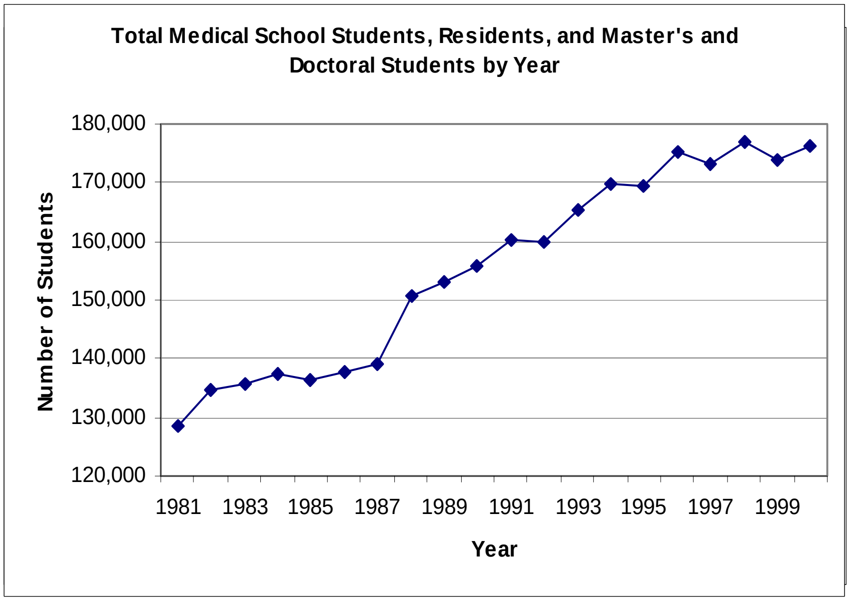

Figure 7-10

Between academic years 1981-1982 and 2000-2001, medical students comprised a decreasing percentage of the total teaching load of medical school faculty; the percentage of the total teaching load represented by medical students decreased from 50.6% to 37.4%. The percentage of the total teaching load represented by residents and postdoctoral students surpassed the

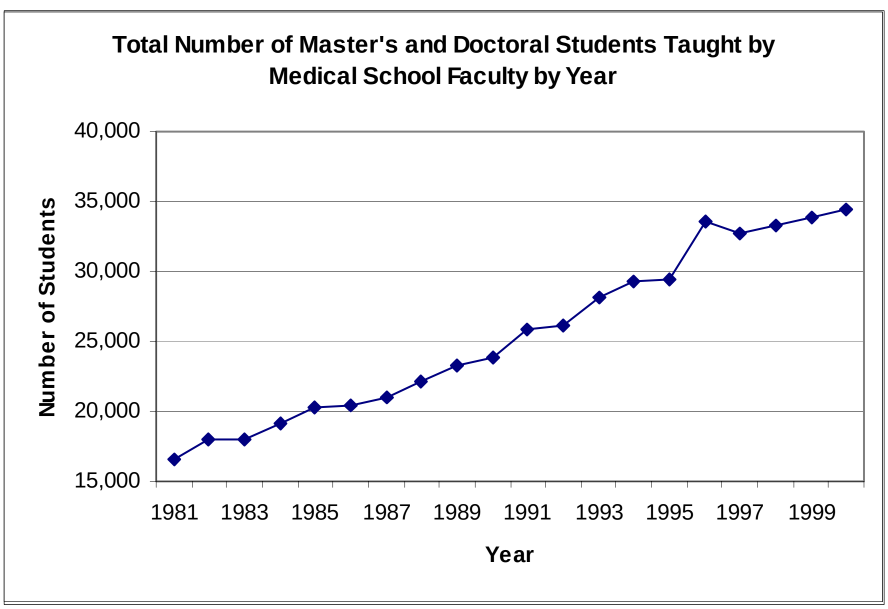

Figure 7-11

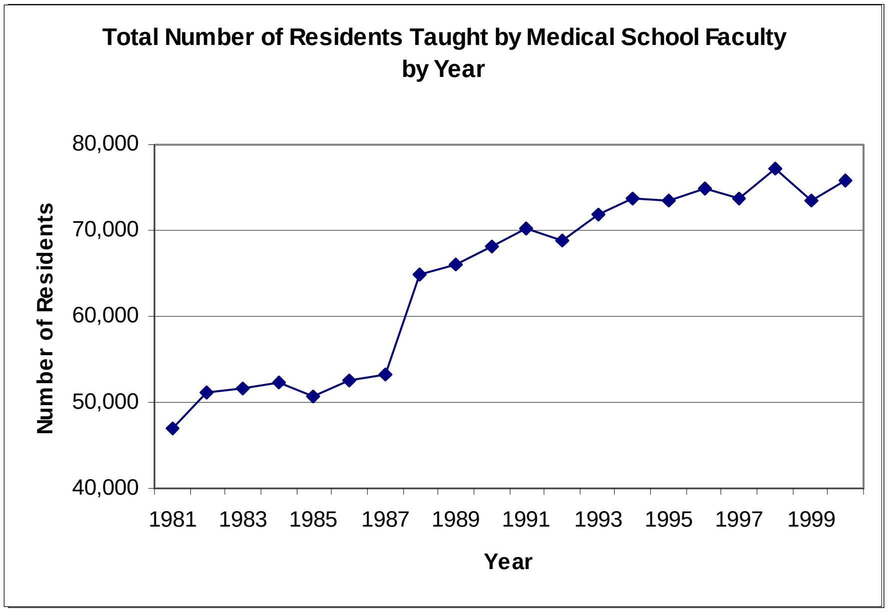

Figure 7-12

percentage of medical students in 1988-1989, increasing from 36.5% of the total in academic year 1981-1982 to 43.0% in 2000-2001. After academic year 1988-1989, the percentage of the total teaching load represented by residents and postdoctoral fellows stayed relatively steady at about 42% to 44%, while the proportion of medical students continued to drop and the proportion of master's and doctoral students increased from about 15% to 20%. These data are shown in Figure 7-13.

Medical school administrative staff. Between academic years 1981-1982 and 2000-2001, the average number of medical school administrative staff positions increased over one-third, from 13.7 to 18.8 per school (see Figure 7-14). An exponential trend line was fit to the data, with an $R^2 = 0.9865$.

Clinical facilities. The average number of clinical affiliations per school during the period of the study is shown in Figure 7-15. Although the percentage change in the number of clinical affiliations is relatively small, the average number generally decreased between 1983-1984 and 1993-1994, increased sharply between 1994-1995 and 1998-1999, and then began to decrease again.

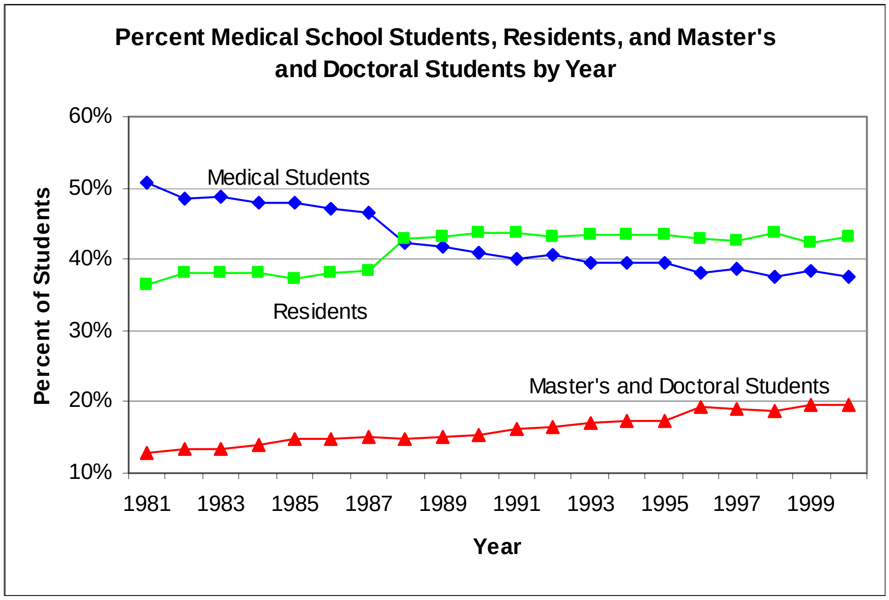

Figure 7-13

The percentage of clinical affiliations that were reported in any two successive years was quite high , ranging from about 90% to 96%. A general decrease in the percentage of affiliations that were the same as the prior year in the latter half of the 1990s reflected the addition of new

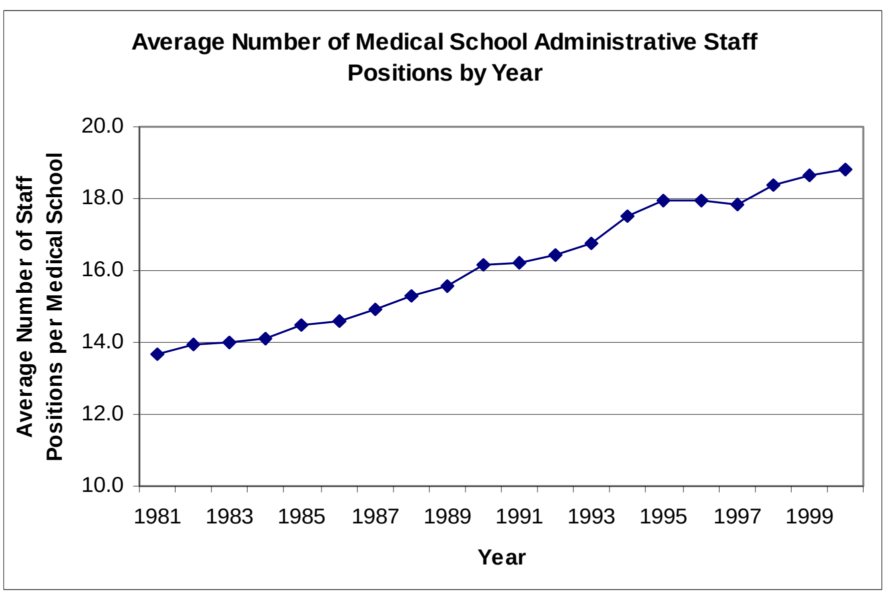

Figure 7-14

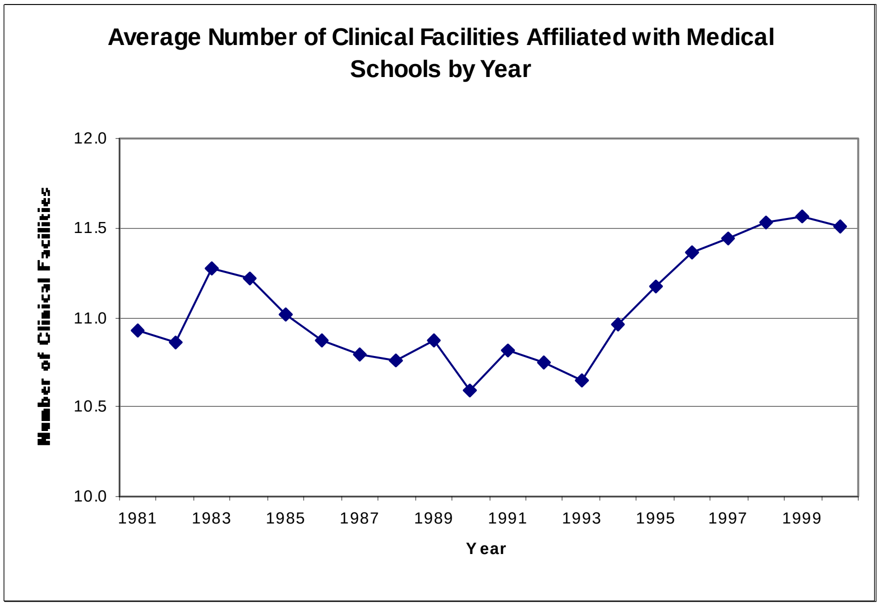

Figure 7-15

clinical affiliations during that time, as shown in Figure 7-16. The lowest value occurred in 1991-1992 and represented a decrease of 6 percentage points from the prior year.

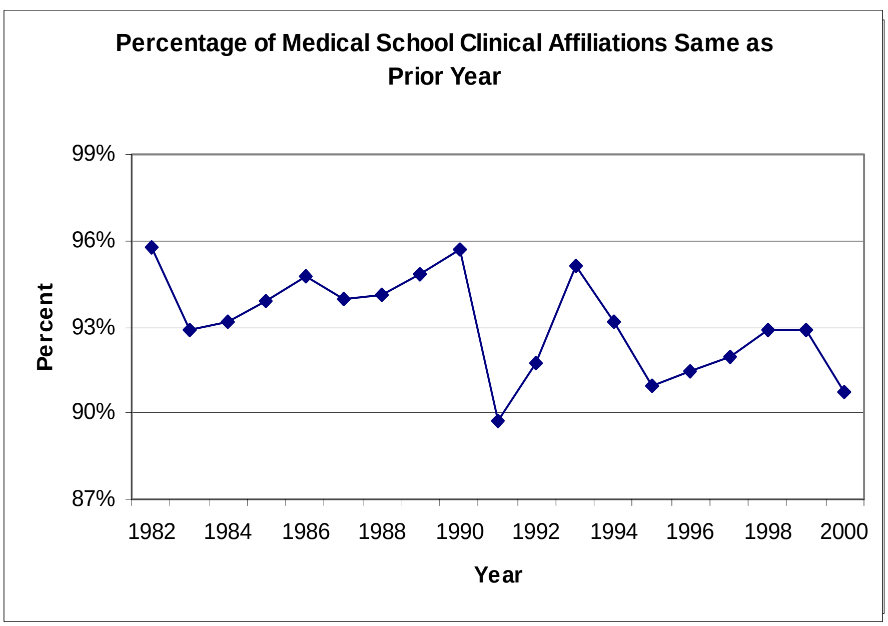

Figure 7-16

Financial Data—Medical Schools by Managed Care Market Group

Total revenue and revenue by source for individual medical schools were available for 1995 through 1998. Using the NIH BRDPI, revenue data were converted to constant 1998 dollars.

Total medical school revenue. Average total revenue per school increased between 1995 and 1998 in constant dollars for schools in each of the three managed care market groups. Schools in high (Group 3) managed care markets consistently received more revenue on average than schools in medium (Group 2) managed care markets; Group 2 schools consistently received more revenue on average than schools in low (Group 1) managed care markets (see Figure 7-17).

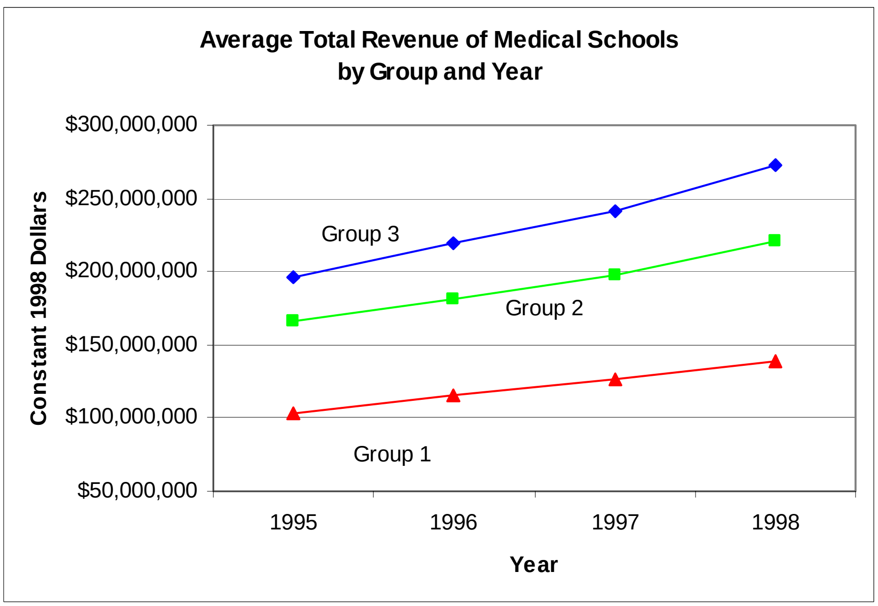

Figure 7-17

Schools in high managed care markets (Group 3) increased in constant dollars from $196.7 million in average total revenue to $273.3 million in 1998. In 1995, schools in medium managed care markets (Group 2) averaged $166.0 million, increasing to $221.1 million in constant dollars in 1998. Schools in low (Group 1) managed care groups received average total revenue of $103.6 million in 1995, increasing to $138.6 million in 1998. In each year, schools in the low managed care market group received about half the average total revenue that schools in the high managed care market group received.

Average total revenue for schools in medium and low managed care markets increased 33.2% and 33.8% in constant dollars, respectively, between 1995 and 1998. Average total revenue for schools in high managed care markets increased at a greater rate in constant dollars (38.9%) during the same time period. The trend data for schools in high (Group 3) and medium (Group 2) managed care markets were described by exponential trend lines with R^2 = 0.9962 and 0.9971, respectively. Data for low (Group 1) managed care market schools were best described by a linear trend line (R^2 = 0.9996).

Federal support. Federal support was the largest source of medical school revenue for each of the groups of schools during the study period. Schools in the high (Group 3) managed care market group consistently received more revenue from the federal government throughout the period than did schools in medium (Group 2) or low (Group 1) managed care market groups (see Figure 7-18).

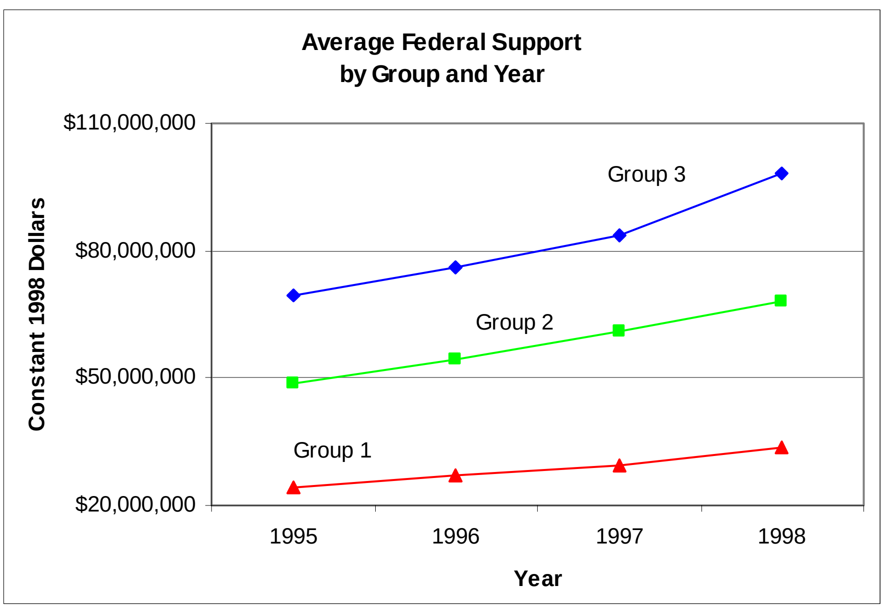

Figure 7-18

Between 1995 and 1998, average federal support for schools in high managed care markets increased exponentially from $69.5 million to $98.1 million (41.0%) in constant 1998 dollars (trend line $R^2 = 0.9784$).

Schools in medium (Group 2) managed care markets received less support from federal sources than schools in high managed care markets. Between 1995 and 1998, average federal support for schools in medium managed care markets increased from $48.8 million to $68.1 million (39.5%) in constant 1998 dollars. A linear trend line ($R^2 = 0.9968$) best described the increase in federal support for these schools.

Schools in low (Group 1) managed care markets received the lowest average amount of federal support between 1995 and 1998, increasing 37.4% from $24.3 million to $33.4 million. An exponential trend line described this increase, with an R^2 value of 0.9939.

Hospital fee revenue. The pattern of hospital fee revenue increased in constant dollars during the period 1995 through 1998, varying among the three groups of schools, as shown in Figure 7-19.

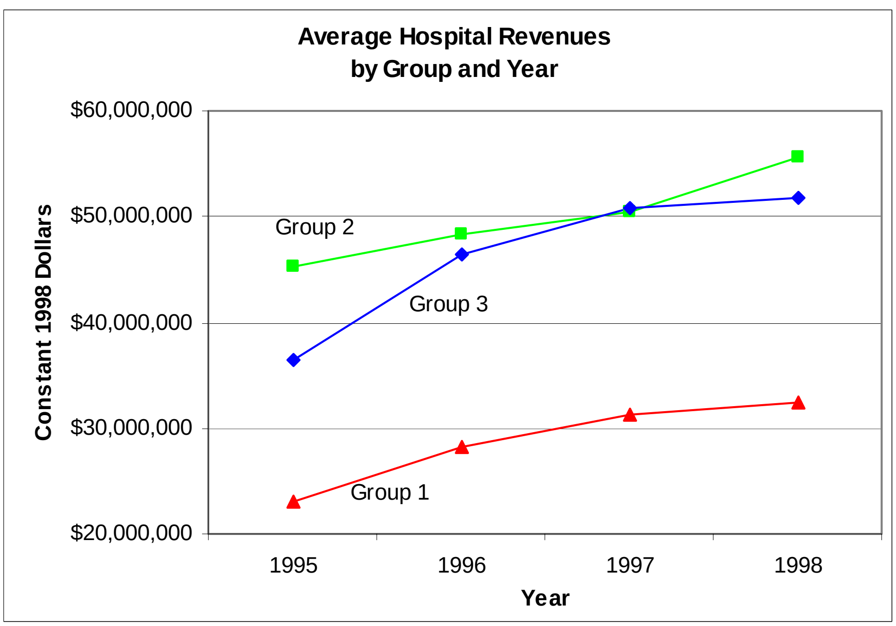

Figure 7-19

Schools in the medium (Group 2) managed care market group had the highest average hospital fee revenue during this period. Revenues from hospital fees increased 23.0%, from $45.2 million to $55.6 million in constant 1998 dollars during the period. An exponential trend line provided a fit with an R^2 = 0.9769.

Average hospital fee revenue in constant dollars for schools in the high (Group 3) managed care market group increased between 1995 and 1997 (from $36.4 million to $50.7 million) to an amount just about equal that of Group 2 schools, which received $50.5 million in hospital fee revenue. This increase nearly leveled off in 1998 at $51.7 million, for a total increase during the four-year period of 42%. This increase was described by a logarithmic function with an R^2 = 0.9669.

Schools in the low (Group 1) managed care market group had lower average hospital fee revenues during this period ($23.0 million in 1995, increasing 40.4% to $32.3 million in 1998), but the increase in revenues, like those at schools in high managed care markets, rose more sharply during the early portion of the period and then leveled off. Like Group 3 schools, average hospital fee revenues at schools in low managed care market areas were described by a logarithmic trend line (R^2 = 0.9908).

State appropriations. Revenues from state appropriations were generally small or nonexistent for private medical schools. Schools in low (Group 1) managed care markets, a group in which public medical schools outnumbered private schools 30 to 10, had the highest average amount of revenue from state appropriations per year, as shown in Figure 7-20. In 1995, state appropriations for these schools averaged $26.4 million in 1998 constant dollars. By 1998, average state appropriations had increased exponentially to $32.2 million, or 22.0% during the four-year period (trend line R^2 = 0.9621).

Average state appropriations to schools in medium (Group 2) managed care markets increased linearly from $20.3 million to $23.8 million, or 17.2% in constant dollars between 1995 and 1998 (trend line R^2 = 0.9963). There were 23 public schools and 18 private schools in this group

Schools in the high (Group 3) managed care markets received the lowest average amount of state appropriations. Average state appropriations among the 21 public schools and 23 private schools were $18.9 million in 1995, increasing exponentially to $22.7 million (trend line $R^2 = 0.9148$).

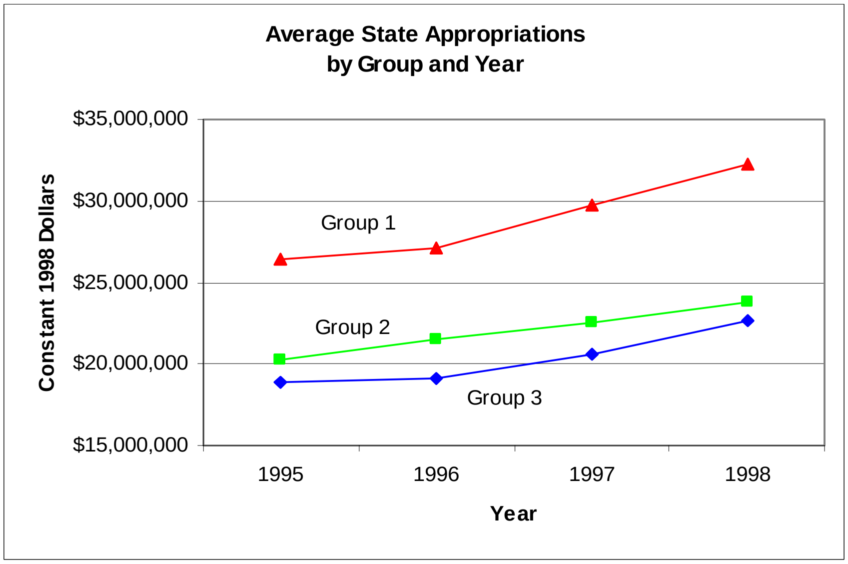

Figure 7-20

Tuition and fee revenue. Schools in high (Group 3) managed care markets received the highest average tuition and fee revenue, as shown in Figure 7-21: $11.4 million in 1995 increasing 21.9% in constant dollars to $13.9 million in 1998 (logarithmic trend line $R^2 = 0.9830$).

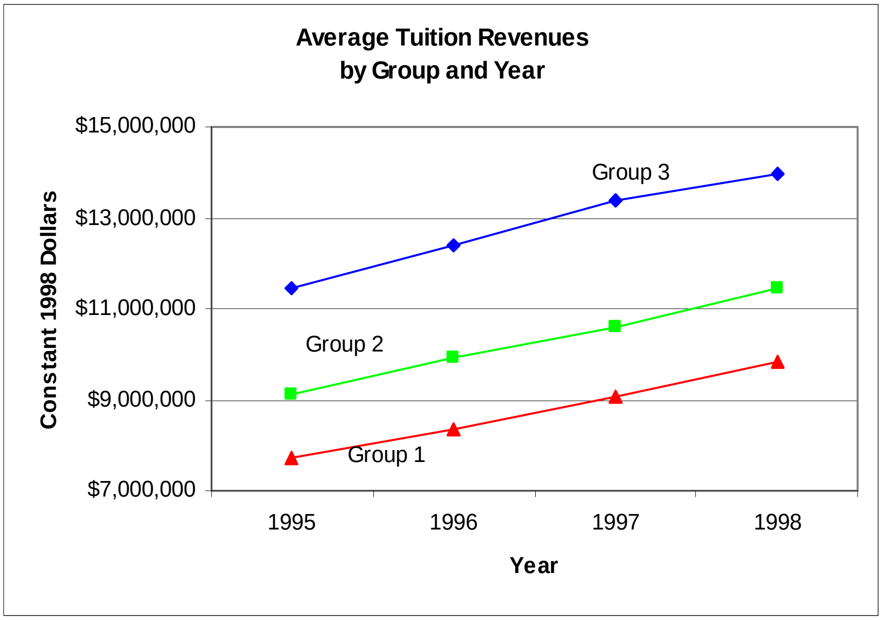

Figure 7-21

Schools in medium (Group 2) managed care markets received an intermediate amount of revenue from tuition and fees. Revenue from this source increased exponentially over the study period from \$9.1 million to \$11.4 million in constant dollars (25.3%; trend line $R^2 = 0.9985$).

Schools in low (Group 1) managed care markets received the lowest average amount of revenue from tuition and fees. Revenue from this source increased exponentially from \$7.7 million to \$9.8 million between 1995 and 1998 in constant dollars (27.2%; trend line $R^2 = 0.9997$).

Grants and contracts. These data were reported as expenditures rather than revenues (see Figure 7-22). Schools in high (Group 3) managed care markets expended the highest average dollars from grants and contracts. In 1995, expenditures averaged \$59.8 million, increasing 45.1% in constant dollars to \$86.8 million. An exponential trend line was fit to the data, resulting in an $R^2 = 0.9766$.

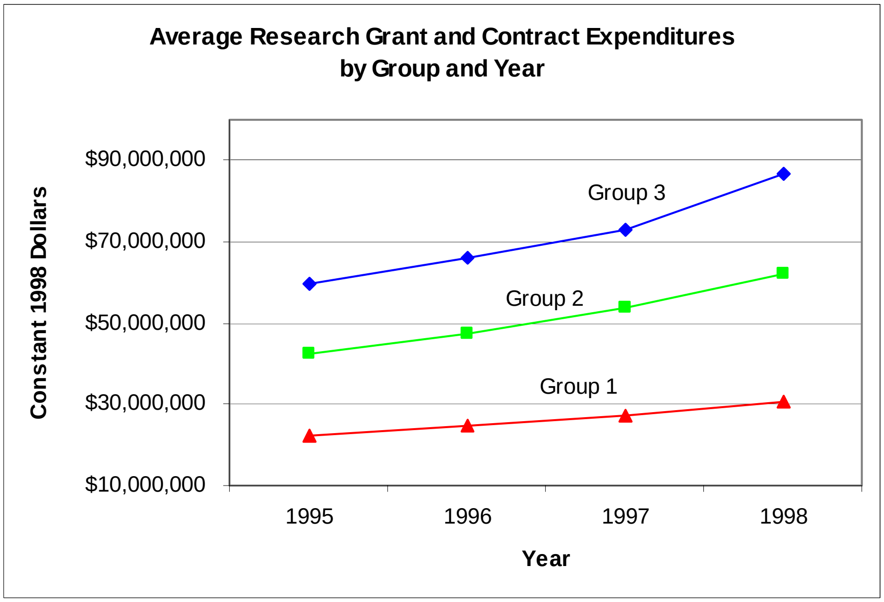

Figure 7-22

Schools in medium (Group 2) managed care markets expended a smaller average amount from grants and contracts. These expenditures increased exponentially over the four-year period from \$42.6 million to \$62.3 million in constant dollars. This increase of 46.2% was the largest increase of the three groups of schools. An exponential trend line fit the data with an R^2 value of 0.9949.

Schools in low (Group 1) managed care markets expended the lowest average amount from grants and contracts. These expenditures increased exponentially from $22.1 million to $30.8 million in constant dollars between 1995 and 1998 (39.4%; trend line $R^2 = 0.9966$).

Total NIH support. Schools in the high (Group 3) managed care market group consistently received more funding from the NIH between FYs 1981 and 2001 than did schools in medium (Group 2) or low (Group 1) managed care market groups, as shown in Figure 7-23.

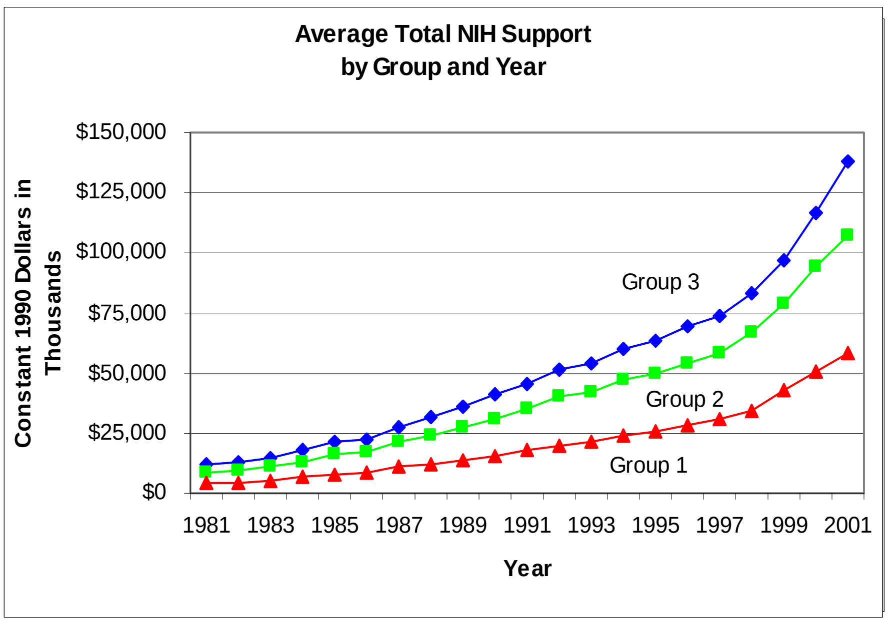

Figure 7-23

Throughout the period, average NIH funding for schools in high managed care markets increased exponentially from $11.6 million to $137.7 million in constant 1990 dollars (trend line $R^2 = 0.9873$).

Schools in medium (Group 2) managed care markets received less average total funding from NIH than schools in high managed care markets. Between FYs 1981 and 2001, average NIH support for schools in medium managed care markets increased from $8.6 million to $106.8

million in constant 1990 dollars. An exponential trend line (R^2 = 0.9878) described the increase in NIH support for these schools.

Schools in low (Group 1) managed care markets received the lowest average amount of total NIH funding between FYs 1981 and 2001, from $4.3 million to $58.5 million. An exponential trend line described this increase (R^2 = 0.9889).

NIH support for research grants. In FY 1981, funding for research grants comprised approximately 85% to 88% of the total funding provided by NIH to medical schools. By FY 2001, the proportion of total funding that supported research had increased to about 92%.

Average NIH research funding provided to schools in high (Group 3) managed care markets was greater in every FY between 1981 and 2001 than average funding provided to schools in either medium (Group 2) or low (Group 1) managed care markets, as shown in Figure 7-24.

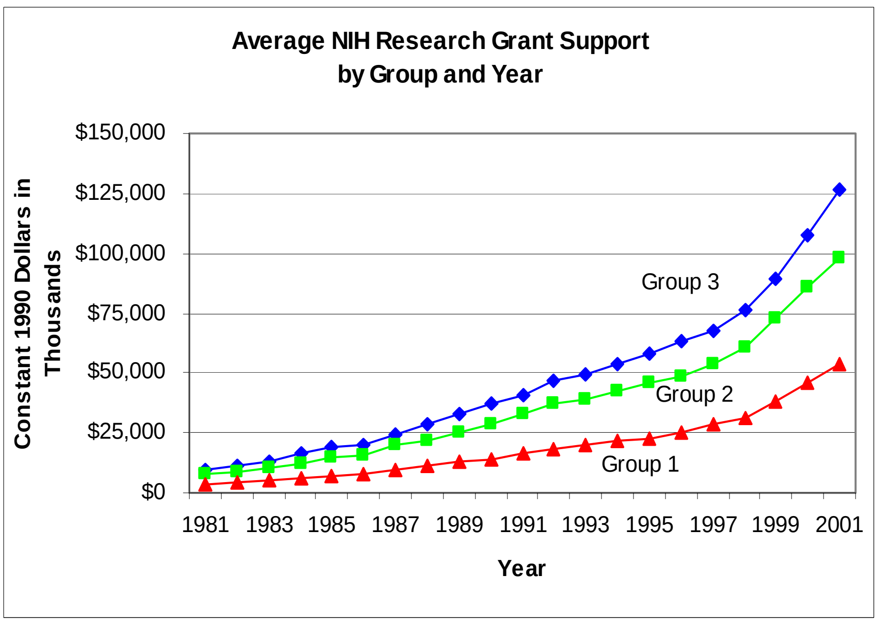

Figure 7-24

Between 1981 and 2001, average NIH research funding for schools in high managed care markets increased exponentially from $10.0 million to $126.6 million in constant 1990 dollars. This represented a percentage increase of 1,170.6% in constant dollars (trend line R^2 = 0.9869).

Schools in medium (Group 2) managed care markets received less average research grant funding from NIH than schools in high managed care markets, although the growth of funding was somewhat greater. Between 1981 and 2001, average NIH research support for schools in medium managed care markets increased from $7.5 million to $98.1 million, or 1,209.4%, in constant 1990 dollars. An exponential trend line (R^2 = 0.9864) described the increase in NIH research support for these schools.

Schools in low (Group 1) managed care markets received the lowest average amount of NIH research grant funding each year between FYs 1981 and 2001. The percentage increase, however, was greater than for schools in high (Group 3) or medium (Group 2) managed care groups—1,317.0% ($3.8 million to $53.6 million in constant 1990 dollars) between FYs 1981 and 2001. An exponential trend line described this increase, resulting in an R^2 = 0.9891.

Institutional Characteristics—Medical Schools by Managed Care Market Group

Enrollment. The average medical student enrollment in medical schools in each managed care market penetration group and year is shown in Figure 7-25. Most of the increase in average enrollment in the Group 3 schools in academic year 1994-1995 was due to the addition of data for MCP Hahnemann School of Medicine. Data for the two medical schools that consolidated to become MCP Hahnemann were not included for the earlier years because there was no reason to assume that the sum of the enrollment data for the two schools would have been appropriate to use. However between academic years 1981-1982 and 1993-1994, the average annual combined enrollment of the Medical College of Pennsylvania and the Hahnemann University School of Medicine ranged from 1,132 to 1,210. In academic year 1993-1994, the year before consolidation, the combined enrollment was 1,207. These numbers suggested that prior to academic year 1994-1995, average annual enrollment in schools in high (Group 3) and medium (Group 2) managed care markets was very similar. In academic year 1981-1982, schools in medium (Group 2) managed care markets had an average enrollment of 540.9 students per school. Schools in high (Group 3) managed care markets averaged 528.9 students per school. In

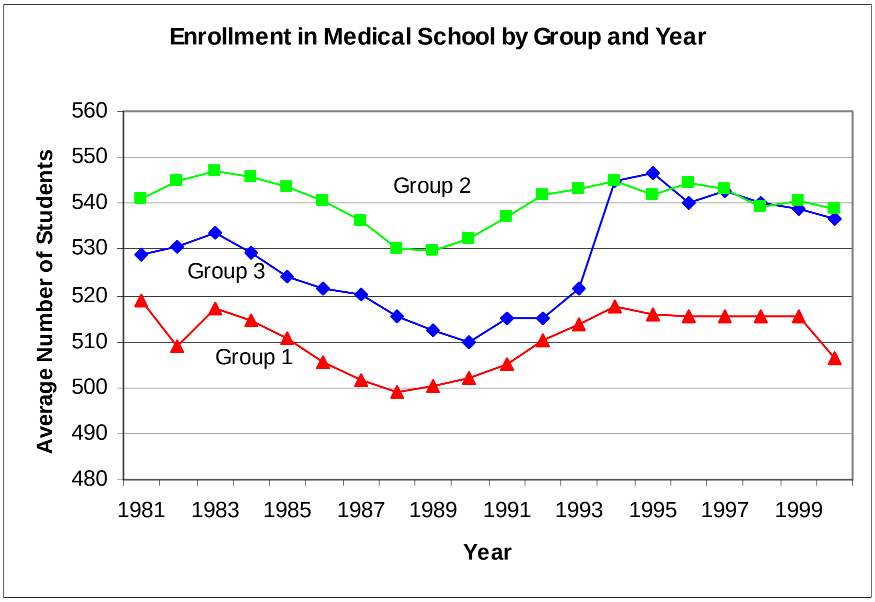

Figure 7-25

academic year 2000-2001 (which included data for MCP Hahnemann), schools in medium and high managed care markets averaged 538.8 and 536.5 students, respectively, as shown in Figure 7-25.

For the entire period, academic years 1981-1982 through 2000-2001, schools in low (Group 1) managed care markets had lower average enrollment than schools in the other two groups. In academic year 1981-1982, schools in low managed care markets averaged 519.0 students; in academic year 2000-2001, these schools averaged 506.3 students. The annual increases and decreases in average enrollment were similar for all three groups of schools.

Graduates. The average number of graduates by managed care market penetration group and year is shown in Figure 7-26. Increases and decreases in annual enrollment were echoed 4 to 5 years later in the graduation figures, indicating that most students were completing their programs according to the standard curriculum. The average number of graduates from schools in high (Group 3) managed care markets increased in academic year 1994-1995 for the same reason that average enrollment increased in that year—the addition of MCP Hahnemann to the dataset. In each year after academic year 1987-1988, schools in low (Group 1) managed care markets had the lowest average number of graduates.

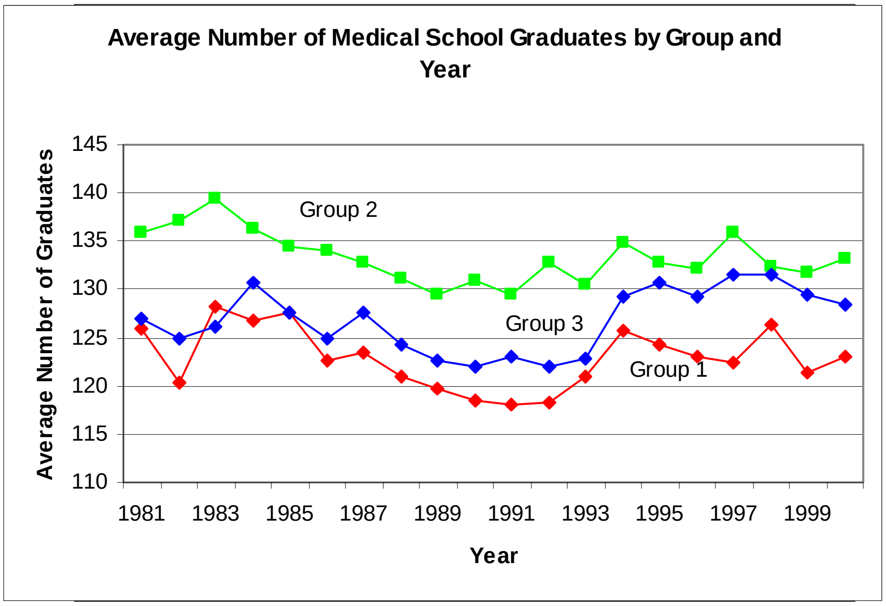

Figure 7-26

In academic year 1981-1982, schools in medium (Group 2) managed care markets had an average of 135.8 graduates per school. Schools in high (Group 3) managed care markets averaged 126.9 graduates per school. In academic year 2000-2001 (which included data for MCP Hahnemann), schools in medium and high managed care markets averaged 133.2 and 128.4 graduates, respectively. Schools in low (Group 1) managed care markets averaged 126.9 graduates per school in academic year 1981-1982 and 123.1 graduates in academic year 2000-2001.

Graduates practicing generalist medicine. In 1999, the AAMC reported data on the percentage of 1991, 1992, and 1993 medical school graduates that had completed an approved, three-year residency training program in pediatrics, family practice, or internal medicine and who had not participated in a subspecialty or non-generalist program through the 1996-1997 residency year. It appeared that in 1998, the AAMC again published the data using the same criteria. In 1997 and 1996, data were reported on 1990, 1991, and 1992 graduates and on 1989, 1990, and 1991 graduates, respectively.

In each of the years 1996, 1997, and 1998, the percentage of graduates practicing generalist medicine in subsequent years increased, as shown in Figure 7-27.

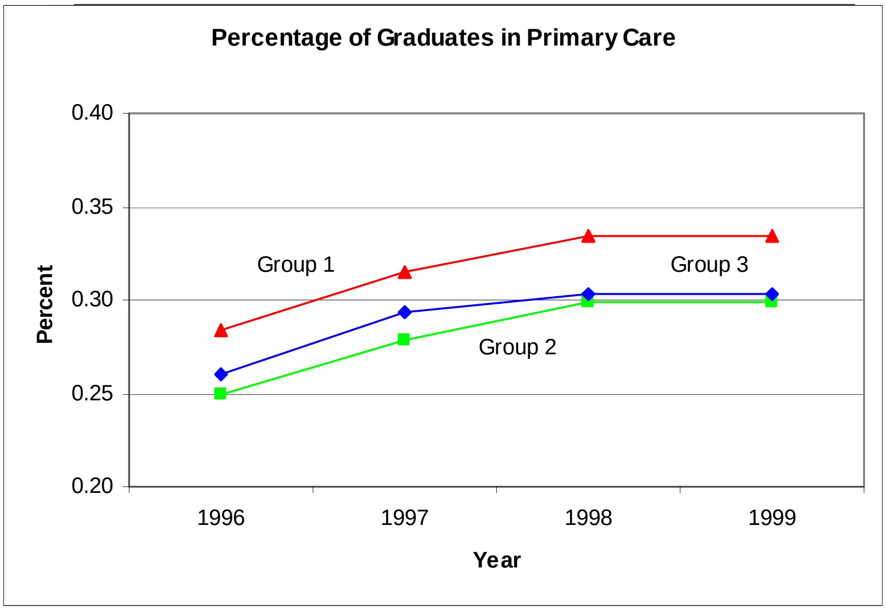

Figure 7-27

In 1996, the percentage of graduates from schools in high (Group 3), medium (Group 2), and low (Group 1) managed care markets who were presumed to be practicing generalist medicine was 26.1%, 25.0%, and 28.4%, respectively. The percentage of generalists produced by schools in low managed care markets increased to 31.5% in 1997 and 33.5% in 1998. The percentage of generalists produced by schools in medium managed care markets was lower than the percentage who graduated from schools in low managed care markets, but the increase over the three-year period was very similar.

Between 1996 and 1997, the percentage of graduates from schools in low and medium managed care markets who were later practicing generalist medicine increased 3.1 and 2.9 percentage points, respectively. Between 1997 and 1998, both groups again increased 2.0 percentage points. The percentage of graduates from schools in high managed care markets who were later practicing generalist medicine increased 3.3 percentage points between 1996 and 1997, which was a slightly greater increase than was observed in the other two groups of schools. Between 1997 and 1998, however, the percentage of graduates from schools in high managed care markets who were later practicing generalist medicine increased by only 1.0 percentage point.

Faculty. The average number of faculty per school increased over the study period for schools in all three managed care market groups, as shown in Figure 7-28.

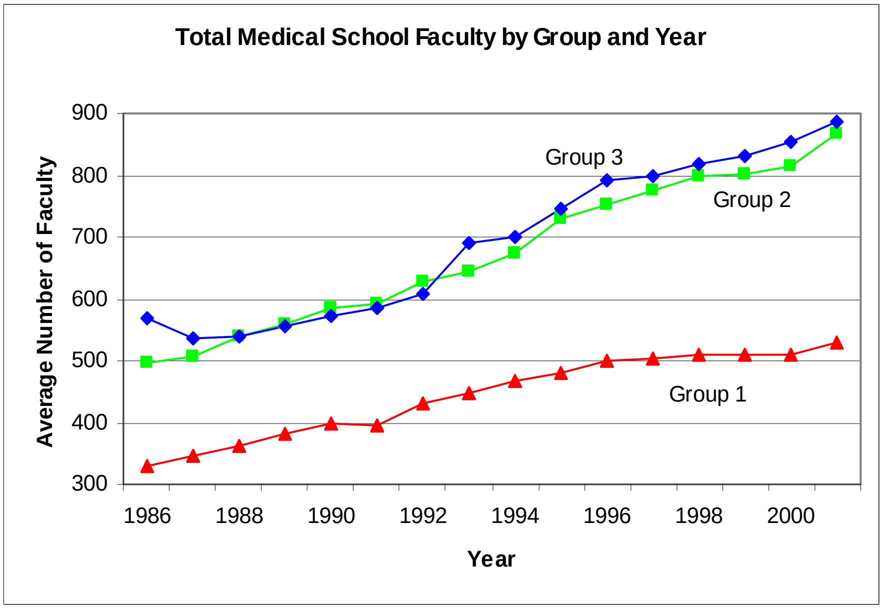

Figure 7-28

Schools in medium (Group 2) managed care markets showed the largest percentage increase between 1986 and 2001 (74.7%), with the average number of faculty growing from 495.6 in 1986 to 865.8 in 2001. The ratio of faculty members to medical students increased from 0.92 to 1 in 1986 to 1.61 to 1 in 2001.

Average faculty size in schools in high (Group 3) managed care markets increased from 568.8 in 1986 to 886.5 in 2001, a 55.9% increase. The ratio of faculty members to medical students increased from 1.08 to 1 in 1986 to 1.65 to 1 in 2001.

Schools in low managed care markets had the smallest average number of faculty during the study period. The average number of faculty in these schools grew from 329.7 in 1986 to 530.0 in 2001, a 60.8% increase. The ratio of faculty members to medical students increased from 0.64 to 1 to 1.05 to 1 in 2001. The average number of faculty members in schools in low managed care markets in 2001 was about equal to the average size of faculties in schools in medium and high managed care markets in 1986. In addition, the average number of faculty in schools in the low (Group 1) managed care markets was flat between 1996 and 2000, while the average number of faculty in schools in high (Group 3) and medium (Group 2) managed care markets continued to increase.

All schools had more faculty members in clinical departments than in basic science departments throughout the study period. Schools in high (Group 3) and medium (Group 2) managed care markets had a similar or larger average number of clinical faculty than schools in low (Group 1) managed care markets. The average number of clinical faculty in schools in high and medium managed care markets also increased at a faster rate than in schools in low managed care markets, as shown in Figure 7-29.

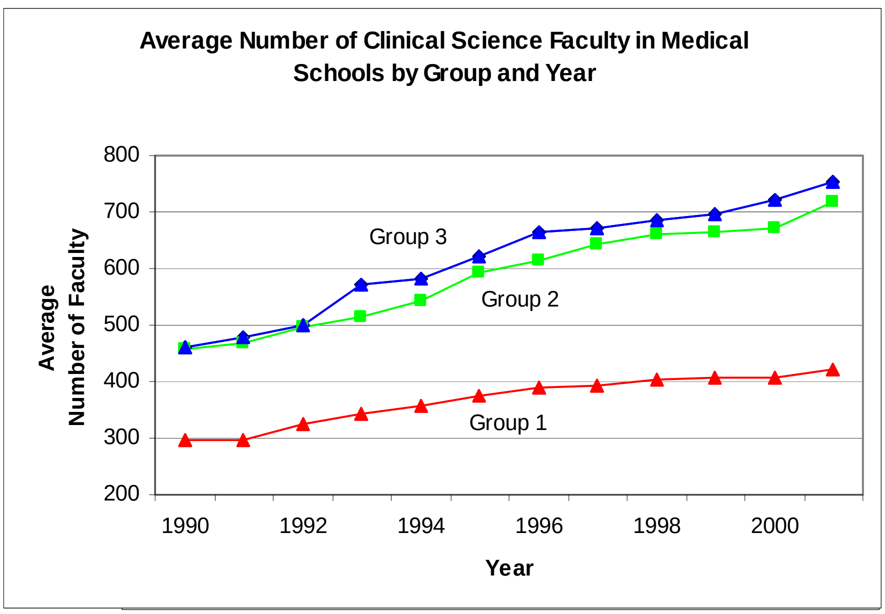

Figure 7-29

In 1990, the average number of clinical faculty in high (Group3) and medium (Group 2) managed care markets was nearly identical (460.0 and 458.5 faculty members, respectively). The average size of clinical faculty in schools in high managed care markets grew at a slightly faster rate (63.5%) than in schools in medium managed care markets (56.7%). As a result, schools in high and medium managed care markets averaged 752.0 and 718.6 clinical faculty members per school, respectively, in 2001. The average size of the clinical faculty in schools in medium managed care markets was about constant between 1998 and 2000.

Schools in low (Group 1) managed care markets averaged 296.4 clinical faculty members in 1990, and increased 42.4% to an average of 422.2 clinical faculty members in 2001. While the average number of clinical faculty increased in schools in low managed care markets between 1991 and 1996, it was about constant between 1997 and 2000.

Although schools in high managed care markets had slightly larger clinical faculties on average, schools in medium managed care markets had larger basic science faculties, as shown in Figure 7-30.

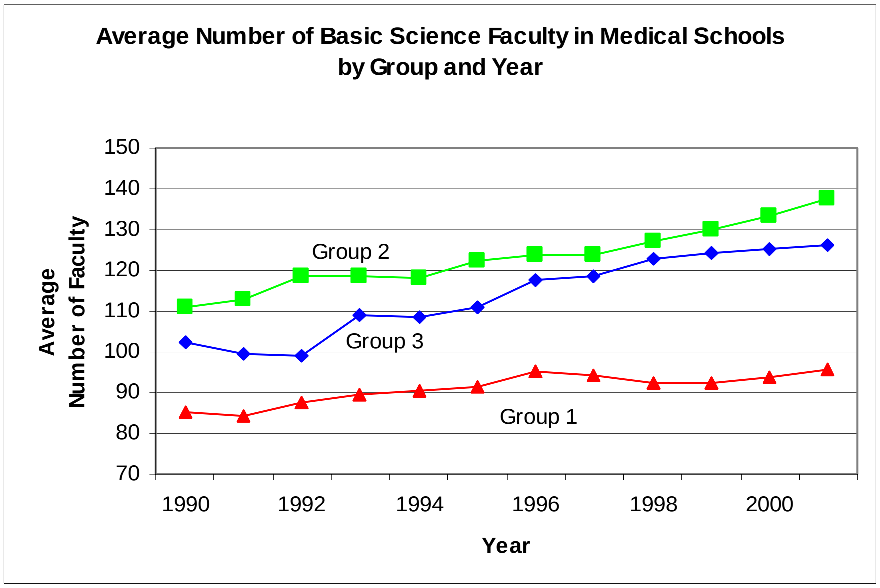

Figure 7-30

Schools in medium (Group 2) managed care markets averaged 111.1 basic science faculty members in 1990, and increased 24.0% to an average of 137.8 faculty members in 2001. The average size of basic science faculty in Group 2 schools increased steadily and rather sharply between 1997 and 2001. The average size of basic science faculties in high (Group 3) managed care markets increased at about the same rate (23.4%), from 102.4 basic science faculty members in 1990 to 126.4 faculty members in 2001. The average size of basic science faculties in low (Group 1) managed care markets grew at about half the rate of faculties in the other two groups of schools, increasing 12.1% from an average of 85.2 basic science faculty members per school in 1990 to 95.6 faculty members in 2001. The average size of basic science faculties decreased in these schools between 1996 and 1999.

Clinical and basic science faculty data were also examined by calculating the ratio of clinical to basic science faculty at each medical school. For all medical schools, clinical faculty outnumbered basic science faculty during the study period by an average of 4 or 5 to 1. Changes in the number of faculty in either group as a proportion of the total number of faculty may indicate changing emphasis on the activities more likely to be undertaken by clinical or basic science faculty. The ratio of clinical to basic science faculty differed by managed care market penetration group, but increased during the study period for all three groups. Schools in the low (Group 1) managed care market penetration group had a clinical to basic science faculty ratio of about 3.5 to 1 in 1990, increasing 27.1% to about 4.5 to 1 in 2001. Schools in the medium (Group 2) managed care market penetration group had an intermediate clinical to basic science faculty ratio, increasing 26.4% from about 4 to 1 in 1990 to over 5 to 1 in 2001. Schools in the high (Group 3) managed care market penetration group had the highest ratio of clinical to basic science faculty in all years, as shown in Figure 7-31, increasing 32.5% between 1990 and 2001 from a ratio of 4.5 to 1 to a ratio of 6 to 1.

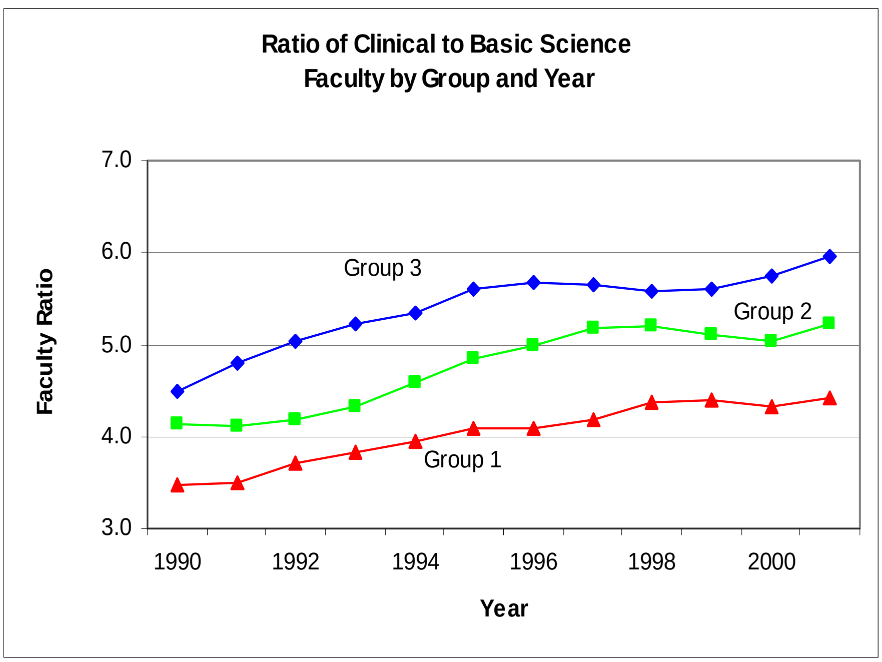

Figure 7-31

Total teaching responsibility. Between academic years 1981-1982 and 2000-2001, faculty in medical schools in high (Group 3) and medium (Group 2) managed care markets consistently had greater average teaching responsibility (teaching load) than faculty in low (Group 1) managed care markets (Figure 7-32). Average teaching loads for all groups increased over the study period, but the teaching loads at schools in high and medium managed care markets increased at a faster rate, particularly after academic year 1987-1988.

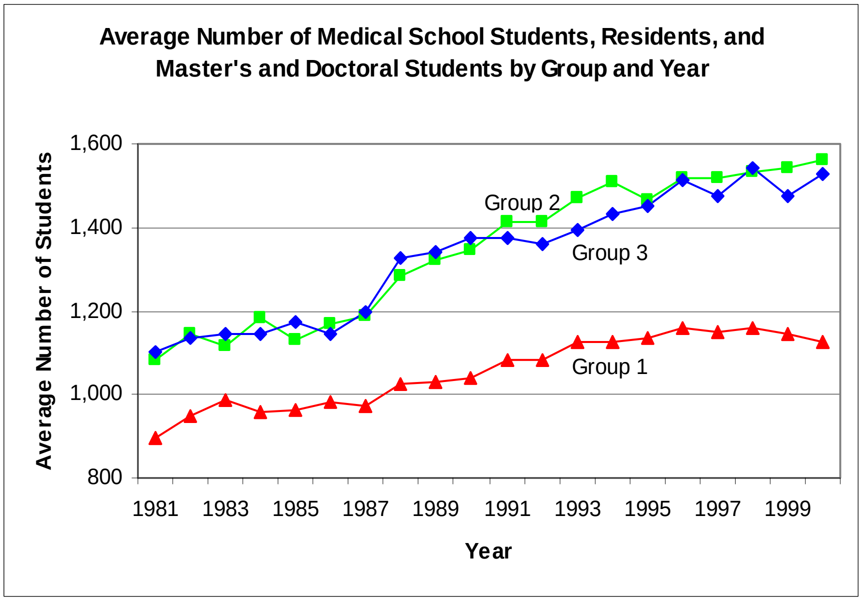

Figure 7-32

In academic year 1981-1982, schools in high (Group 3) managed care markets reported the largest teaching load, with an average of 1,104.9 students per school. Schools in medium (Group 2) managed care markets averaged 1,083.5 students per school, and schools in low (Group 3) managed care markets averaged 893.8 students per school in academic year 1981-1982. By academic year 2000-2001, schools in medium (Group 2) managed care markets had the highest average teaching load, increasing 44.0% to an average of 1,559.7 students. Schools in high (Group 3) managed care markets had an average of 1,528.0 students per school (a 38.3% increase), and schools in low (Group 1) managed care markets continued to have the lowest average teaching load, increasing 25.8% to 1,124.5 students.

Detailed data on the types of students that comprised total teaching load at each school provided an opportunity to examine the ratio of three types of students—residents, master's and doctoral students, and medical students—in schools in each of the three managed care markets. Between academic years 1981-1982 and 1987-1988, the data also included an "Other" category that was not well defined except to note that it did not include continuing education students. Beginning in academic year 1988-1989, when the Other category was no longer reported, the number of residents noticeably increased.

In academic year 1981-1982, the percentage of residents at schools in high (Group 3) managed care markets was 40.5%, as shown in Figure 7-33.

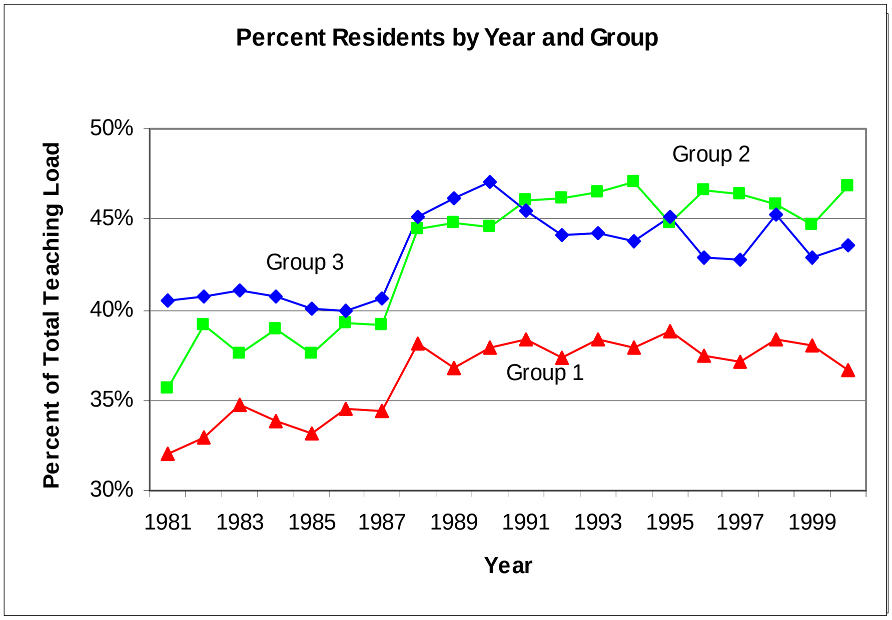

Figure 7-33

At schools in medium (Group 2) managed care markets, the percentage was intermediate (35.7%), and at schools in low (Group 1) managed care markets, the percentage was lowest (32.0%). By academic year 2000-2001, schools in medium managed care markets had the highest percentage of residents (46.8%—an increase of over 11 percentage points). The percentage of residents at schools in high managed care markets was slightly lower than the percentage at schools in medium managed care markets (43.6%), and the percentage at schools in low managed care markets was lowest (36.7%).

Master's and doctoral students comprised the smallest percentage of the total teaching load in all schools, as shown in Figure 7-34.

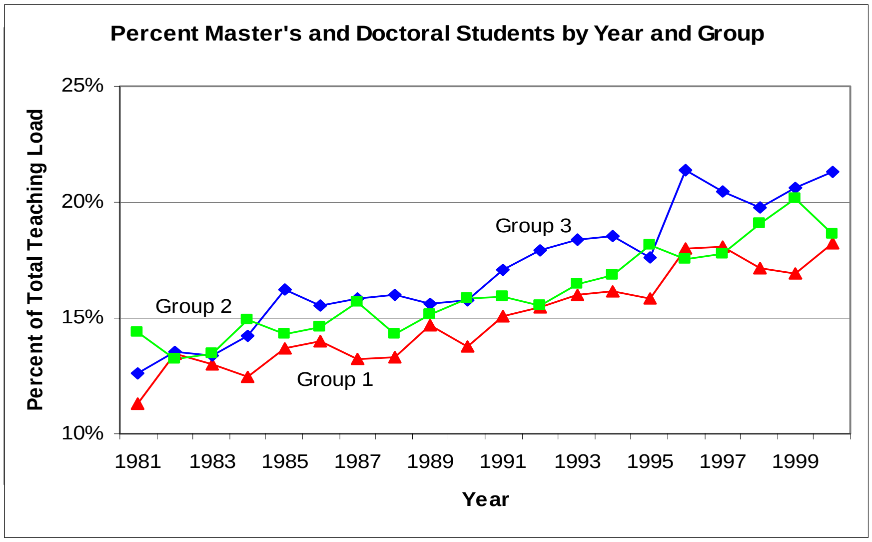

Figure 7-34

In academic year 1981-1982, the percentage of master's and doctoral students at schools in medium (Group 2) managed care markets was 14.4%, the highest percentage of any of the three groups of schools. At schools in high (Group 3) managed care markets the percentage was slightly lower (12.6%), and at schools in low (Group 1) managed care markets the percentage was lowest (11.3%). By academic year 2000-2001, schools in high (Group 3) managed care markets had the highest percentage of master's and doctoral students (21.3%), while schools in medium (Group 2) and low (Group 1) managed care markets had similar percentages of master's and doctoral students (18.6% and 18.3%, respectively).

Early in the study period, medical students comprised the largest percentage of the total teaching load in all schools, as shown in Figure 7-35. In academic year 1981-1982, the percentage of medical students at schools in low (Group 1) managed care markets was 56.6%, the highest percentage of any of the three groups of schools. At schools in medium (Group 2) managed care markets, medical students accounted for about half of the total teaching load (49.9%), and at schools in high (Group 3) managed care markets the percentage was slightly lower (46.9%). By academic year 2000-2001, the percentage of medical students had decreased at schools in all three managed care market groups. Schools in medium (Group 2) managed care markets had the largest decrease in percentage of medical students (to 34.5%). The percentage of medical

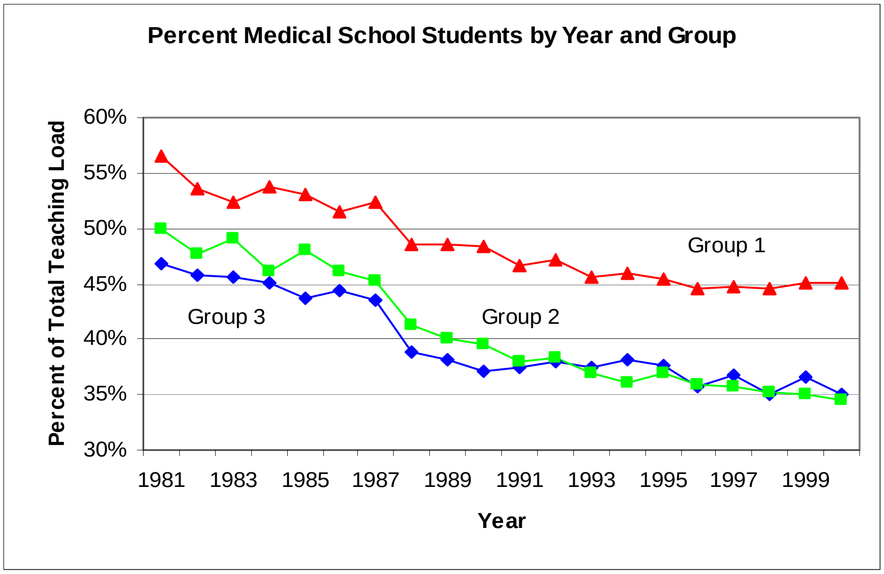

Figure 7-35

students at schools in high (Group 3) managed care markets decreased to 35.1% by academic year 2000-2001, and at schools in low (Group 1) managed care markets the percentage of medical students decreased to 45.0%.

During the period of the study, the average number of residents and postdoctoral students trained at medical schools increased, as shown in Figure 7-36. For all three groups of schools, the average number of graduate medical students increased very little between academic years 1981-1982 and 1987-1988 but showed a substantial increase in 1988-1989, due to elimination of the Other category of reported data. The average number of residents and postdoctoral students at schools in medium (Group 2) managed care markets increased again in academic year 1991-1992, surpassing the average number at schools in high (Group 3) managed care markets. In academic year 1981-1982, schools in high managed care markets averaged 467.6 residents and postdoctoral students; this number increased to an average of 681.9 (45.8%) in 2000-2001. The average number of residents at schools in medium managed care markets showed the greatest percentage increase—75.1%, from an average of 417.3 in academic year 1981-1982 to 730.7 in 2000-2001. The average number of residents at schools in low (Group 1) managed care markets increased by about the same percentage as the number at schools in high managed care markets—44.1%, from an average of 301.5 in academic year 1981-1982 to 434.5 in 2000-2001.

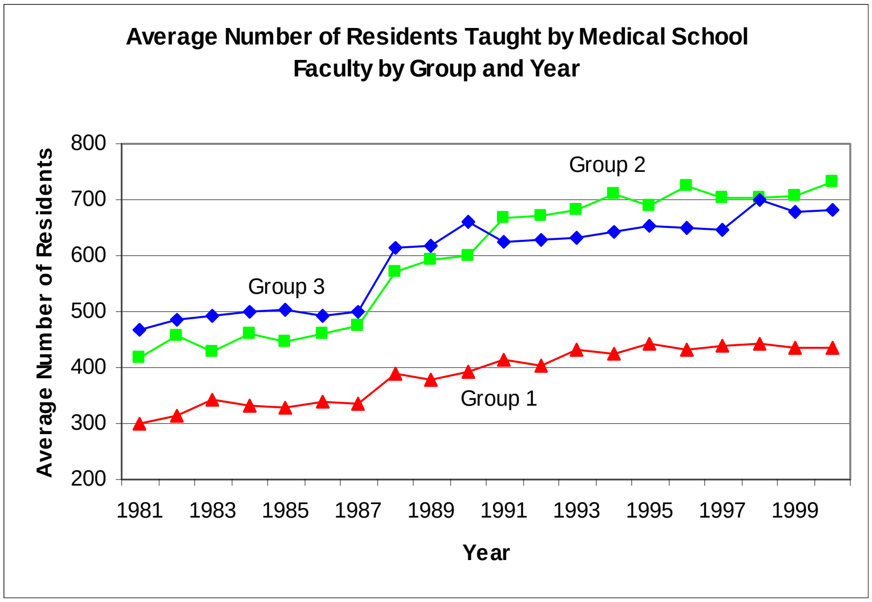

Figure 7-36

The number of residents and postdoctoral students trained at schools in low managed care markets was, however, approximately steady after academic year 1993-1994.

The average number of master's and doctoral students trained at schools in all three managed care market groups increased by the largest percentage of any type of student, as shown in Figure 7-37. At schools in high (Group 3) managed care markets, the number of master's and doctoral students increased 139.6% between academic years 1981-1982 and 2000-2001, from an average of 142.1 to 340.6 students per school. The average number of master's and doctoral students at schools in medium (Group 2) managed care markets also increased over 100% between academic year 1981-1982 and 2000-2001. In academic year 1981-1982, these schools averaged the highest number of master's and doctoral students (155.8), increasing 101.0% to an average of 313.2 students in 2000-2001. Schools in low (Group 1) managed care markets had the lowest number of master's and doctoral students in academic year 1981-1982 (103.9), nearly doubling during the study period to an average of 205.4 in academic year 2000-2001.

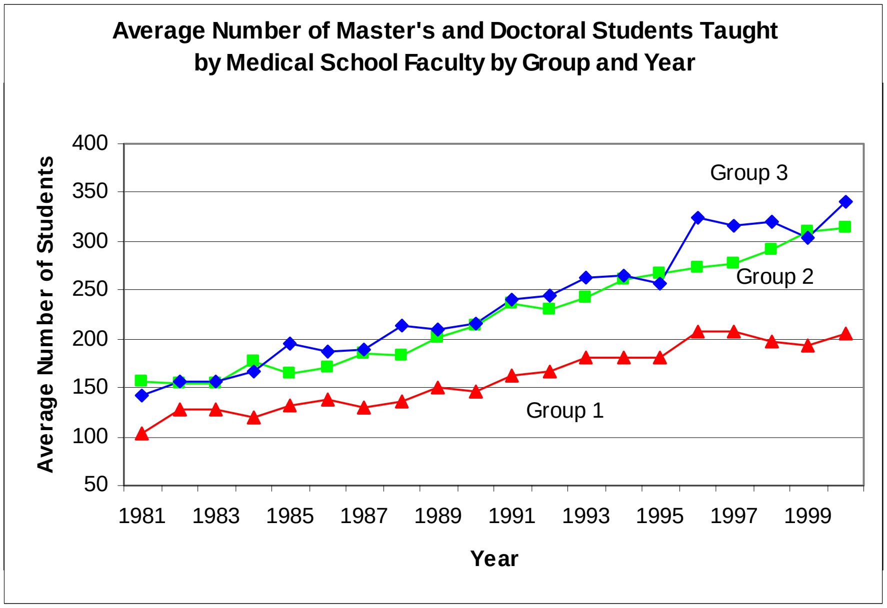

Figure 7-37

Medical school administrative staff positions. The average number of medical school administrative staff positions increased during the study period for each of the three managed care market groups of schools, as shown in Figure 7-38. Schools in medium (Group 2) managed care markets showed the largest percentage increase in administrative staff positions. They increased 41.2% from an average of 14.4 administrative staff positions in academic year 1981-1982 to 20.3 staff positions in 2000-2001. Administrative staff positions at schools in high (Group 3) managed care markets increased as well, but at a slower rate. In academic year 1981-1982, these schools averaged 13.6 administrative staff positions, while in 2000-2001 they averaged 18.7 staff positions—an increase of 37.2%. Schools in low (Group 1) managed care markets had the lowest average number of positions, and the average number of positions increased at the slowest rate. The average number of administrative staff positions at schools in low managed care markets was 13.0 in academic year 1981-1982, and increased 33.2% to 17.3 positions in 2000-2001.

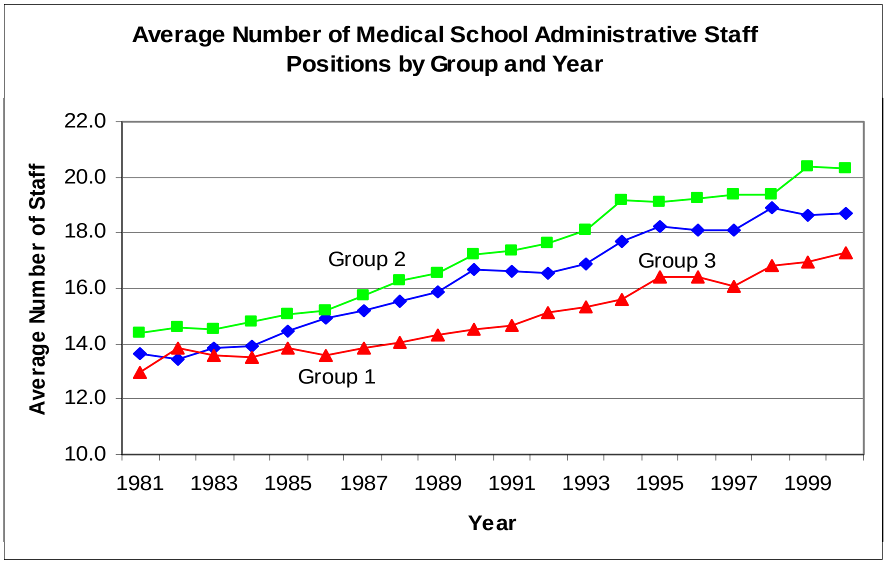

Figure 7-38

Clinical facilities. Medical schools in each of the three managed care market groups behaved differently over the course of the study period with respect to the number of affiliated clinical facilities, as shown in Figure 7-39.

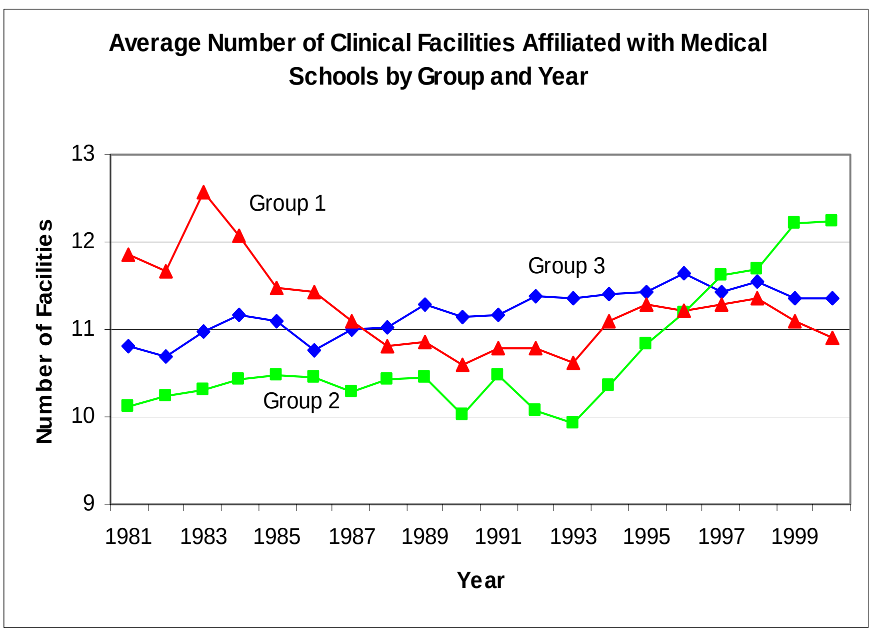

Figure 7-39

Schools in high (Group 3) managed care markets increased their average number of affiliated clinical facilities by a modest 5.2% between academic years 1981-1982 and 2000-2001, from an average of 10.8 to 11.4 clinical facilities. These schools did not exhibit any sizable annual increases or decreases in the average number of clinical affiliations during the period of the study.

Schools in medium (Group 2) managed care markets increased their average number of clinical affiliations very slowly, from 10.1 to 10.5 between academic year 1981-1982 and 1989-1990. After that year, the average number of clinical affiliations oscillated annually until hitting a minimum value of 9.9 in academic year 1993-1994. Following that year, the number of clinical affiliations increased sharply and steadily, yielding a 23.3% increase between academic years 1993-1994 and 2000-2001. This group of schools was largely responsible for the increase in the average number of clinical affiliations observed for all schools after academic year 1993-1994. During the same period (academic year 1993-1994 to 2000-2001), schools in high (Group 3) managed care markets increased the number of clinical affiliations by less than 1%, and schools in low (Group 1) managed care markets increased the number of clinical affiliations by a modest 2.6%.

Schools in low (Group 1) managed care market penetration areas had the highest average number of clinical affiliations at the beginning of the study period (11.8 in academic year 1981-1982). This number increased to 12.6 in academic year 1983-1984 before dropping to a minimum of 10.6 average clinical affiliations in academic year 1993-1994. Although the average number of clinical affiliations subsequently increased somewhat, the average number of clinical affiliations had dropped again to 10.9 in academic year 2000-2001. Overall, schools in Group 1 showed a decrease of 8% in the average number of clinical affiliations between academic years 1981-1982 and 2000-2001.

Comparative Characterization of Medical Schools Over the Study Period

In the previous chapter, the most currently available data were used to characterize the three groups of schools on the basis of the three missions of medical schools (teaching, research, and patient care). Using those data, schools in high managed care markets were characterized as primarily research institutions; schools in medium managed care markets were characterized as primarily teaching institutions, which also provided a significant amount of patient care; and schools in low managed care markets were characterized as primarily public schools that fulfilled all three missions on a smaller scale than the other two groups of schools. The evidence presented in this chapter described the study variables over time for the three groups of schools.

Schools in high managed care markets

Schools in high managed care markets, described as primarily research institutions on the basis of current data, can also be characterized as research institutions on the basis of data for the entire study period. This group of schools was consistently the recipient of large amounts of NIH funding and funding for research from all sources. In the earliest year of the study period, total NIH funding and NIH funding for research grants given to schools in high managed care markets averaged about 140% of the funds awarded to the average medical school in the U.S. By the last year of the study period, this percentage had dropped only slightly to about 135%, an indicator that these schools continued to be very active in conducting biomedical research. During the same period, funding from NIH for research training (training grants and fellowships) was highest for schools in high managed care markets. The amount of funding for these activities became increasingly disproportionately awarded to Group 3 schools during the period, with fellowship funding in 2000-2001 averaging over 150% of the amount awarded to the average medical school in the U.S.

Schools in high managed care markets also had the highest average total revenue and revenue from federal support throughout the study period. Research funding no doubt contributed significantly to this finding. Average total revenue for schools in high managed care markets in the early part of the study period was about 125% of the average at all U.S. medical schools; by the end of the study period, it had risen to 139% of the average total revenue at all medical schools.

Schools in high managed care markets had the largest average number of faculty and clinical faculty as well as the highest ratios of clinical to basic science faculty and faculty members to medical students throughout the study period. It may seem incongruous that the number of faculty in clinical departments was growing at the same time that research revenues were also rapidly increasing. These two observations can be reconciled by the fact that the number of Ph.D. faculty—faculty who are much more likely than M.D. faculty to be NIH principal investigators—in clinical departments more than doubled between 1981 and 1999.[5] By 2001, more Ph.D. faculty members were in clinical departments than in basic science departments.[6]

Although schools in high managed care markets did not have the highest average number of administrative staff positions, they did have the highest percentage of administrative staff positions that were the same as the previous year in the first year of the study period. They did not, however, have the highest percentage of positions that were the same as the previous year in the last year of the study period. This suggests that the amount of organizational change increased over the study period.

In the previous chapter, an examination of current total teaching responsibility data revealed that faculty at schools in medium managed care markets had the highest average total teaching load. In approximately the first half of the study period, however, faculty at schools in high managed care markets had a slightly higher average total teaching load. One reason for this change can be found by looking at the types of students taught by the medical school faculty. At the beginning of the study period, schools in high managed care markets were responsible for teaching the highest number of residents; residents also represented over 40% of the total teaching load—the highest of any group of schools. By the end of the study period, schools in the high managed care markets were no longer responsible for training the largest number of residents. At the same

[5] QRC, "Medical School Faculty: Principal Investigator Tables," (Bethesda, Maryland: National Institutes of Health, 1995).
[6] Di Fang, "Growth of Ph.D. Faculty in Clinical Departments of U.S. Medical Schools, 1981-1999," (Washington, D.C.: Association of American Medical Colleges, 2001).

time, however, schools in high managed care markets assumed the lead role in training master's and doctoral students. At the end of the study period, these schools were responsible for the largest average number of master's and doctoral students. Schools in medium and high managed care markets were responsible for a similar average number of master's and doctoral students through about 1995-1996. After that year, master's and doctoral students at schools in high managed care markets rose rather sharply, an increase that coincided with an increase in NIH research training awards and NIH research funding to this group of schools.

Master's and doctoral students receive support from a variety of sources—most notably, they receive funds that are earmarked for research training (e.g., NIH training grants and fellowships); students are also supported on research grants. While master's and doctoral students participate in research during their studies, the activities of postdoctorates are centered almost exclusively on research. The data available for this study combined counts of residents and other types of postdoctoral students. It was not possible therefore, to determine whether there was a concomitant increase in new Ph.D.s performing research as postdoctoral students at schools in high managed care markets. The average number of residents and fellows increased at schools in high managed care markets, but not nearly as rapidly as the average number at schools in medium managed care markets. The significant infusion of research funds at schools in high managed care markets suggests that the combined data for residents and other postdoctorates may mask a leveling off or even a decline in the number of residents that received clinical training at schools in high managed care markets.

In summary, medical schools in high managed care markets were primarily research institutions during the entire study period. Increases in average revenues, and changes in the mix of clinical and basic science faculty and of students comprising the total teaching load suggest that these schools may have leveraged their research capacity to maintain their activities and functions in high managed care markets.

Schools in medium managed care markets

Schools in medium managed care markets, described as primarily teaching institutions which also provided a significant amount of patient care on the basis of current data, can be similarly characterized on the basis of data for the entire study period. These schools had the highest average number of medical students enrolled, and produced the highest average number of graduates throughout the study period. They also had the highest average number of basic science faculty members; the number of basic science faculty members increased consistently throughout the study period. Schools in medium managed care markets had the highest average number of administrative staff positions throughout the study period.

Faculty at schools in medium managed care markets had the highest average total teaching load in 2000-2001. They did not have the highest average level of teaching responsibility in the earlier years of the study period; faculty at schools in high managed care markets had a slightly higher average total teaching load. One reason for this change can be found by looking at the types of students taught by the medical school faculty. At the beginning of the study period, schools in medium managed care markets were responsible for teaching the highest average number of master's and doctoral students. By the end of the study period, schools in medium managed care markets were no longer responsible for training the highest average number of master's and doctoral students. However, they were responsible for teaching the highest average number of residents, a distinction held by schools in high managed care market areas early in the study period. Master's and doctoral students receive research training; residents receive primarily clinical training.

Schools in medium managed care markets had the highest average revenues from hospital fees throughout the study period, although they did not have the highest average number of clinical faculty. This suggests that the opportunity for accruing revenue from the provision of patient care may have been greater at schools in medium managed care markets than at schools in high or low managed care markets. Revenue from this source increased steadily at schools in medium managed care markets, although revenues from hospital fees had leveled off at schools in high and low managed care markets. Schools in medium managed care markets had the highest average number of clinical affiliations in 2000-2001, but this was not the case in 1981-1982. The average number of clinical facilities increased about twice as fast as the number affiliated with schools in high managed care markets, and about four times as fast as the number of clinical facilities affiliated with schools in low managed care markets.

In summary, schools in medium managed care markets appear to have maintained their commitment to training clinicians throughout the study period. The change in the types of students (other than medical students) that comprised the total teaching load suggests that teaching and training were important activities at these schools. Schools in medium managed care markets also provided a significant amount of patient care, an activity that was enhanced by the increase in clinical affiliations and which resulted in a steady increase in revenue from hospital fees.

Schools in low managed care markets

On the basis of the most currently available data, schools in low managed care markets were described as smaller, mostly public schools that fulfilled all three missions on a smaller scale than the other two groups of schools. These schools had the highest average state appropriations throughout the study period, a reflection of their predominantly public ownership. Over the study period, average revenues for research funding were about 55% of the average revenues at all medical schools. Average revenue from patient care was about two-thirds of the average hospital fee revenue at all schools at the beginning of the study period. By the end of the study period, this percentage had increased to about three-quarters of the population average. At the beginning of the study period, schools in low managed care markets had the highest average number of clinical affiliations; this may possibly be explained if we examine the demographics of the states in which these schools are located and the ownership of the schools. These schools tended to be in smaller population states; it is consistent with the service orientation of these mostly public schools to provide statewide services. By the end of the study period, schools in low managed care markets no longer had the highest average number of clinical facilities affiliated with the medical schools.

In summary, the focus of schools in low managed care markets was on teaching medical students, as evidenced by the relatively high proportion of medical students in their total teaching responsibility. Changes in the study variables were less dramatic in these schools.

Chapter 8. Results of Graphical and Nonlinear Mathematical Analyses

The preceding chapter presented a detailed description of the trends found by examining each of the study variables over the study period. The XY line graphs helped to describe changes over time. They also added to the body of rich description that I developed during the course of this research study. This rich description, which is one of the major contributions of this research study, not only provides detailed information about AMCs, from the perspective of multiple indicators, but also contains evidence with which to formulate an explanation of the behavior of this population of institutions. The trend lines that were drawn to fit the observed data were calculated to depict a line that minimized the differences between the trend line and the observed data at every data point. These trend lines indicated that very few of the XY line graphs of variables were best depicted by a linear trend line; a nonlinear trend line was best for many of the variables. The level of detail in the rich descriptions allowed me to develop generalizations about the patterns of behavior that emerged for all medical schools and within each of the managed care market groups of schools. The apparent presence of nonlinearity and the emergence of identifiable patterns of behavior tentatively confirmed the reasonableness of treating AMCs as a complex adaptive system.

This chapter presents two additional sets of results: (1) a graphical analysis in a phase plane format that is often used in chaos research[1] and which was designed to further describe and explain the nature of the emerging patterns of institutional behavior; and (2) a mathematical analysis designed to confirm the presence of nonlinearity in the variables describing the AMC system.

Graphical Analysis

Phase portraits were designed to serve as maps of system activity over time, and as such, they can reveal the underlying order, or attractor, of the nonlinear processes at work in the system.

Standard phase portraits that illustrate a point attractor, a two-period cycle, a four-period cycle, and chaos (strange attractor) were presented in chapter 5. With a little practice and a review of these standard graphs, visual inspection of the phase portraits of study data can reveal a story about the characteristics of the systems that are represented on the graphs.

- Does the trajectory stay in the upper right quadrant? If so, the system values are generally increasing.
- Does the trajectory visit all four quadrants? Perhaps the system is chaotic—the trajectory never reaches the same point twice under the defined interval of time.
- Does the trajectory alternate between the same or similar points in two diagonally opposite quadrants? The oscillation suggests that the operative attractor is a two-period limit cycle—a form of periodic attractor that often implies stability.
- Does the trajectory seem to focus on a cluster of points? This suggests that the system has reached a stable equilibrium or fixed point.
- Does the trajectory exhibit one pattern during one part of the study period and another pattern during another part of the study period? Something happened to deflect the system from its attractor. Perhaps it will (or does) return to its original attractor, or perhaps it will (or does) settle into a new attractor. Such an occurrence should prompt the researcher to ask why this happened.

Phase portraits of selected individual variables, typically those with more than 12 years of data, were constructed and examined in an effort to map, identify, and characterize the underlying structure of the system described by the longitudinal data.

As described in chapter 5 of this dissertation, the data were graphed on a two-dimensional Cartesian plane divided into four quadrants. The horizontal and vertical axes intersected in the middle of the plane at coordinates 0,0. The data points were plotted on the phase plane using the values for time period t on the Y-axis and the values for the preceding time period, $t-1$, on the X-axis.

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[1] L. Douglas Kiel and Euel Elliott, *Chaos Theory in the Social Sciences: Foundations and Applications* (Ann Arbor: The University of Michigan Press, 1997).

For each data point, the value at time *t* could be positive (above the horizontal axis) or negative (below the horizontal axis), indicating an increase or decrease from the previous time, *t-1*, respectively. The value at time *t-1* could be positive (on the right of the vertical axis) or negative (on the left of the vertical axis), indicating an increase or decrease from the prior time period. The value of *t-1* for the first point on the graph was always set to zero. For the second point on the graph, the value of *t-1* was equal to the value of *t* for the first point on the graph. Like the first point on the graph, the value of *t* for the second point could be positive (above the horizontal axis) or negative (below the horizontal axis). Each successive point on the graph was placed such that the value on the X-axis was the value of the variable at time *t-1*, and the value on the Y-axis was the value of the variable at time *t*. The time series data points were plotted and a line was drawn connecting the points in chronological order to create a trajectory. The graphical analysis focused on the size and direction of changes in the values of the variables over time. The absolute size of the variable at each point in time is not apparent in the phase portrait, nor is it a component of phase plane graphical analysis.

The change in a variable over time was evaluated by noting both the magnitude of difference between two successive points, and the direction of the trajectory. To assist the reader in interpreting the phase portraits, the beginning and end of each trajectory are noted on the graphs. Successive points on the graph that remained within one quadrant indicated that the direction of change (positive or negative) was the same as that of the prior time period. Two successive data points on the graph that were not in the same quadrant indicated that the direction of change was the opposite of that of the prior time period and that the amount of change was great enough to move the trajectory from one quadrant to another. That is, when the trajectory moved from one quadrant to another, the first of two data points represented an increase from the previous time period and the second data point represented a decrease from the first data point, or the first data point represented a decrease from the prior time period and the second data point represented an increase from the first data point. When the changes were not large enough to move the trajectory from one quadrant to another, the trajectory still appeared to change direction.

Clusters of points near coordinate 0,0 indicated that the changes over time were quite small regardless of the direction. If the direction of change alternated between positive and negative, the successive data points on the phase portraits alternated diagonally between Q2 and Q4, or Q1 and Q3. It was also possible for a variable to show more than one type of pattern over the entire period of time that was examined. For example, a system that showed fluctuations before settling into a stable equilibrium would show a cluster of points near coordinate 0,0 at the end of the trajectory.

Phase portraits of each of the individual variables for all medical schools and for the managed care market groups of schools are presented in the next sections of this chapter. Visual inspection of the phase portraits yielded a qualitative description of the system measured by the data variable. The presence of a point attractor (i.e., a cluster of data points) or a periodic attractor (i.e., data points that were in diagonally opposite quadrants) was interpreted as the presence of stability in the system. The presence of orbital trajectories (i.e., data points that visited all four quadrants) was interpreted as the presence of chaotic or strange attractors. The presence of more than one type of attractor on the phase portrait was interpreted as a change in the system's attractor during the study period.

Financial Data—All Medical Schools

Total revenue for all schools and revenue from tuition and fees, parent university support, faculty practice plans, hospital and other medical school programs, and grants and contracts were available for the period academic years 1981-1982 through 1998-1999.

The phase portrait of data for total revenues is shown in Figure 8-1. All of the data points were in Q1, indicating that in all years the total revenue (in current dollars) increased. The trajectory during the first half of the time period resembled the standard phase portrait of exponential data. Midway through the study period (academic year 1988), the trajectory made a small reversal to the left, indicating that the rate of increase had suddenly diminished. In academic year 1996, total revenue again showed a decrease in the rate of increase, but strongly recovered in academic year 1997.

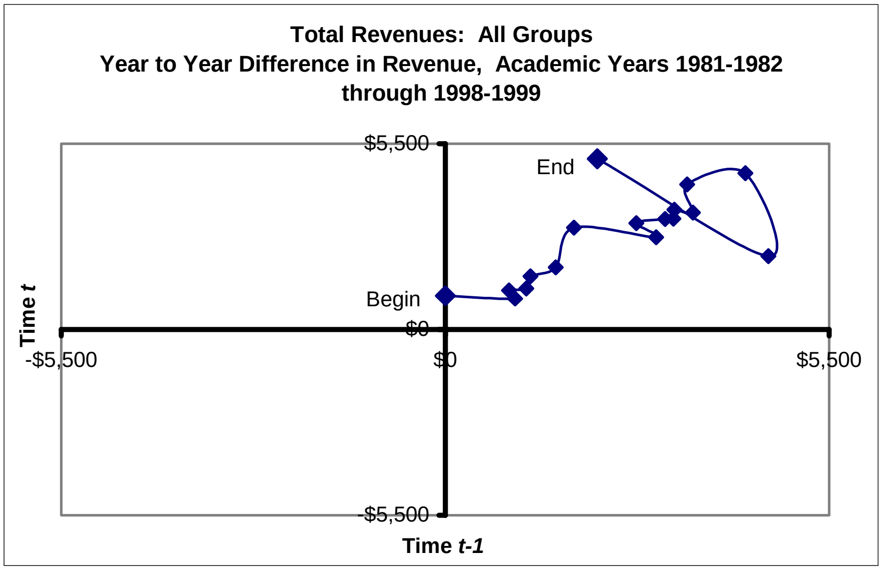

Figure 8-1

Revenues from faculty practice plans showed a pattern similar in very general terms to total revenues, as shown in Figure 8-2.

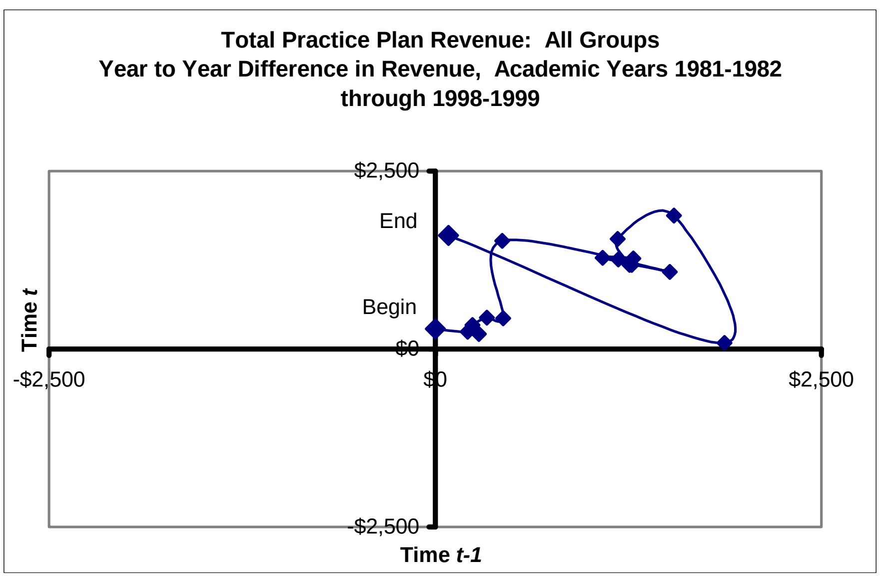

Figure 8-2

Specifically, the phase portrait for practice plan revenue showed a pattern of two clusters of points; one cluster occurred early in the period (up through academic year 1986) near the 0,0 coordinate, and the other cluster was approximately in the center of Q1. After significant growth in practice plan revenue, the increases "stalled" in academic year 1988. Close examination showed that this second cluster consisted of a series of small oscillations. This was followed by a rather dramatic change in the pattern in the last few years of the study period, as the revenue increased moderately and then decreased and increased again. It was unclear whether the trajectory was entering a period of erratic (random-appearing) behavior, but it does appear that periods of stability were interrupted by periods of instability.

The tuition and fee revenue trajectory on the phase portrait was also similar to the trajectory of total revenues, as shown in Figure 8-3.

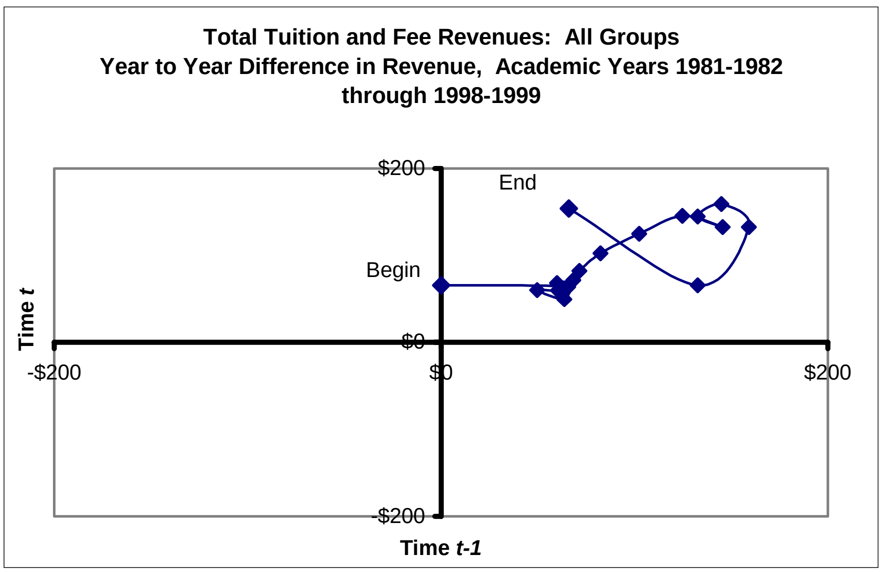

Figure 8-3

All of the points of the trajectory were in Q1, indicating that the tuition and fee revenue increased throughout the entire period. The trajectory on the phase plane began with a cluster of points, indicating a fairly high degree of stability in this source of revenue until about 1989. This was followed by an increase that appeared to be exponential, and then by a small decrease, which was too small for the trajectory to enter Q2. The small scale of successive changes during the early 1990s suggested that the trajectory was settling into another stable point. However, this was followed by another increase, which indicated that the trajectory of tuition and fee revenue had not reached another stable point.

The trajectory of parent university support on the phase portrait visited all four quadrants, as shown in Figure 8-4.

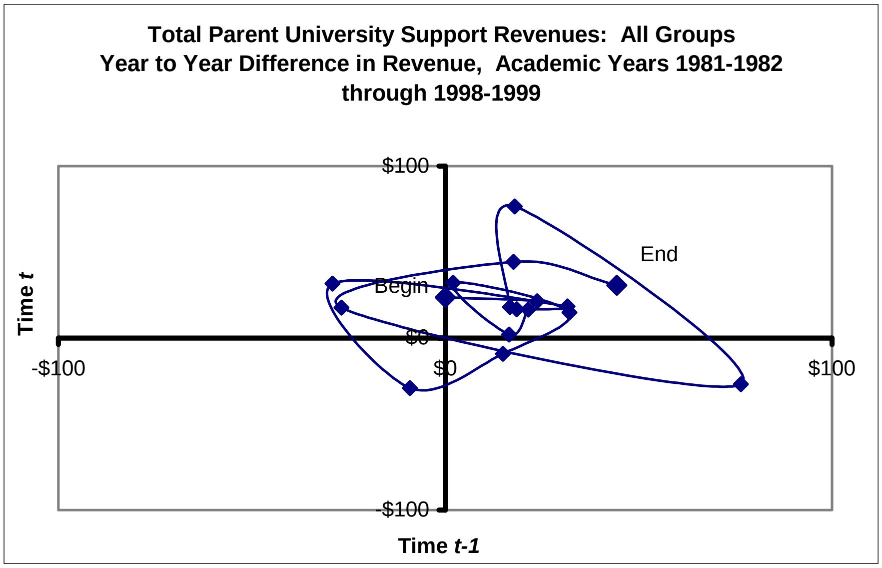

Figure 8-4

Although it is difficult to discern on the phase portrait, the trajectory consisted of three orbits of increasing size. The earliest in the time period was also the smallest, and resided entirely in Q1. The second was similar in shape to the first, but covered more territory on the phase plane and consequently visited Q4, Q3, and Q2 (in that order) before it returned to Q1 at nearly the same point on which it began. The third orbit, which traced the marginal differences in parent university support in the late 1990s, began with a small cluster of points but subsequently traced the largest of the three orbits. It began in Q1, visited Q4, passed through coordinate 0,0 on its way to Q2, and returned to Q1. This trajectory suggested that revenues provided by a parent university had become increasingly unstable over the time period of the study, and that the size of the increase or decrease in revenues from the previous year had become increasingly difficult to predict.

Revenues received by medical schools from hospitals and other medical school programs generally increased during the study period, as shown in Figure 8-5. Nearly all of the points of the trajectory were in Q1 but there were numerous changes in direction. The most prominent characteristics of the trajectory were two non-overlapping orbits. The first (and earliest) was nearer coordinates 0,0 and briefly entered Q4 and Q2 before it returned to Q1. The trajectory of the second orbit was entirely in Q1 and was also characterized by an oscillation in the trajectory, this time between 1991 and 1993. The oscillation was preceded by a sharp increase followed by a decrease, which suggested that this period of greater variation probably extended at least from 1990 to 1994. The final point of the trajectory was very near a point of the first orbit, and it is unclear whether the trajectory was poised to repeat the first orbit or to do something else entirely.

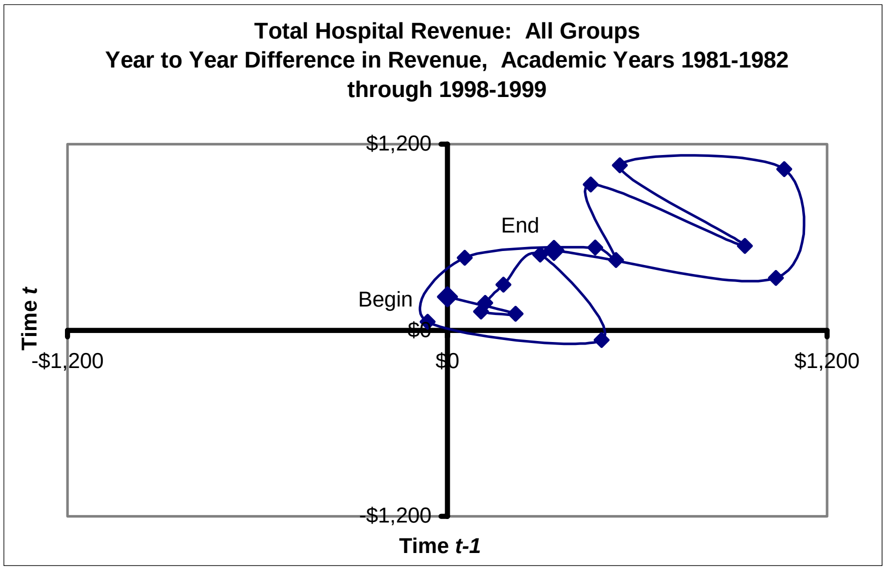

Figure 8-5

Average NIH support for all medical schools is shown in Figure 8-6. The trajectory was in Q1, which indicated that NIH funding increased during the entire study period. The trajectory illustrated two eras in the NIH budget: the period after FY 1997, during which Congress doubled the NIH budget, and the prior period, in which annual budget increases were more modest. The trajectory of the year-to-year revenue changes in the late 1990s is characteristic of exponentially increasing data (see sample Phase Plot of Exponential Data in chapter 5). In order to see the structure of the trajectory of revenues from all NIH support for medical school activities in the pre-budget-doubling period, the later data points were eliminated from the graph and the scale of the axes was reduced, as shown in Figure 8-7. This phase portrait showed that beginning in the mid-1980s, the trajectory was primarily characterized by oscillations; i.e., increases in revenue, in constant dollars, received from NIH were alternately, and fairly stably, larger and smaller in a regular pattern, compared to the prior year.

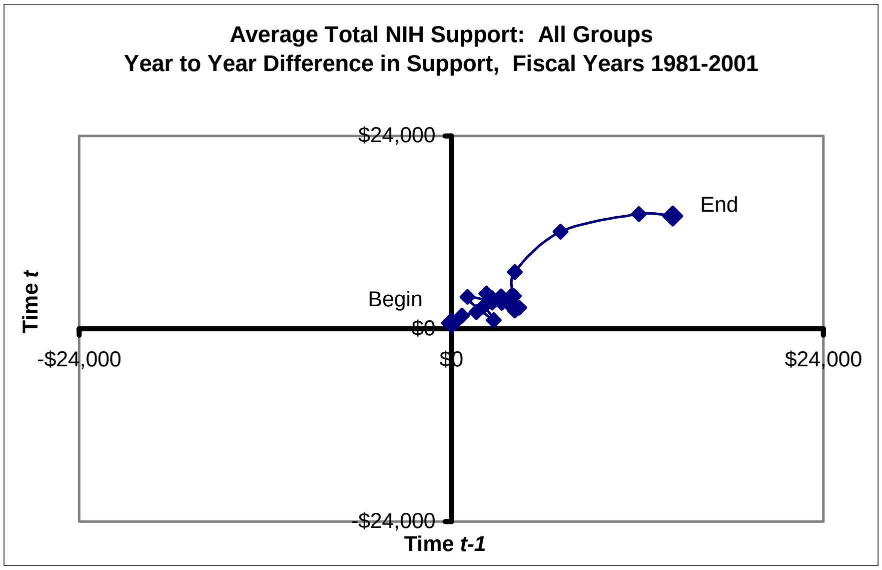

Figure 8-6

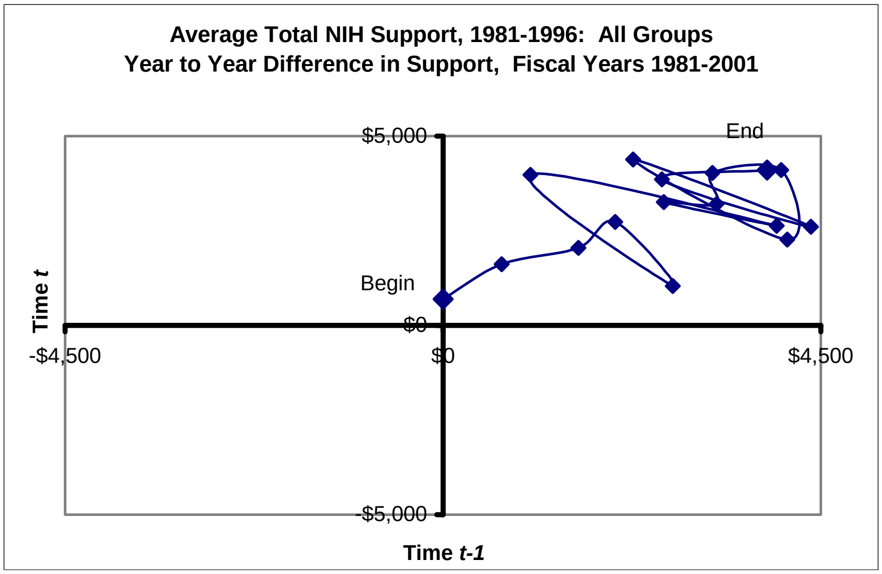

Figure 8-7

Because most NIH support was for research grants, the trajectory of NIH research grant support (see Figure 8-8) closely tracked the average amount of NIH support for all activities.

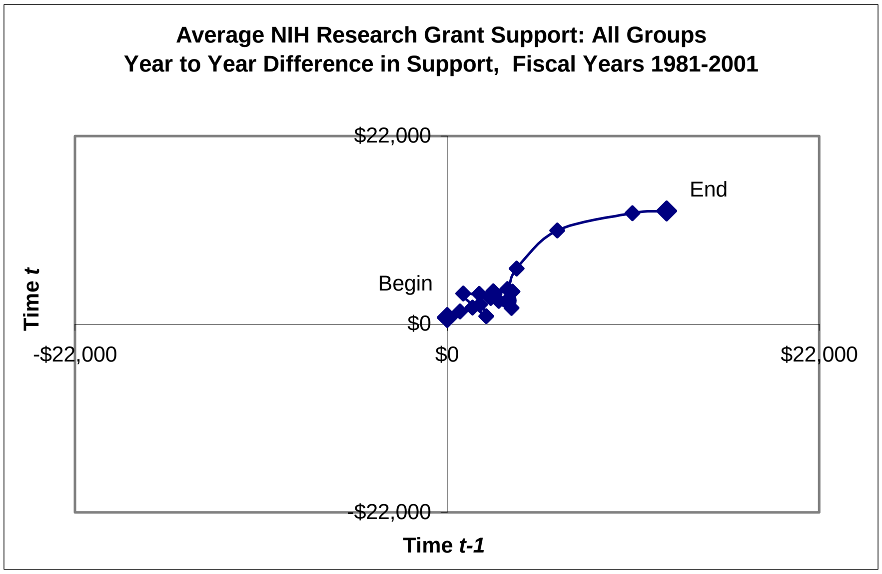

Figure 8-8

Another NIH-supported activity of interest at medical schools is research training. Research training support is provided in the form of fellowships to individual students and institutional training grants, for which the recipient institutions choose the students to receive the financial support. The trajectory of research training support is similar in the earliest years to the trajectory of total and research grant support from NIH, as shown in Figure 8-9.

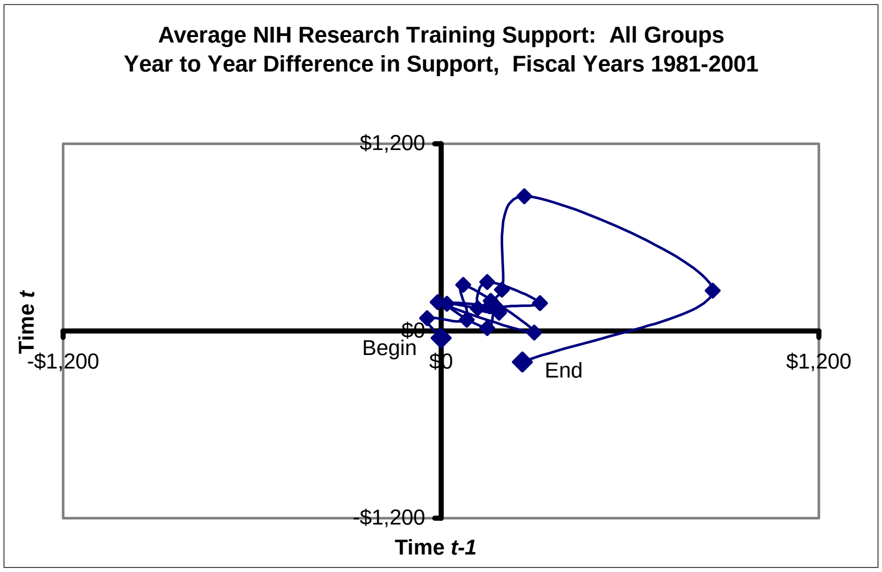

Figure 8-9

The trajectory of this source of revenue was initially clustered in Q1; in 1997, there was a sizable increase that was followed by decreases.

Institutional Characteristics—All Medical Schools

Enrollment. The trajectory of medical school enrollment exhibited both orbits and oscillations during the study period, as shown in Figure 8-10. During the initial years of the study period, the trajectory began in Q1 and traced a moderately sized orbit which paused in Q3 to oscillate for several iterations and which nearly avoided visiting Q2 before it returned to Q1. A second orbit began in Q1 and visited Q4 before it ended, with an extended period of oscillation that paralleled the earlier oscillations, in a location nearer to coordinate 0,0. It appeared that the underlying structure of the system exhibited stability during part of the study period and instability during other parts of the study period.

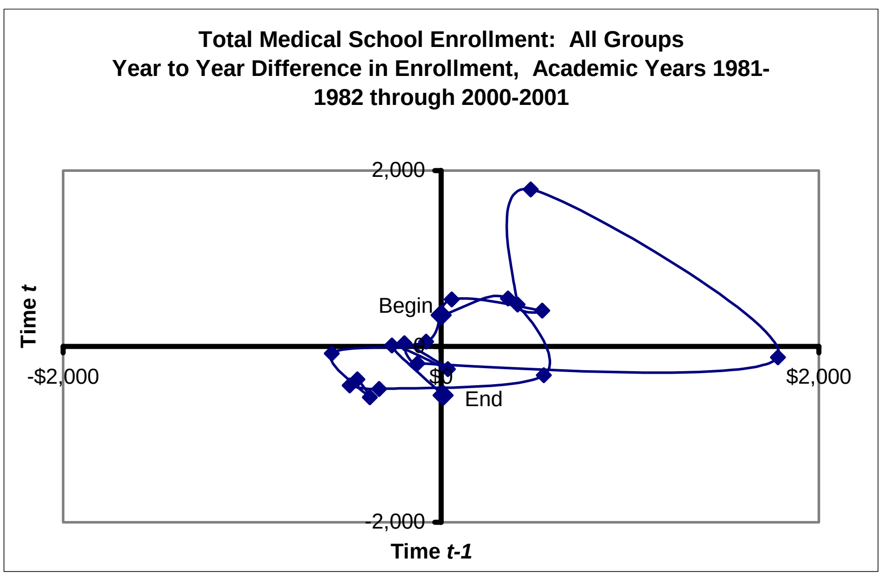

Figure 8-10

Graduates. The trajectory of medical school graduates was not an echo of the enrollment trajectory (see Figure 8-11). Instead of exhibiting tight oscillations, the trajectory consisted of a series of orbits that visited all four quadrants multiple times. The primary determinant of the number of medical students graduating each year is the number of medical students enrolled, so the instability implied by the trajectory was not an expected result. It is also not a result that was obvious from the line graphs of the average number of medical school graduates per year during the study period.

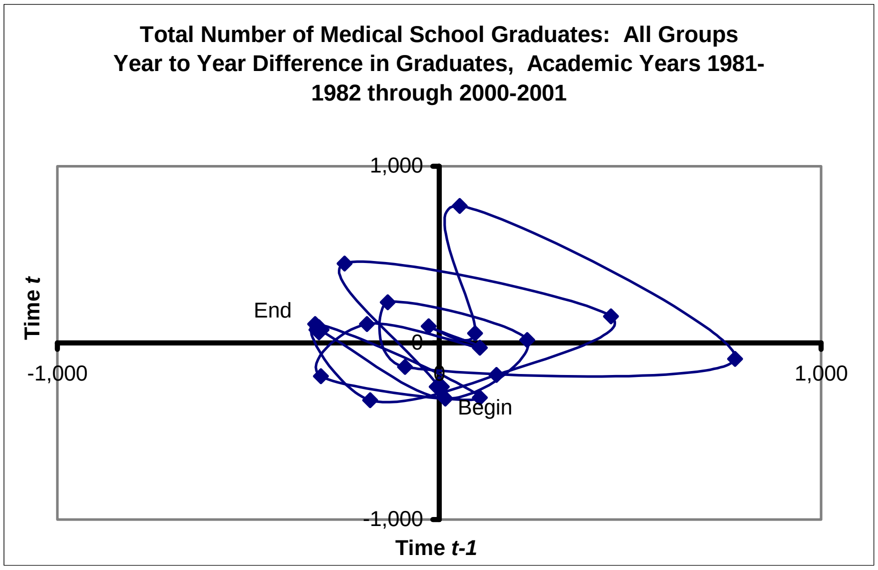

Figure 8-11

Faculty. The trajectory of the total number of medical school faculty began in Q2 but otherwise was located exclusively in Q1, as shown in Figure 8-12.

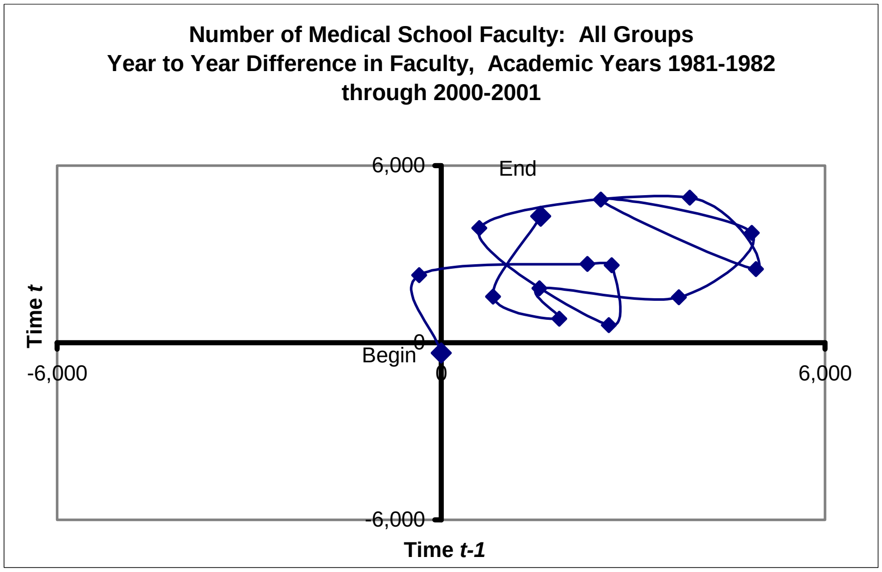

Figure 8-12

It looped around and was characterized by a smaller orbit within the larger one. A change of pattern near the end of the trajectory is followed by an increase that could presage another orbit. The pattern of the trajectory indicates that while the average number of faculty increased during the study period, the increases were not steady.

The trajectory of the number of clinical faculty in all medical schools was very similar to the trajectory of the total number of faculty, as shown in Figure 8-13. This was because clinical faculty members comprised about 80% of the total faculty. Both the large orbit and the orbit-within-an-orbit were apparent in the phase portrait of clinical faculty.

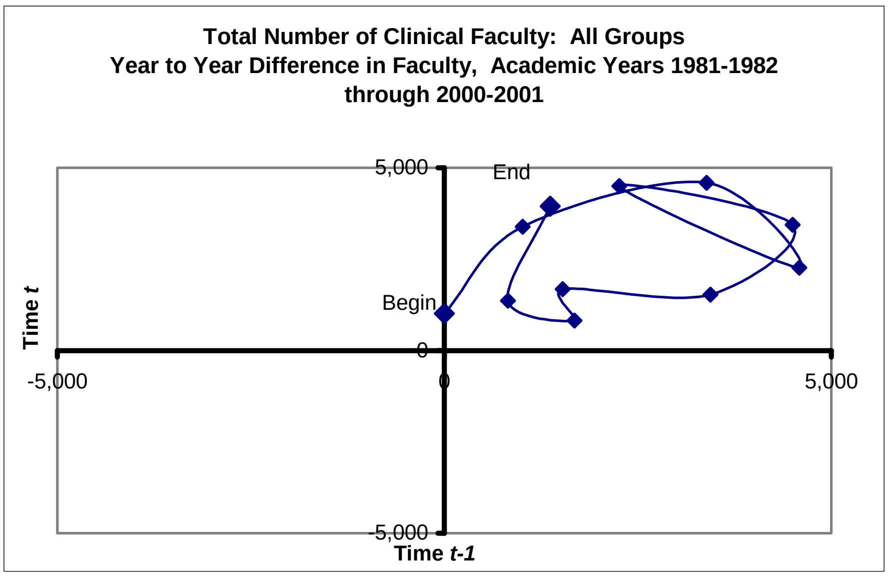

Figure 8-13

The trajectory of the number of basic science faculty in all medical schools was primarily, but not entirely, in Q1, as shown in Figure 8-14. The trajectory made about 2½ tight orbits of similar size before changing pattern in the last two years of the study period. Because of this repetition, this phase portrait shows a pattern more like “textbook” examples of chaotic attractors. The limits of the direction and amount of change the average number of basic science faculty is likely to exhibit can be clearly seen. The last few data points suggest that the system has been disturbed. After additional time has passed, it will be possible to determine whether the trajectory returned to the original attractor pattern or formed a new attractor.

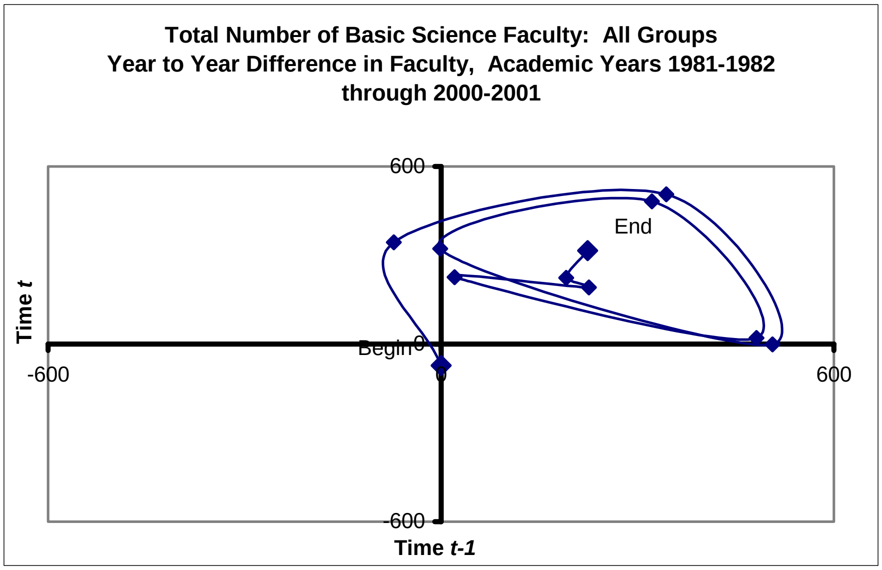

Figure 8-14

Total teaching responsibility. The most obvious feature of the trajectory of the total teaching load of medical school faculty was the oscillations between Q2 and Q4, as shown in Figure 8-15.

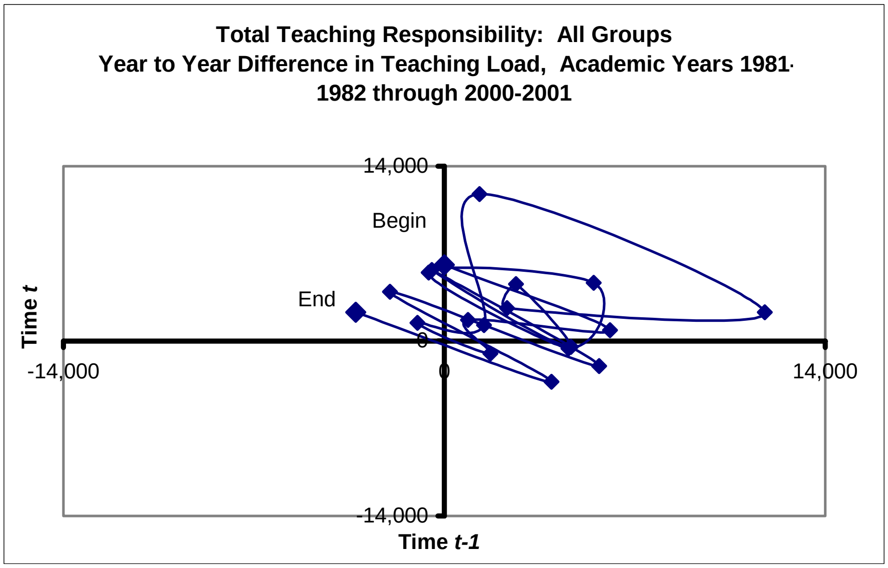

Figure 8-15

However, when the trajectory was viewed in "real time" by plotting the points one at a time in sequence, it was also apparent that the initial trajectory consisted of two orbits of differing sizes in Q1. The oscillations appeared at the end of the trajectory, representing changes in the data after 1995 and a qualitative change toward stability in the pattern of the teaching load at medical schools.

The components of total teaching responsibility were the types of students: residents, master's and doctoral students, and medical students. The teaching responsibility for residents at all medical schools is shown in Figure 8-16.

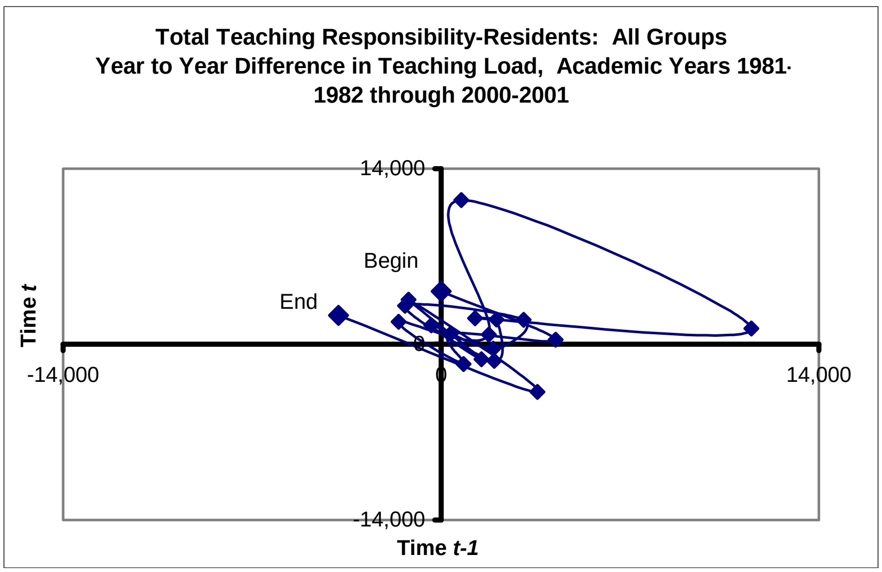

Figure 8-16

Like total teaching responsibility, the trajectory of the residents' data consisted of a series of orbits ending in several iterations of oscillations between Q2 and Q4. The teaching responsibility for master's and doctoral students at all medical schools is shown in Figure 8-17. The trajectory was located primarily in Q1, and unlike the trajectories of total teaching responsibility and teaching responsibility for residents, the trajectory of the teaching responsibility for master's and doctoral students consisted of alternating orbits and oscillations. The initial orbits and oscillations were relatively tight and small, located entirely in Q1. The last orbit was larger, and the trajectory visited Q4 and Q2 before settling into another series of oscillations in the final years of the study period. While located primarily in Q1, these phase portraits exhibited both instability and stability in their changing patterns during the study period.

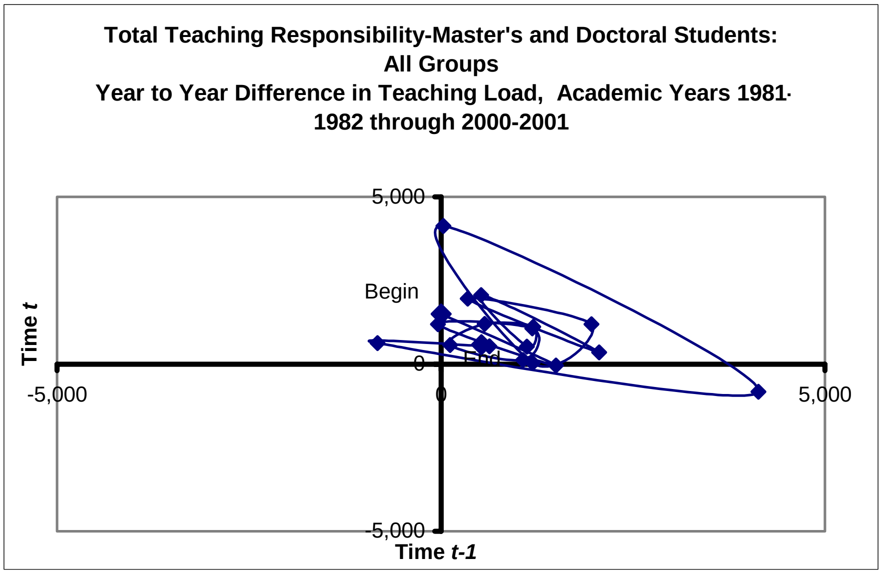

Figure 8-17

The phase portraits indicated that total teaching responsibility as well as its components was not stable over the entire study period. For brief episodes during the study period, teaching responsibility systematically alternated between two sets of values, suggesting an underlying periodic attractor. During other times, teaching responsibility changed by larger amounts in a random-appearing manner.

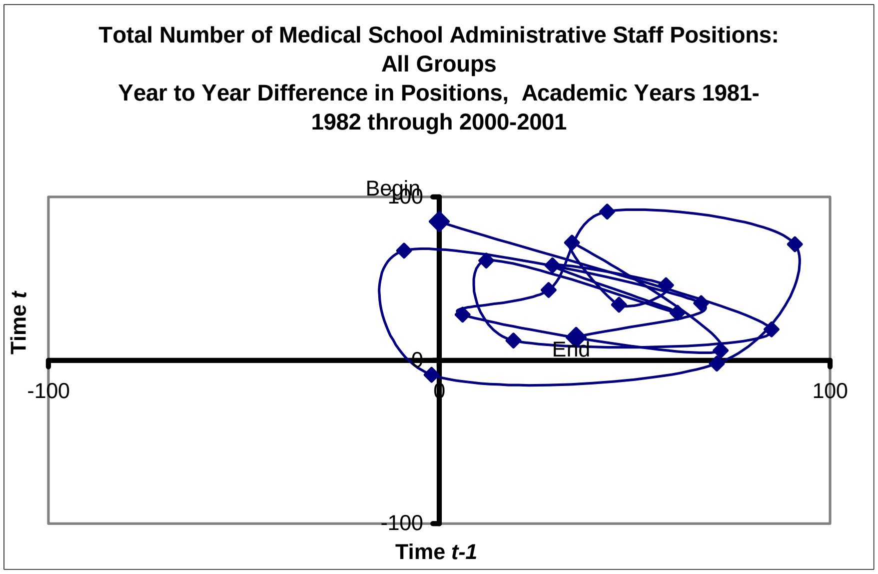

Figure 8-18

Medical school administrative staff. The trajectory of the number of medical school administrative staff positions consisted of a series of increasingly larger orbits, as shown in Figure 8-18. Initially, the orbits were located entirely within Q1 but the last and largest orbit visited all four quadrants. This may indicate a change in the limits or boundaries of the underlying attractor, although the basic shape of the attractor did not change. It also suggests that the attractor is chaotic.

The phase portrait of the percentage of medical school administrative staff positions that were also present in the preceding year showed a trajectory that visited all four quadrants multiple times and appeared to be centered around coordinate 0,0 (see Figure 8-19).

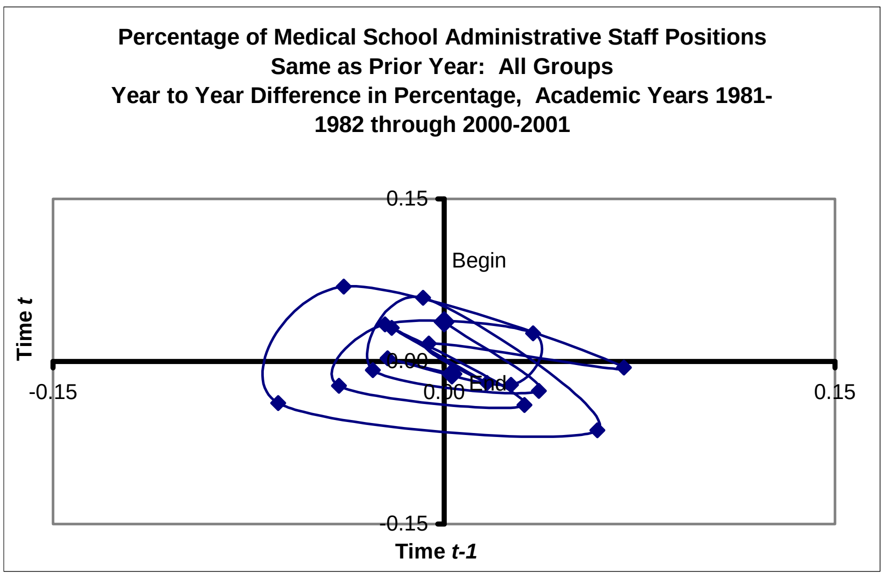

Figure 8-19

This phase portrait strongly resembled the standard nonlinear phase portrait which was generated using a constant that characterized chaotic systems (see Phase Plot of Logistic Equation: a = 3.950). During the study period, the trajectory was random-appearing but was bounded within a specific set of values.

Clinical facilities. The trajectory of the average number of clinical facilities with which medical schools established affiliations visited all four quadrants, but did not trace a series of smooth orbits (see Figure 8-20). The trajectory changed direction several times but, overall, showed the limits of the values that might be expected in this unstable system.

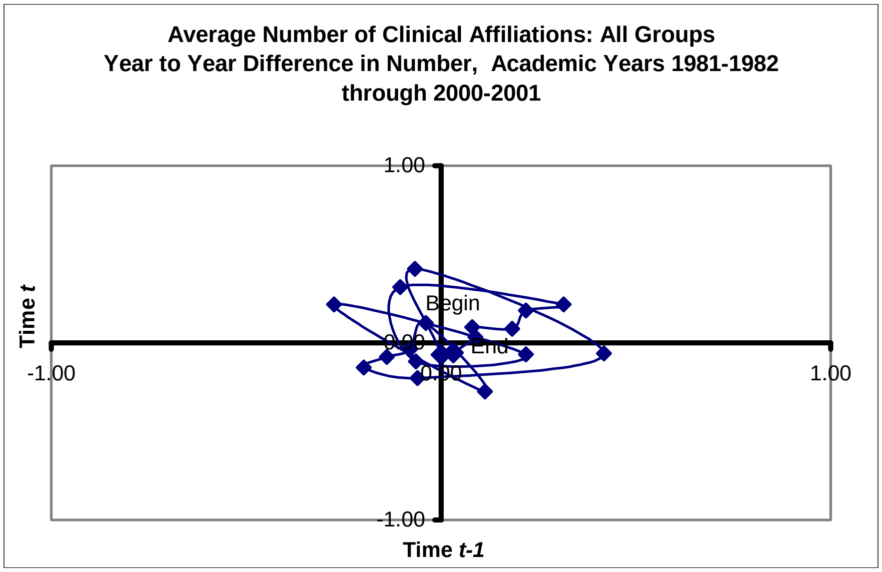

Figure 8-20

The trajectory of the percentage of clinical facilities that were also affiliated in the prior year displayed a more consistent pattern, as shown in Figure 8-21.

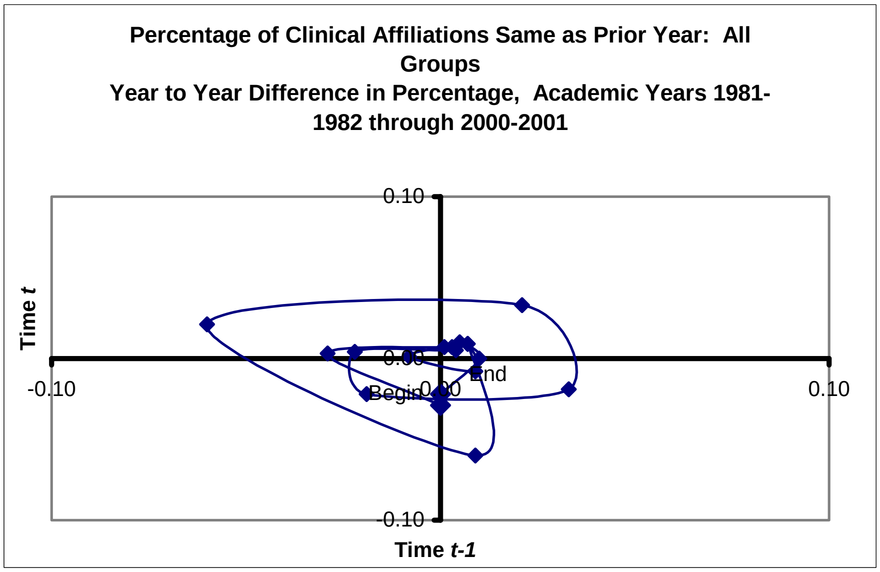

Figure 8-21

The sequence of the trajectory was not obvious from the phase portrait, but when the points were plotted one at a time in sequence, it became apparent that during the early portion of the study period the trajectory was converging in increasingly smaller orbits on coordinate 0,0; that is, the variable was settling down to a stable equilibrium. In the later part of the study period, however, the trajectory changed and traced increasingly larger orbits that visited all four quadrants. This suggested that something disturbed the system enough to move it away from a periodic attractor to a very different, and possibly chaotic, attractor.

Phase portraits of the financial and institutional characteristics data for all medical schools can be classified into two groups: trajectories that resided entirely or mostly in Q1, and trajectories that traversed all four quadrants. With the exception of financial support from a parent university, revenue reported by medical schools tended to increase fairly steadily throughout the study period; that is, year-to-year decreases were rarely large enough to carry the trajectory out of Q1. Within Q1, certain features were visible in the trajectories. For example, Figure 8-2 showed two clusters of points—periods of very little year-to-year change—punctuated first by an increase and then by a decrease near the end of the study period. A different pattern was exhibited by the trajectory of average total NIH support early in the study period in FYs 1981-1996—the period prior to a doubling of the NIH budget. NIH revenue to medical schools began with strong year-to-year increases, but a small orbit and a series of oscillations, all within Q1, characterized the last 10 years of the period. The phase portraits provided an unmistakable indicator of the year-to-year variability in NIH funding provided to medical schools between 1986 and 1996.

Compared to the financial data variables, the trajectories of the institutional characteristics' variables were more likely to visit all four quadrants of the phase plane. None of the trajectories appeared to represent a system in a state of equilibrium during the entire study period. Some trajectories were more active than others; i.e., they visited all four quadrants more than one time. This suggested that the variables plotted on the phase portraits were showing chaotic behavior—that they represented activities or functions that were changing in a non-repeating pattern across all medical schools and throughout the entire study period. Moreover, some of these trajectories (e.g., the percent of clinical affiliations that were the same as the prior year) appeared to qualitatively change during the study period, suggesting a change in the underlying attractor.

Other trajectories, such as the average number of basic science faculty, followed tight orbital patterns that strongly illustrated the pattern of the underlying chaotic attractor. Still others, such as the trajectory of the year-to-year changes in total teaching responsibility, exhibited oscillations that suggested that the underlying attractor was alternating between two values (i.e., a two-period attractor) and could be considered stable.

These phase portraits provided a picture of the year-to-year changes for all medical schools, for each of the study variables. Analysis of the graphs consisted of a qualitative "reading" of the trajectory in order to obtain a sense of the underlying structure, or attractor, that described the system. The phase portraits contributed to the rich description developed in chapters 6 and 7 and suggested which variables might be of particular interest when the managed care market groups of schools were examined in a similar graphical analysis. The results of those analyses are presented in the next sections of this chapter.

Financial Data—Medical Schools by Managed Care Market Group

Each set of three phase portraits (managed care market groups, 1, 2, and 3) was graphed on axes with the same scale. This allowed an additional comparison of the magnitude of year-to-year changes across groups.

Total NIH support. The trajectories that showed the year-to-year changes in total NIH support for the three groups of schools were quite similar (see Figures 8-22, 8-23, 8-24). Because the trajectories were plotted on axes of the same scale, differences in average funding, particularly between schools in low managed care markets (Group 1) and schools in high managed care markets (Group 3), were quite apparent. Like the trajectory for all schools, there was one pattern with small oscillations during the pre-budget-doubling era and another, exponentially increasing pattern for the period in which the NIH budget was doubled.

Differences in the trajectories were apparent in the last several data points. Schools in low managed care markets (Group 1) appeared to have benefited from the increase in the NIH budget in 1997, but the increased funding for these schools was not sustained. Schools in the medium

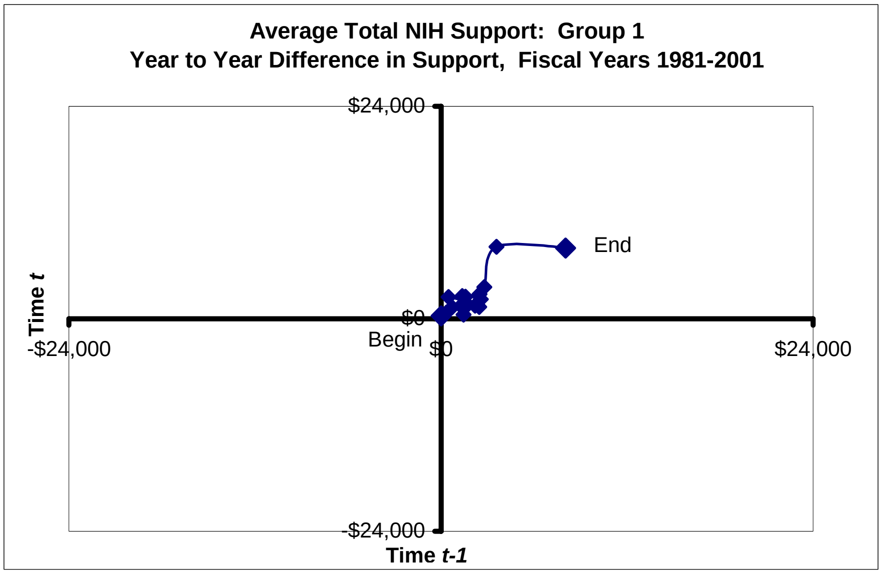

Figure 8-22

managed care markets (Group 2) received increased funding during the early part of the NIH budget-doubling period, but funding dropped in the last year of available data. Schools in high managed care markets (Group 3) were most able to sustain the receipt of NIH funding, but the trajectory for these schools also showed only a slight increase during the last year plotted. These

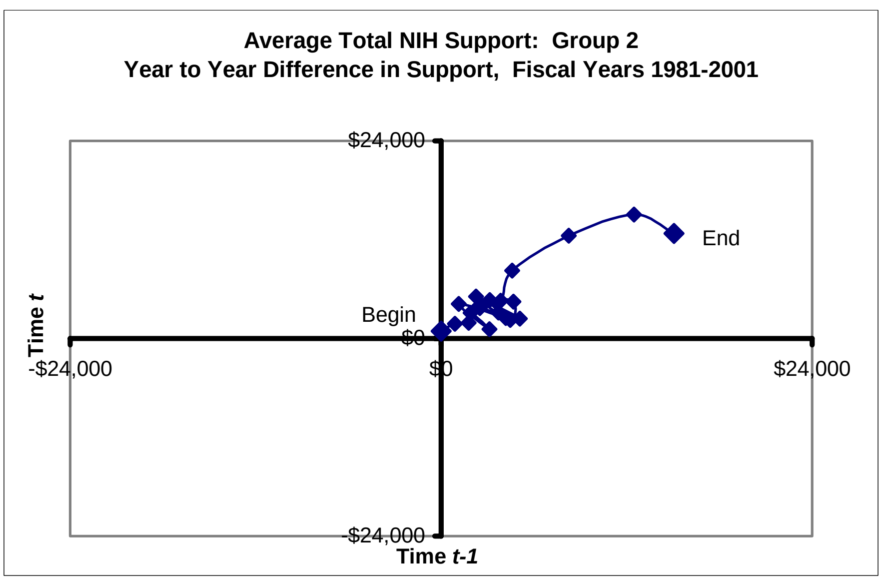

Figure 8-23

differences, and the change in slope of the trajectory were fairly obvious on the phase portrait, but not obvious on the line graph of NIH funding.

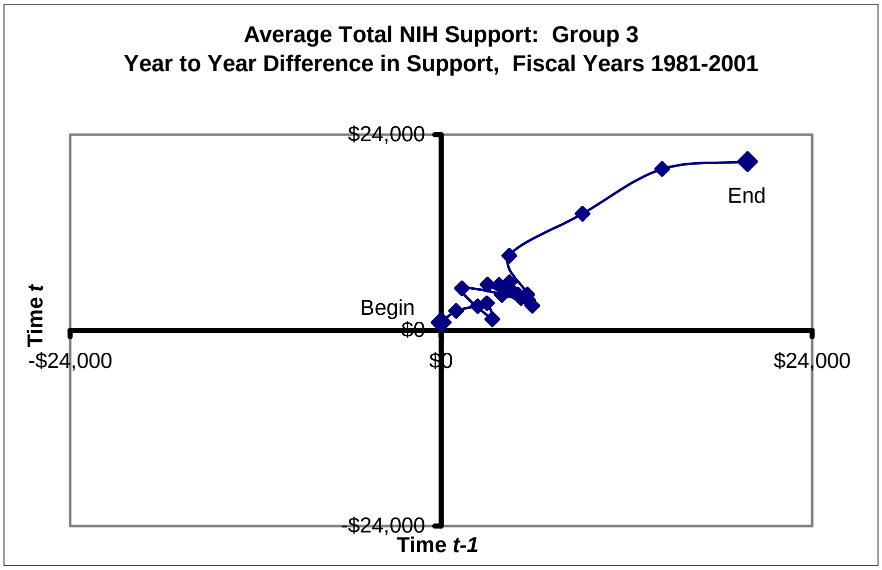

Figure 8-24

NIH support for research grants. Because most NIH support was for research grants, the trajectory of NIH research grant support very closely tracked the average amount of NIH support for all activities (see Figures 8-25, 8-26, 8-27).

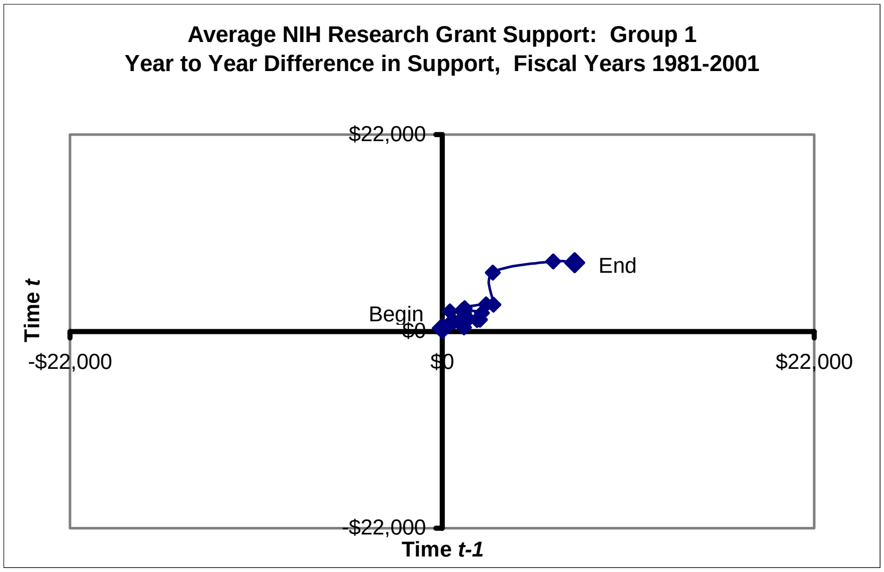

Figure 8-25

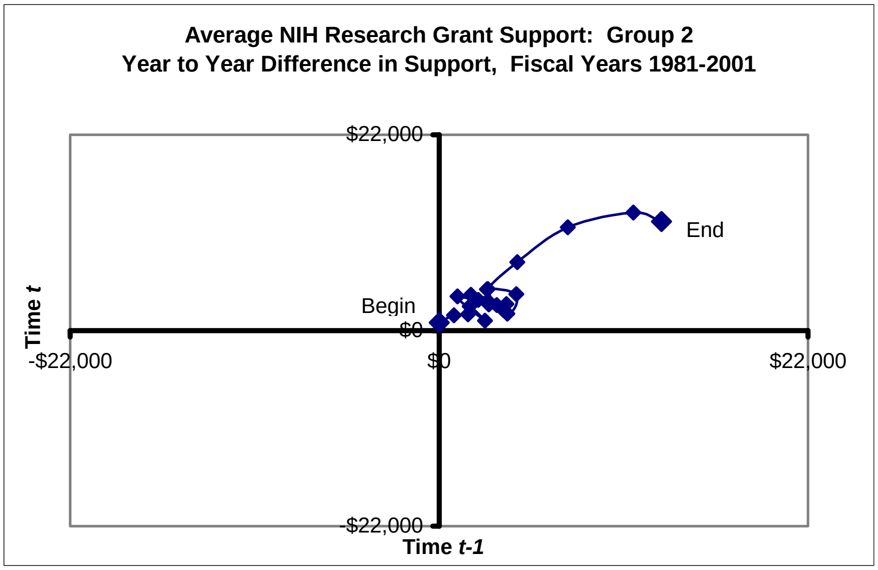

Figure 8-26

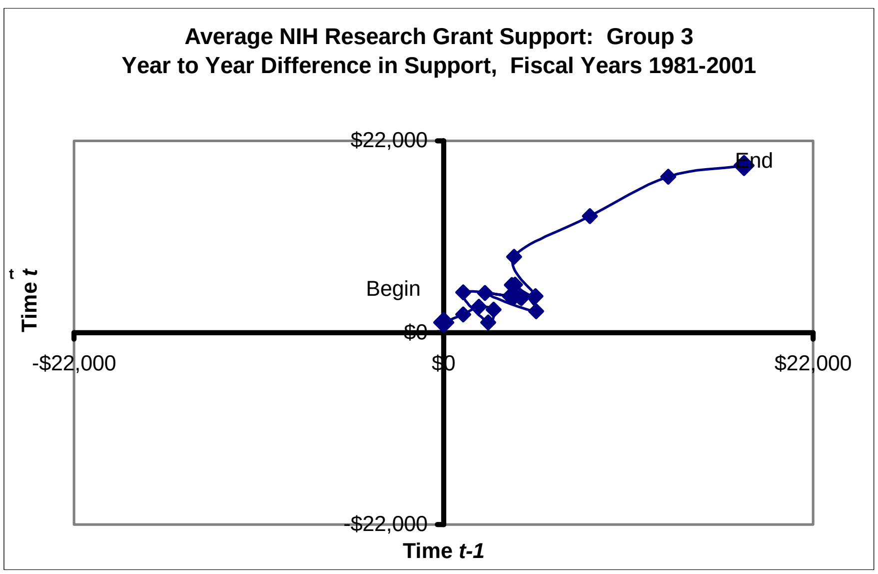

Figure 8-27

NIH support for research training. The trajectories of NIH training grant and fellowship support to the three groups of schools were more dissimilar than the trajectories for NIH total or research grant support. The trajectory of NIH research training support for schools in low managed care markets (Group 1) was tightly centered on coordinate 0,0 until about 1996. Just prior to 1996 the trajectory showed an oscillation, and after 1996 it showed the characteristic exponential increase that was evident in other NIH funding data, but only for one year (see

Figure 8-28). After that, these schools began to receive decreased amounts of training support from NIH.

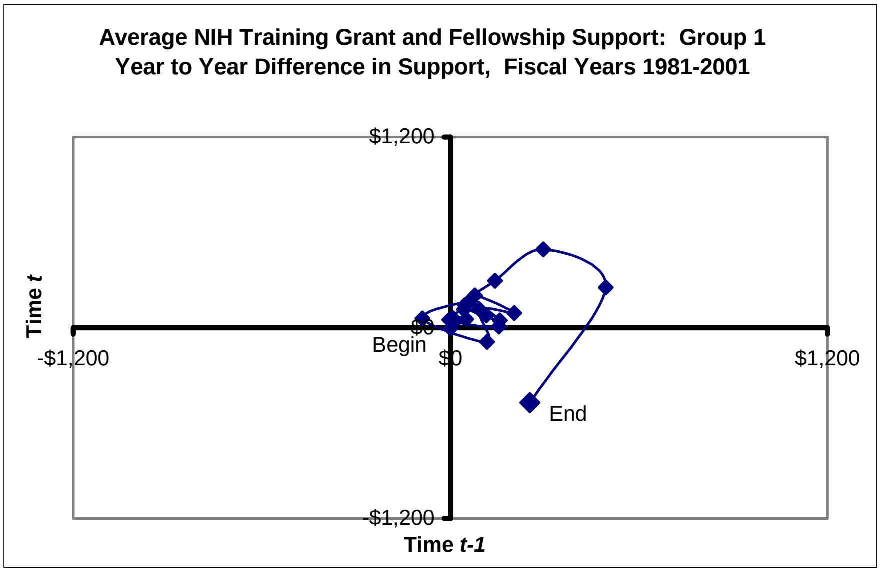

Figure 8-28

The trajectory of NIH training support for schools in medium managed care markets (Group 2) was primarily in Q1, as shown in Figure 8-29.

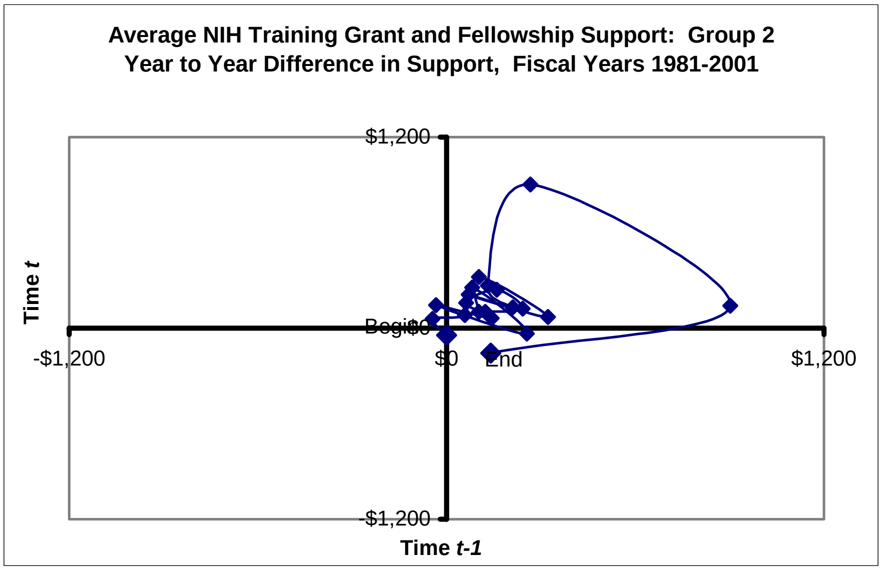

Figure 8-29

It traced a series of compressed orbits that were slowly moving away from coordinate 0,0, and also showed a tendency toward oscillations. A large increase occurred one year later than in Group 1 schools, and was also followed by a smaller increase and a decrease.

The trajectory of NIH research training support for schools in high managed care was similar to that of Groups 1 and 2, but on a larger scale, as shown in Figure 8-30. Both the small orbits and oscillations near coordinate 0,0 and the large and small increases during the budget-doubling era can be seen.

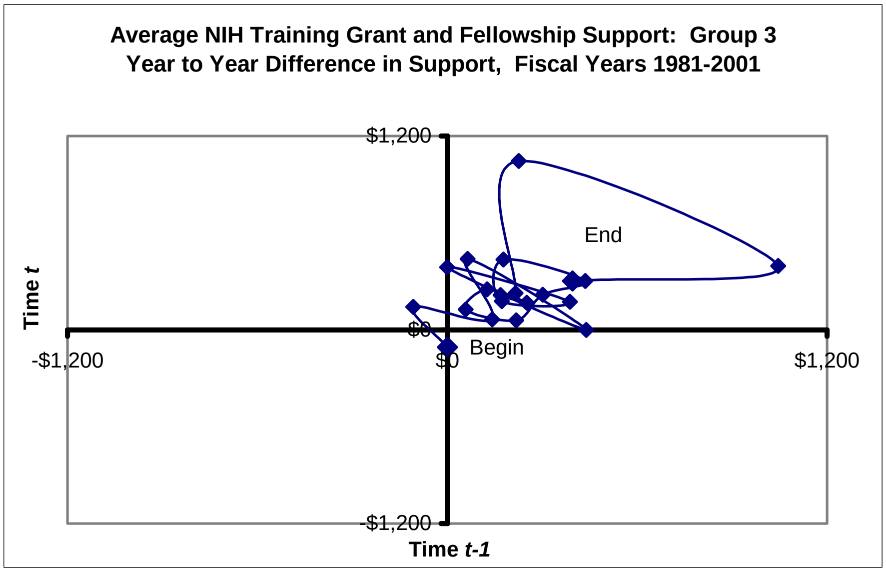

Figure 8-30

XY line graphs of NIH support of medical schools showed steadily increasing values during most of the study period. Phase plane graphs of NIH support showed a cluster of points early in the time period, and a sharply increasing trajectory in Q1 near the end of the study period. The clusters of points were nearest coordinate 0,0 for schools in low managed care markets (Group 1), slightly farther from coordinate 0,0 for schools in medium managed care markets (Group 2), and farthest from coordinate 0,0 for schools in high managed care markets (Group 3). These observations about the clusters of points indicate that the size of annual increases in NIH funding was fairly stable and larger for Group 2 schools than for Group 1 schools, and larger for Group 3 schools than Group 2 schools. The latter portion of the trajectory for each of the three groups differed in the degree to which it approached the upper right-hand corner of Q1, and for the point at which it leveled off or turned downward. Group 3 schools preserved their substantial receipt of NIH funds better than the other two groups of managed care market schools, as evidenced by the "tail" on the latter part of the trajectory of their data. The phase plane graphs revealed not only differences among the three groups of schools, but also differences in the pattern of funding during the pre-budget-doubling and budget-doubling periods of NIH appropriations. These differences were more difficult to discern on the XY graphs, but were quite apparent in the phase portraits.

Institutional Characteristics—Medical Schools by Managed Care Market Group

Each set of three phase portraits (managed care market groups, 1, 2, and 3) was graphed on axes with the same scale. This allowed an additional comparison of the magnitude of year-to-year changes across groups.

Enrollment. The trajectory of year-to-year changes in medical student enrollment at schools in low managed care markets (Group 1) visited all four quadrants, as shown in Figure 8-31.

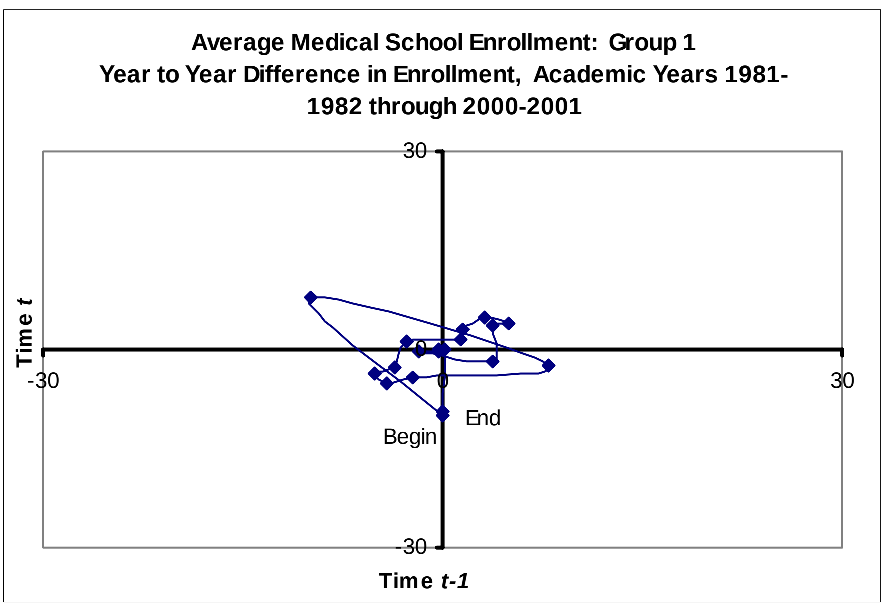

Figure 8-31

In doing so, it converged on coordinate 0,0 in 1998, indicating that this variable had reached stable equilibrium. However, in the last year in which data were available, the trajectory dropped, moving away from coordinate 0,0. This may have signaled a move away from equilibrium or it may have been a one-year aberration.

The trajectory of student enrollment at schools in medium managed care markets (Group 2) made one orbit through all four quadrants during the first half of the study period, as shown in Figure 8-32. It began to trace a second orbit but reversed course and oscillated between Q4 and Q2 instead. This was followed by another partial orbit near the end of the study period, after which the trajectory appeared to begin another series of oscillations. Over time, enrollment in this group of schools appeared to approach stable equilibrium on two occasions.

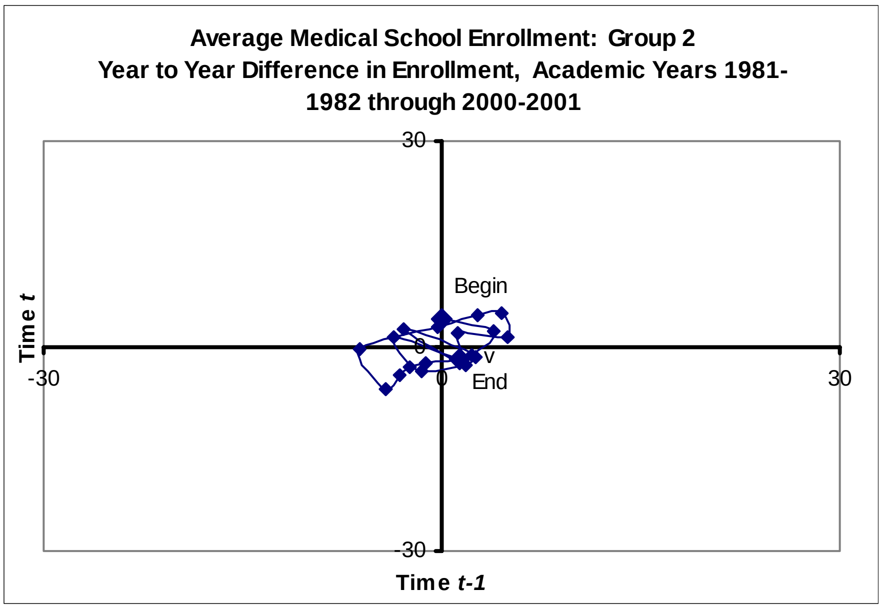

Figure 8-32

The trajectory of medical school enrollment at schools in high managed care markets (Group 3) showed the most variability, as shown in Figure 8-33. The trajectory first makes a partial orbit through three quadrants and then executes an unusually small orbit entirely within Q3. This was followed by a larger orbit through all four quadrants and ended with two sets of oscillations. It was difficult to discern whether the underlying attractor was one that takes more than 20 data points to become clear or whether two or more attractors were operational during the study period.

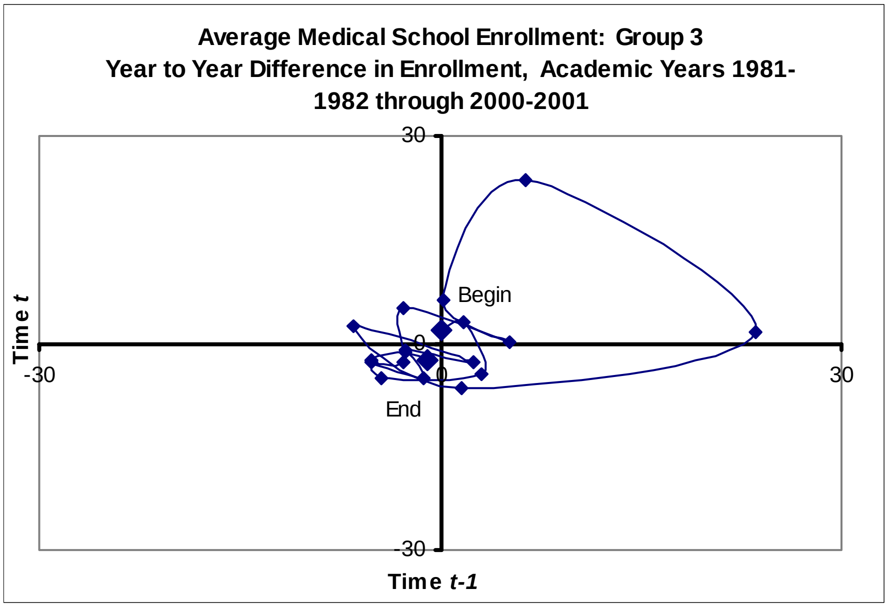

Figure 8-33

Graduates. The trajectories of the average number of medical students graduating from schools in each of the three managed care market groups visited all four quadrants (see Figures 8-34, 8-35, 8-36). Each of the trajectories was also composed of a combination of orbits and oscillations. Schools in medium managed care markets (Group 2) showed the smallest amount of year-to-year variation as well as the most prominent oscillations. The phase portraits identified differences in the variability of the average number of graduates in the three managed care market groups. The shape of the trajectories also showed the limits or boundaries of the values within which the average number of graduates would be expected to vary.

Faculty. The trajectories of the average number of medical school faculty at schools in each of the three managed care market groups were primarily or exclusively located in Q1 (see Figures 8-37, 8-38, 8-39). There was evidence in each trajectory of several iterations of oscillations; that is, the size and/or direction of the year-to-year changes in the average number of faculty

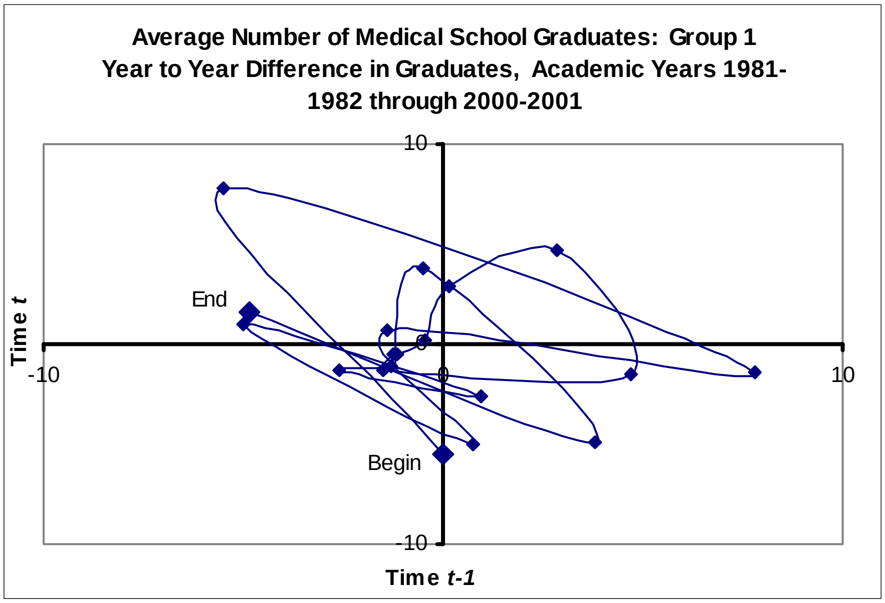

Figure 8-34

systematically alternated over a period of years. These occurred in 1989-1991 in the data for schools in high managed care markets (Group 3), in 1991-1993 for schools in medium managed care markets (Group 2), and in 1994-1996 for schools in low managed care markets (Group 1). The sequence of the onset of oscillations—occurring first in schools in high managed care

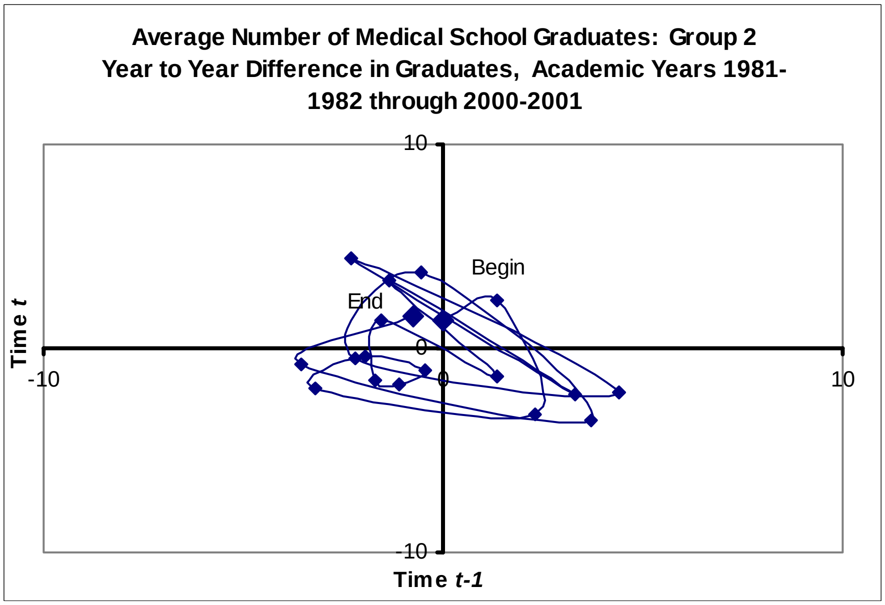

Figure 8-35

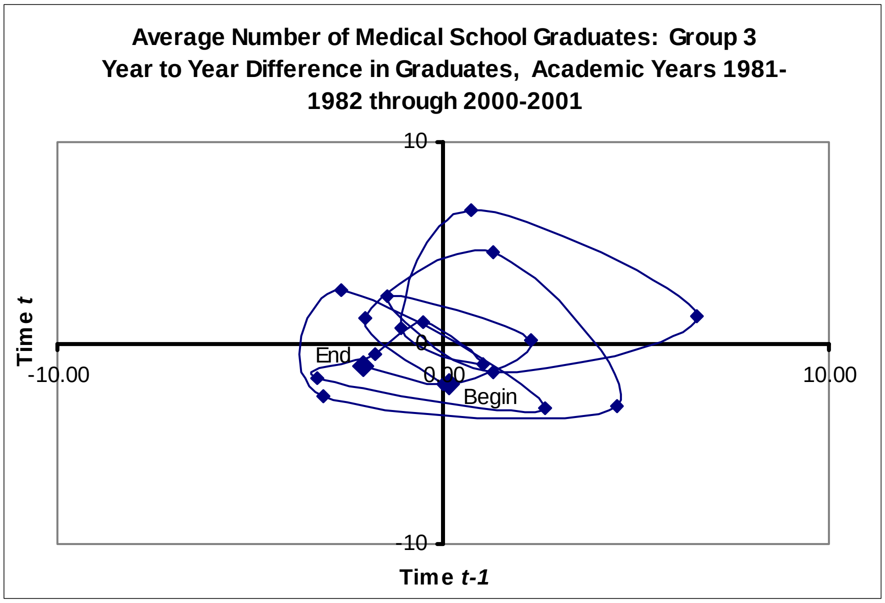

Figure 8-36

markets—suggests the possibility of a relationship between managed care and a change in the pattern of staffing of medical school faculty toward a stable equilibrium. In addition, the trajectory of the average number of medical school faculty at Group 1 schools showed a tendency to settle into a small cluster of points early in the study period (1987-1989) and again in 1993.

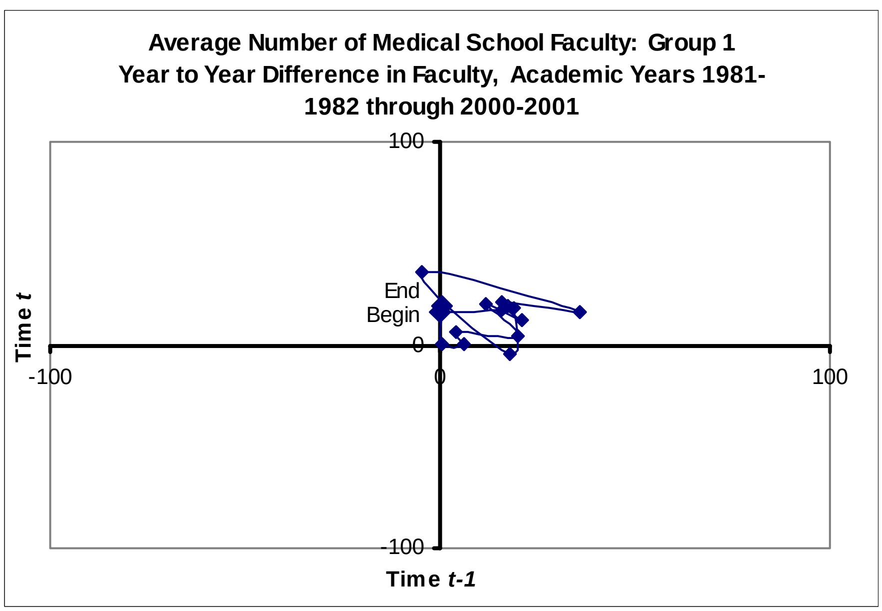

Figure 8-37

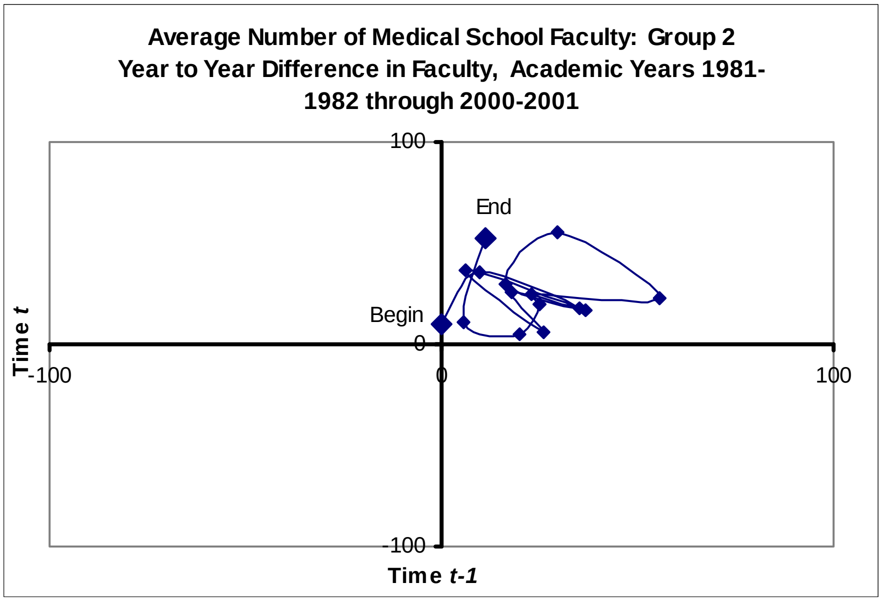

Figure 8-38

The trajectories of the average number of clinical faculty were slightly easier to visually inspect because there were fewer data points. The trajectories were primarily or exclusively located in

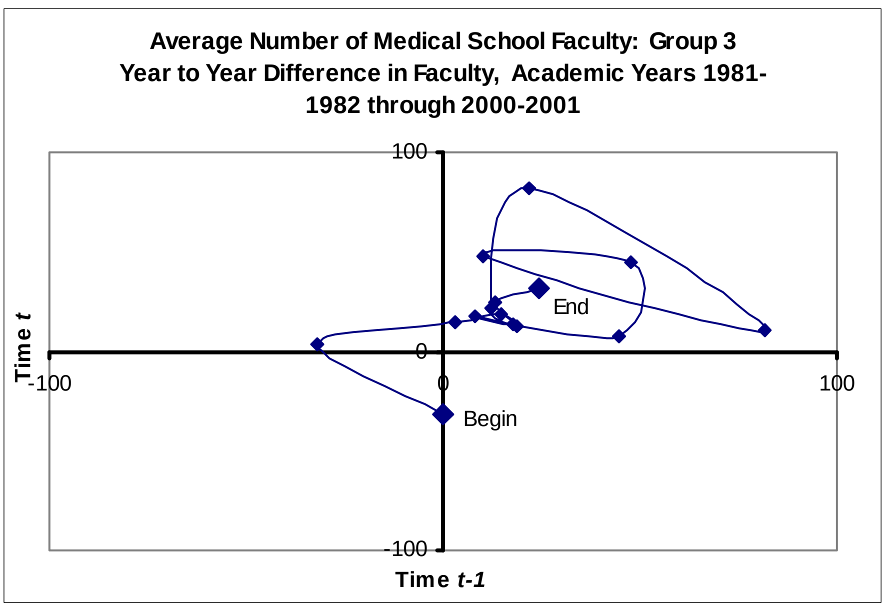

Figure 8-39

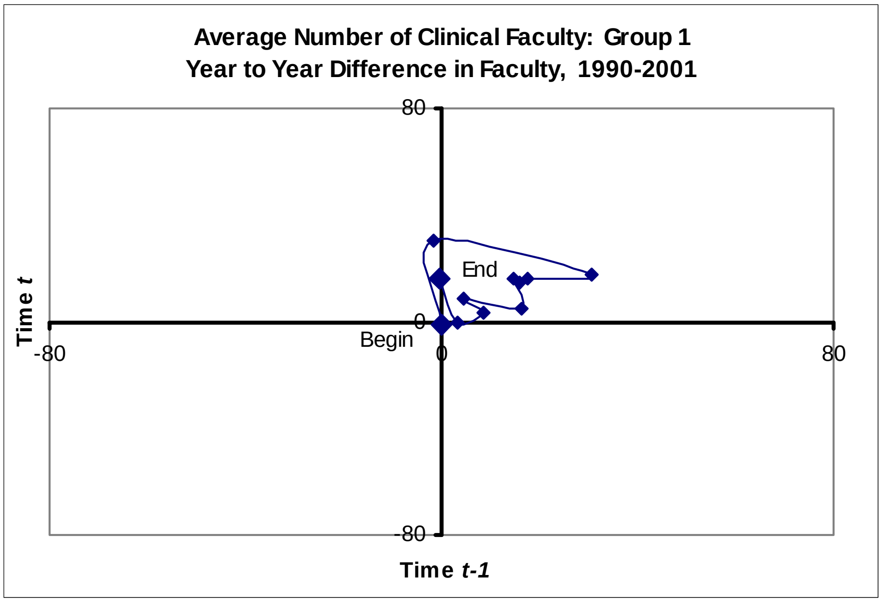

Figure 8-40

Q1 (see Figures 8-40, 8-41, 8-42). Although they were all located in Q1, each had a different shape and boundaries of different sizes. The trajectory of the average number of clinical faculty at schools in high managed care markets (Group 3) showed the greatest variation and boundary size.

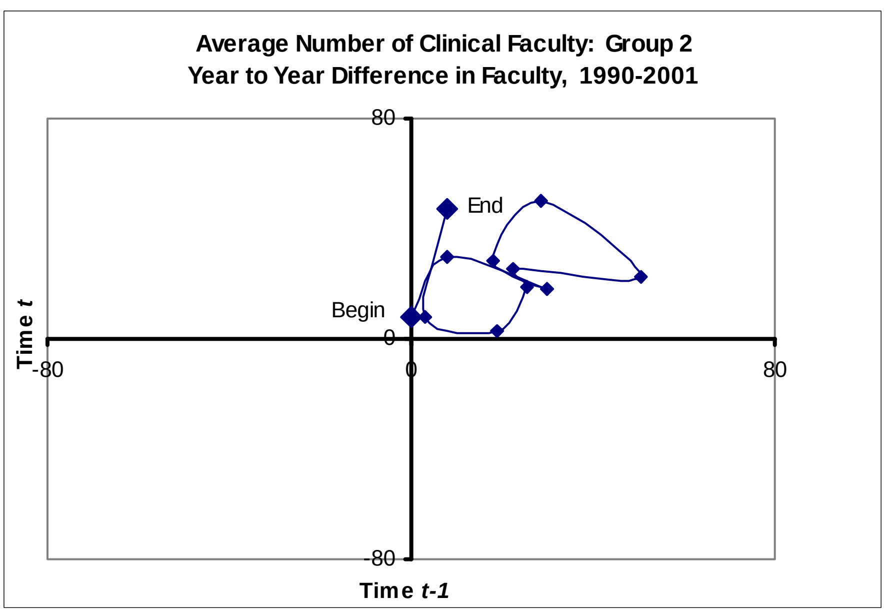

Figure 8-41

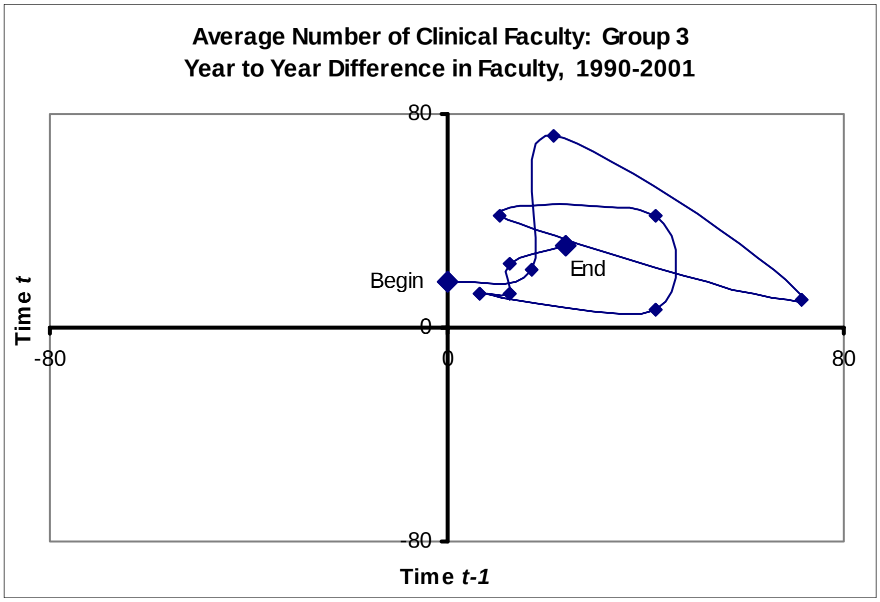

Figure 8-42

The trajectory of the average number of clinical faculty at schools in medium managed care markets (Group 2) had two non-overlapping orbits, suggesting an underlying chaotic attractor. The trajectory traced half of the lower orbit (nearest coordinate 0,0), the entire second orbit, and then the second half of the lower orbit.

The three trajectories of the average number of basic science faculty were more similar in general shape than the trajectories of data for all faculty and clinical faculty (see Figures 8-43, 8-44, 8-45). All three trajectories also visited all four quadrants of the phase plane, and the limits within which the year-to-year changes were likely to occur are apparent. Like the trajectory of the average number of clinical faculty, schools in high managed care markets (Group 3) showed the greatest variation and year-to-year difference in the average number of basic science faculty.

Total teaching responsibility. The trajectories of the average total teaching responsibility of faculty at schools in the three managed care market groups were characterized by oscillations see Figures 8-46, 8-47, 8-48). The trajectories of average total teaching responsibility of faculty at schools in medium (Group 2) and high (Group 3) managed care markets showed the trajectory oscillations at the end of the period for which data were available, 1997-1999. The trajectory of

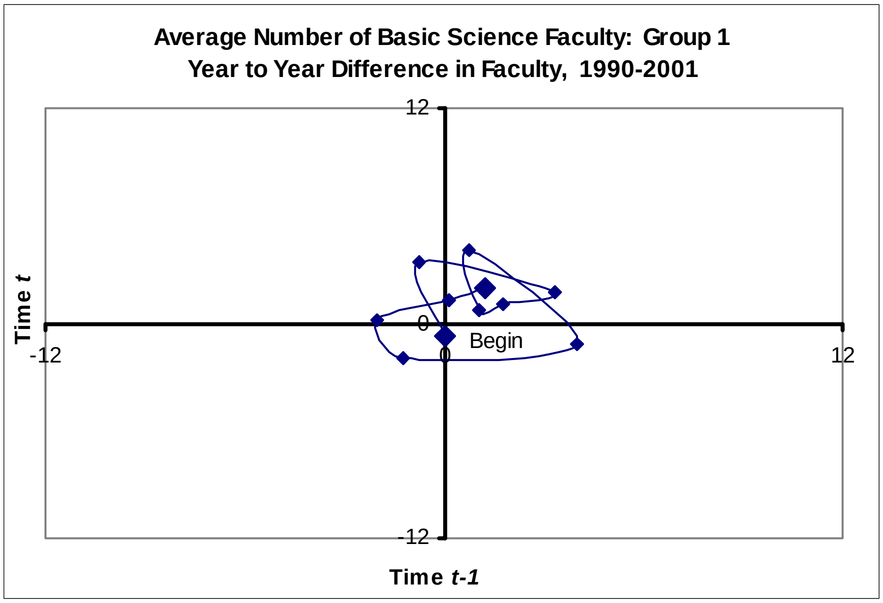

Figure 8-43

the total teaching responsibility data for faculty at schools in low managed care markets (Group 1) showed two periods of small oscillations—

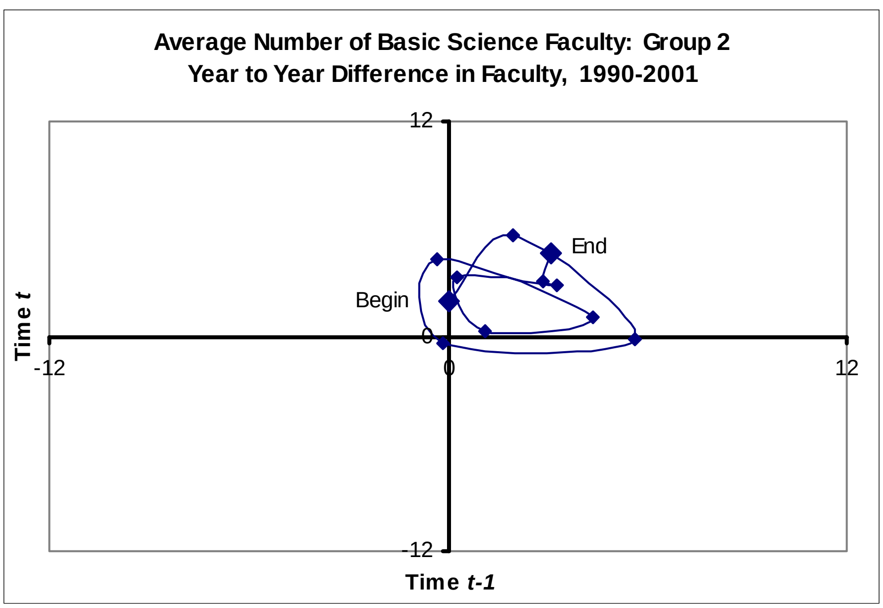

Figure 8-44

1986-1988 and 1991-1993. The underlying attractors implied by these trajectories can be interpreted as fairly stable two-cycle or four-cycle periodic attractors. With enough data points, the behavior of the system is likely to resemble the sample phase plots in chapter 5, where *a* = 3.4 or 3.5.

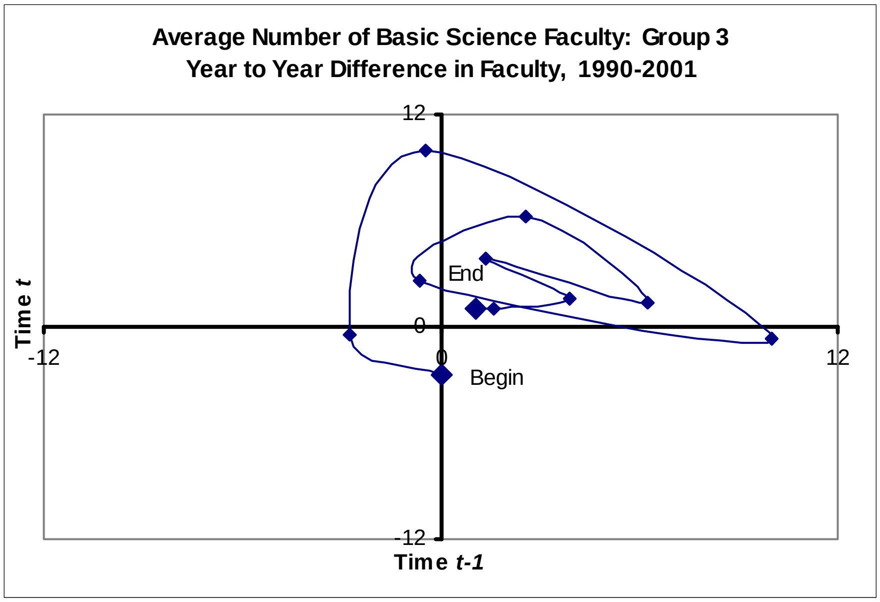

Figure 8-45

The trajectory of the data for teaching responsibility for residents at schools in low managed care markets (Group 1) was characterized by small oscillations near the coordinate 0,0 during most of the period for which data were available, as shown in Figure 8-49. The trajectory of the data for teaching responsibility for residents at schools in medium managed care markets (Group 2) was characterized by two periods of oscillations—1982-1985 and 1994-1996, as shown in Figure 8-50. The trajectory of the data for teaching responsibility for residents at schools in high managed care markets (Group 3) was characterized by a clustering of data points near coordinate 0,0 during two periods—1981-1986 and 1992-1996, as shown in Figure 8-51. These trajectories showed both periods of stability—either oscillating between two points or clustered at one point—interspersed among periods of instability in the system as the trajectory traced orbits that visited all four quadrants of the phase plane. This qualitative analysis suggests specific time periods that would be of particular interest.

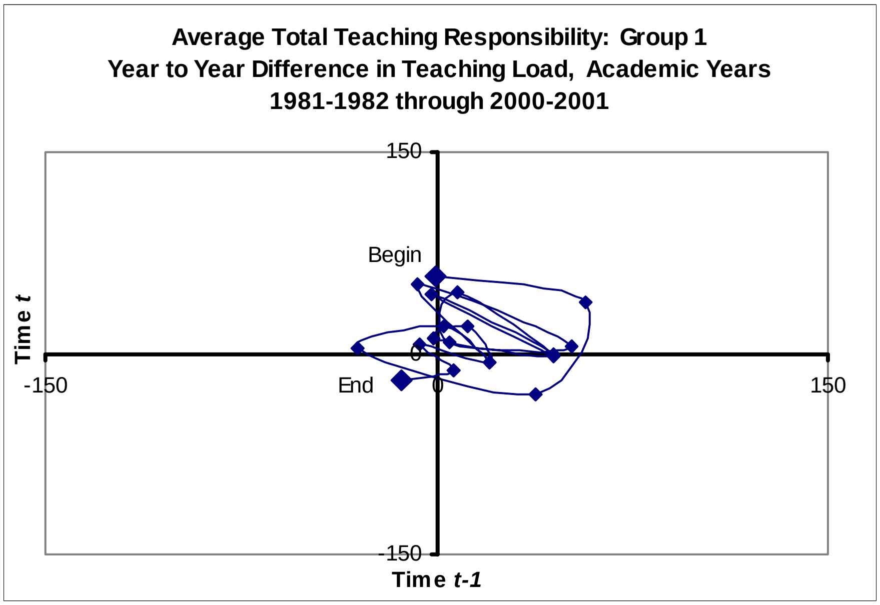

Figure 8-46

The trajectory of the data describing teaching responsibility for master's and doctoral students at schools in low managed care markets (Group 1) was characterized by a series of increasingly smaller orbits centered on coordinate 0,0, as shown in Figure 8-52. The trajectory appeared to be

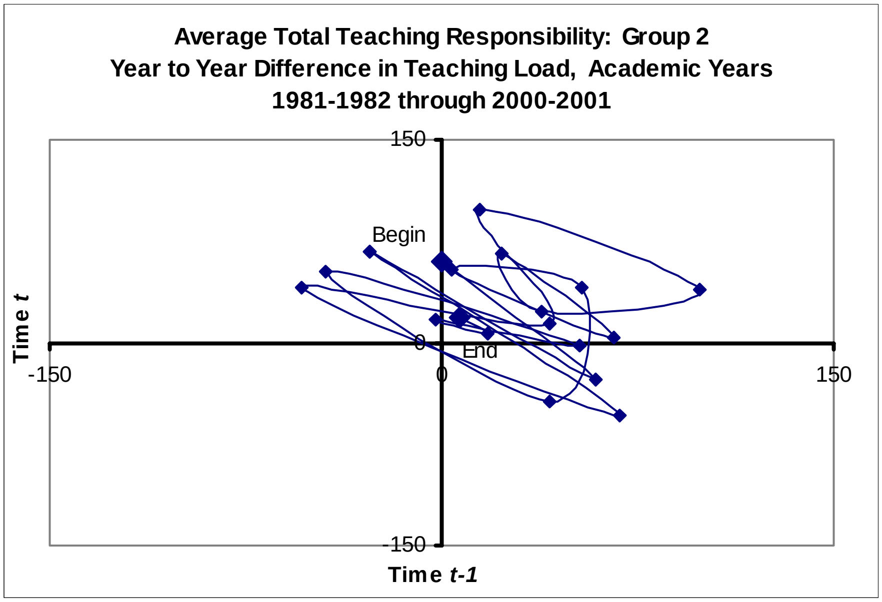

Figure 8-47

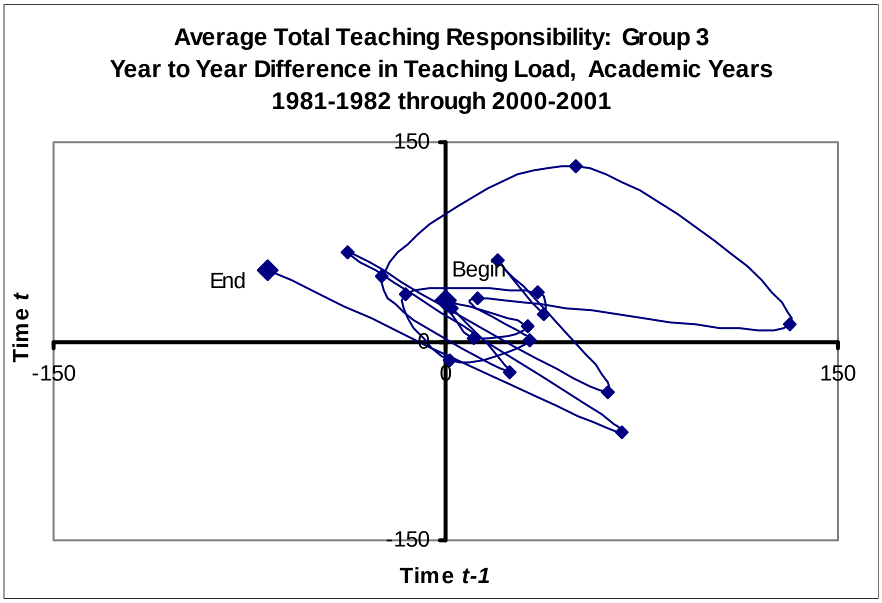

Figure 8-48

converging on a single small area, but at the end of the study period it traced another larger orbit. The trajectory of the data for teaching responsibility for master's and doctoral students at schools in medium managed care markets (Group 2) looked similar to the trajectory for Group 1, but was

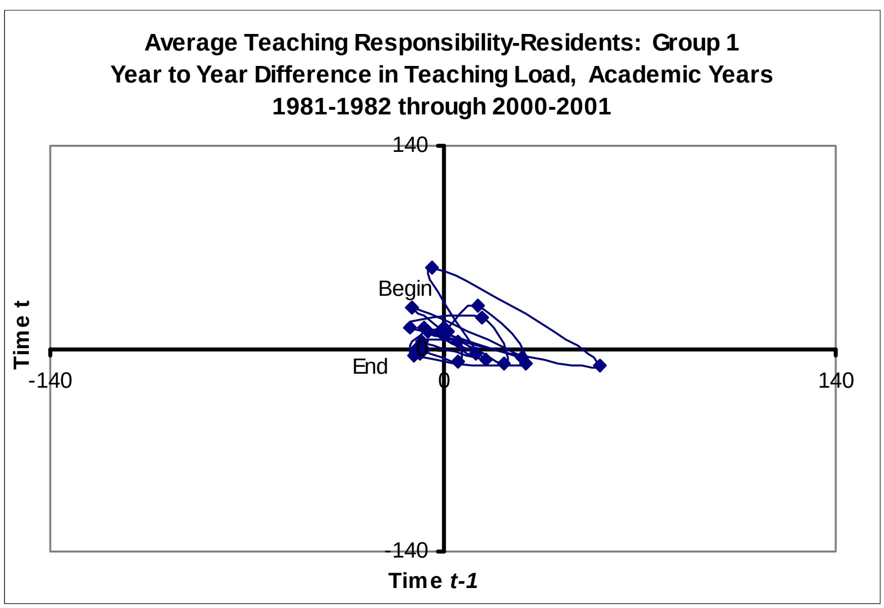

Figure 8-49

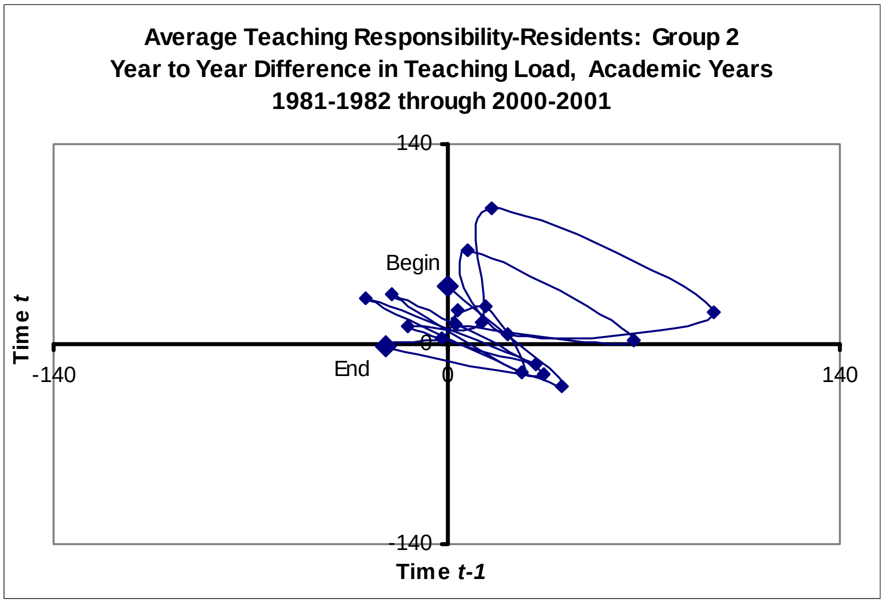

Figure 8-50

characterized by several small, abrupt changes in the direction of the trajectory, as shown in Figure 8-53. Overall, the trajectory for Group 2 was the most tightly bounded of the three groups, and was centered a little to the right of coordinate 0,0. The trajectory of the data for

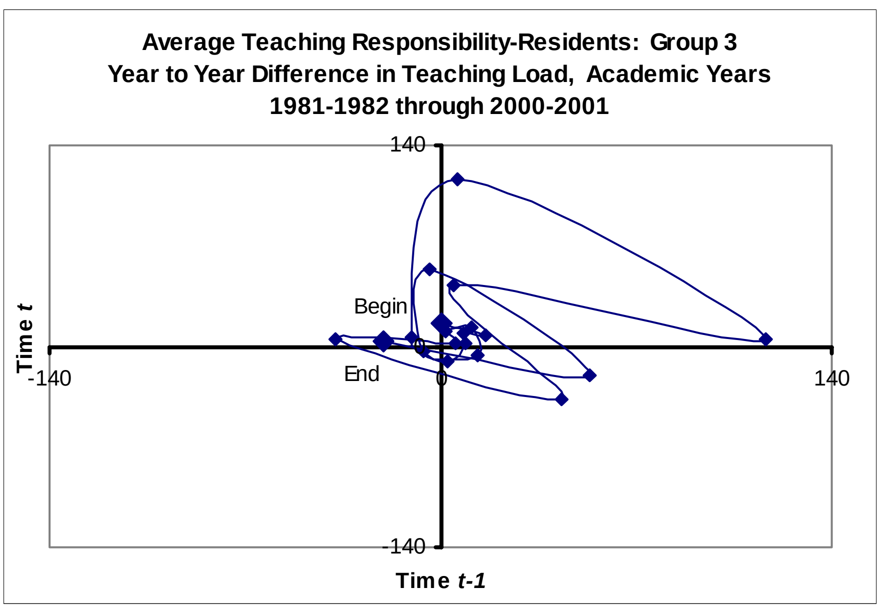

Figure 8-51

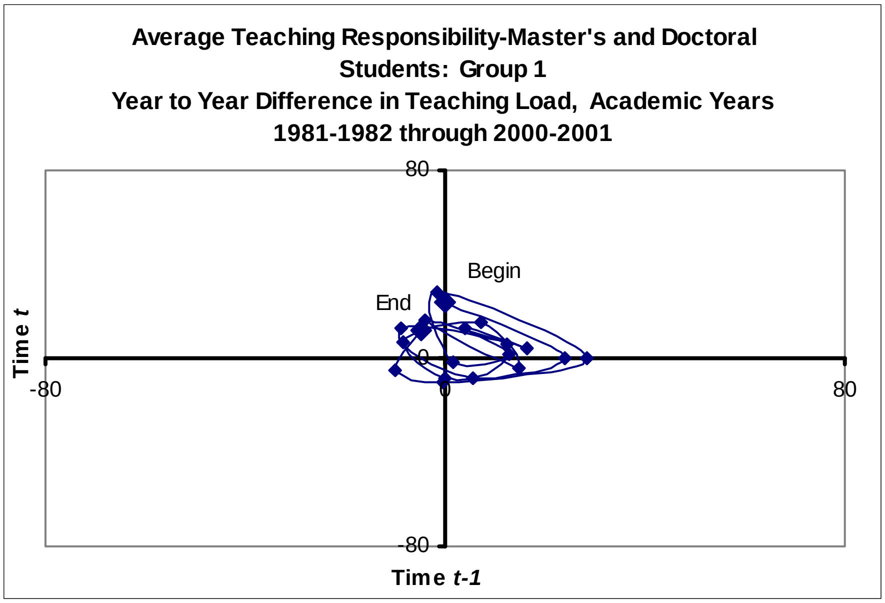

Figure 8-52

teaching responsibility for master's and doctoral students at schools in high managed care markets (Group 3) was characterized by a series of increasingly smaller orbits located primarily in Q1 during most of the period for which data were available, as shown in Figure 8-54. From

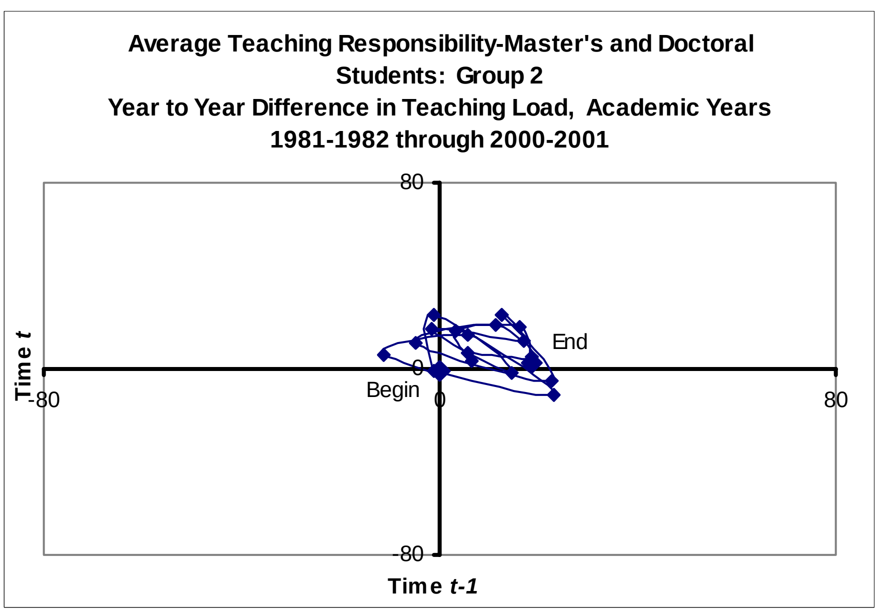

Figure 8-53

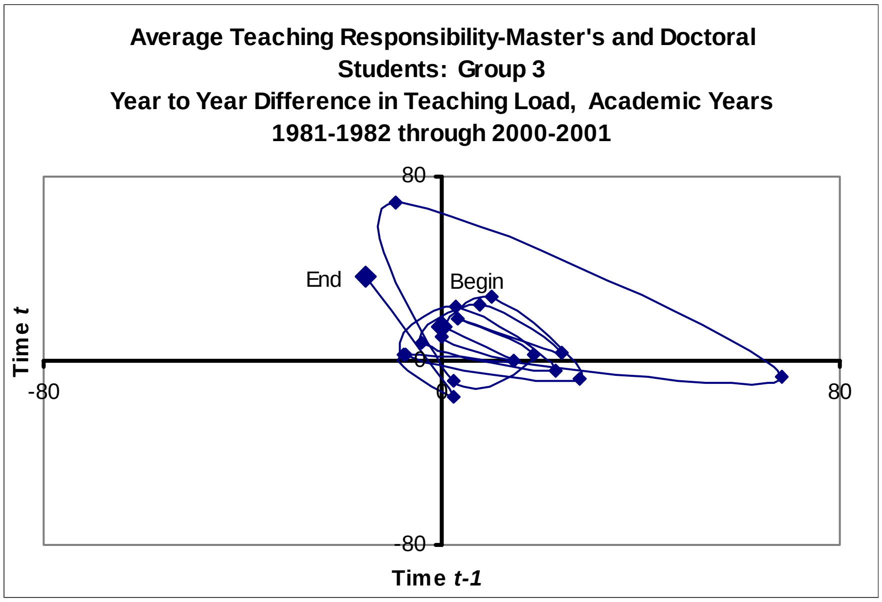

Figure 8-54

1995 through the end of the study period, the trajectory traced a single large orbit through all four quadrants. These trajectories passed through all four quadrants but were not round orbits. A qualitative description of their shape would place them between a periodic oscillation and a chaotic or strange attractor. The Group 3 data in particular suggested the possibility of a higher-n periodic attractor (e.g., an 8-limit or 16-limit cycle). If these data represent such an attractor, and a graphical analysis of twenty data points would not by itself allow this determination, then it follows that for this data variable schools in high managed care markets were closer to a chaotic state than schools in other managed care markets.

Medical school administrative staff. Unlike several of the other variables in the study model, the size or "boundedness" of the trajectories of marginal changes in the average number of medical school administrative staff positions was approximately the same for schools in all three managed care market groups. The trajectory of the number of medical school administrative staff positions at schools in low managed care markets (Group 1) visited all four quadrants of the phase plane, as shown in Figure 8-55. This was also true of the trajectory of data for the number of medical school administrative staff positions at schools in high managed care markets (Group 3), although in this group of schools a greater portion of the area of the trajectory was located in

Q1, as shown in Figure 8-56. The size of the orbits of the trajectory increasingly became larger toward the end of the period for which data were available. The trajectory of the number of medical school administrative staff positions at schools in medium managed care markets (Group 2) twice briefly visited a position near coordinate 0,0, implying a convergence on a stable equilibrium, but was otherwise characterized by orbits that were primarily confined to Q1, as shown in Figure 8-57. None of these trajectories were interpreted as representing a system in stable equilibrium.

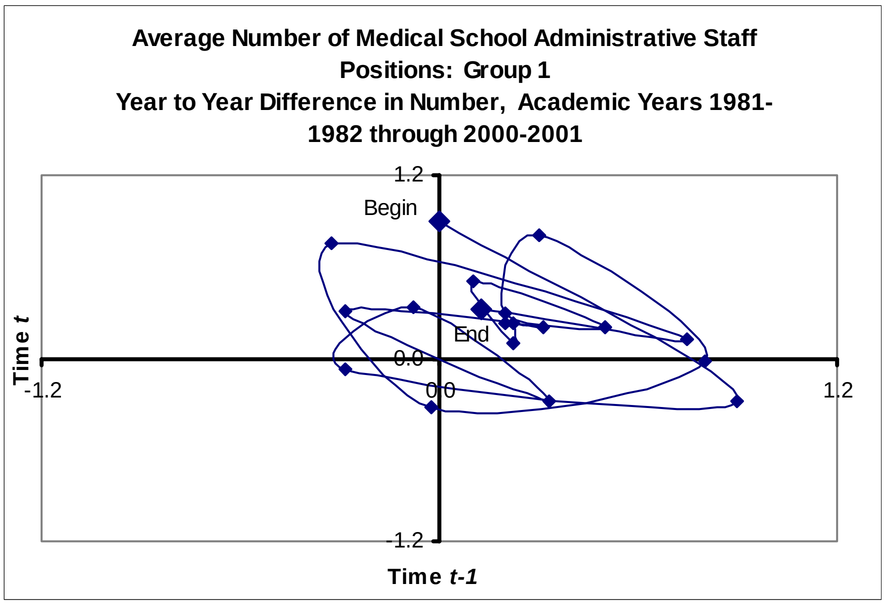

Figure 8-55

The trajectories of the percentage of medical school administrative staff positions that were the same as the prior year at schools in the three managed care market groups all visited all four quadrants of the phase plane (see Figures 8-58, 8-59, 8-60). The trajectory of data for schools in low managed care markets (Group 1) showed a series of smooth orbits interrupted by movement toward coordinate 0,0. The trajectory of data for schools in medium managed care markets (Group 2) showed a tendency to cluster low in Q1 during the early portion of the study period, although orbits later in the study period appeared to be converging on coordinate 0,0. This trajectory also showed the least amount of variability. The trajectory of data for schools in high managed care markets (Group 3) was characterized by increasingly larger orbits that visited all four quadrants of the phase plane; the trajectory also transitioned to oscillations between Q4 and

Q2 in 1989 through 1993. None of these trajectories indicated that the system represented on the phase portrait was at stable equilibrium throughout the study period.

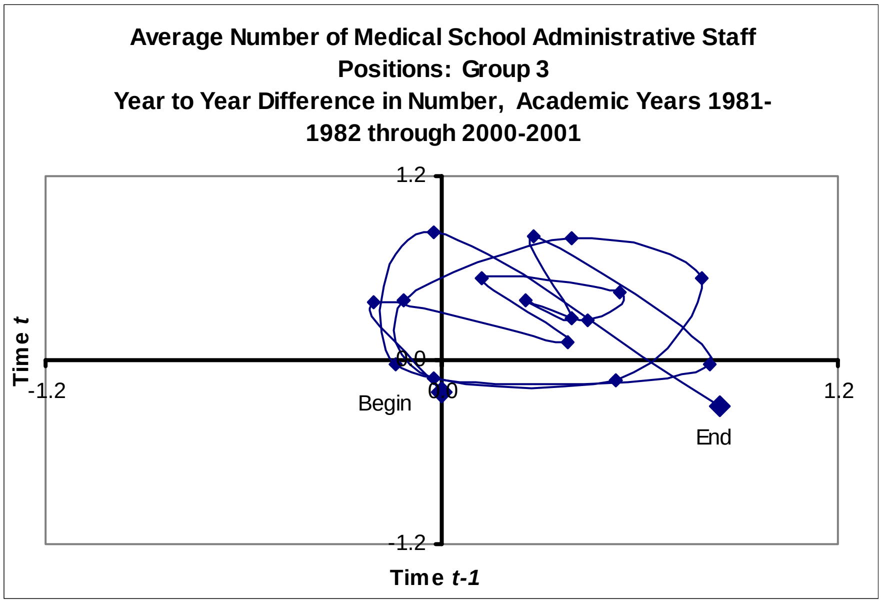

Figure 8-56

Clinical facilities. The trajectories of the data describing the average number of clinical facilities with which medical schools had reported affiliations each visited all four quadrants of the phase plane (see Figures 8-61, 8-62, 8-63). The year-to-year changes in the average number of clinical affiliations at schools in low managed care markets (Group 1) were the most volatile of any group. The number of data points in the trajectory below the horizontal axis reflected the decrease in average clinical affiliations in Group 1 during the study period. The trajectory of the data for the average number of clinical affiliations at schools in medium managed care markets (Group 2) traced a series of three orbits of increasing size. This pattern was interrupted in 1994, as the direction of the trajectory changed and began to oscillate at the end of the study period, suggesting an underlying periodic attractor and increased stability. The trajectory of the data for the average number of clinical affiliations at schools in high managed care markets (Group 3) traced the most tightly bounded orbits. They were characterized by several sets of unusual oscillations that alternated between Q4 and Q1 and Q4 and Q2.

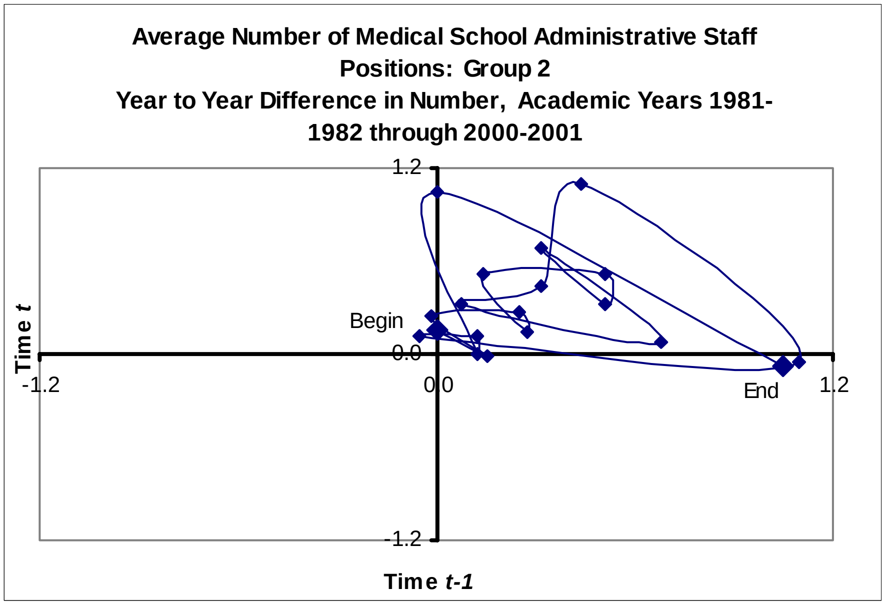

Figure 8-57

The trajectories of the data describing the percentage of clinical affiliations that were the same as the prior year at medical schools in each of the three managed care markets are shown in Figures 8-64, 8-65, 8-66. The trajectory of data for schools in low managed care markets (Group 1) visited all four quadrants of the phase plane and traced a figure eight across the quadrants. A brief period of oscillations appeared in 1987-1989. The trajectory of data for schools in medium

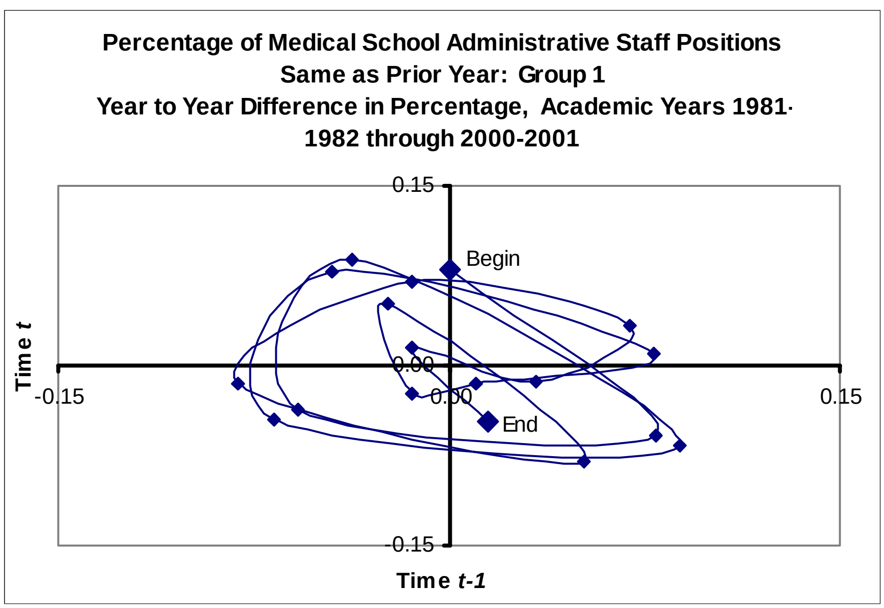

Figure 8-58

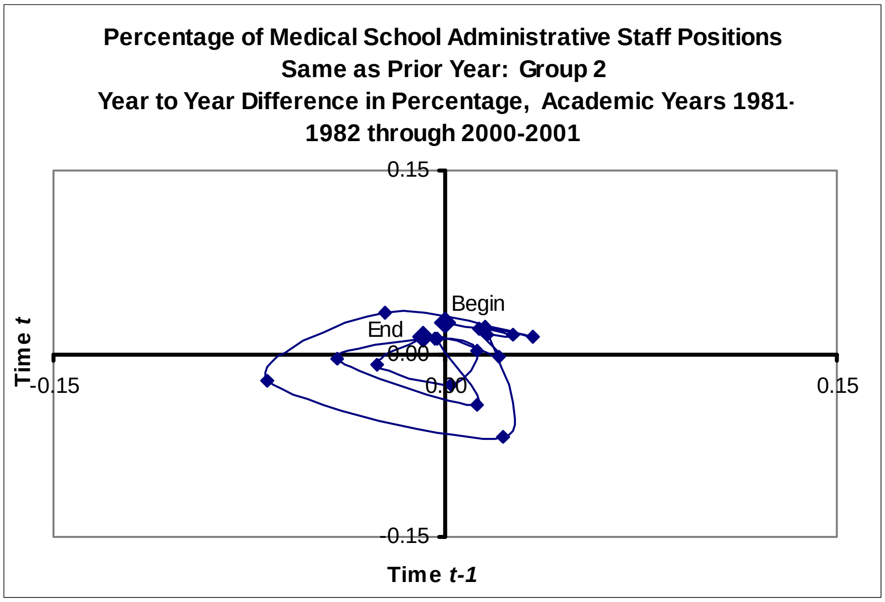

Figure 8-59

managed care markets (Group 2) showed two periods in which the trajectory appeared to converge on coordinate 0,0—1987-1989 and 1996-1999. In other time periods, the trajectory orbited through all four quadrants. The trajectory of data for schools in high managed care

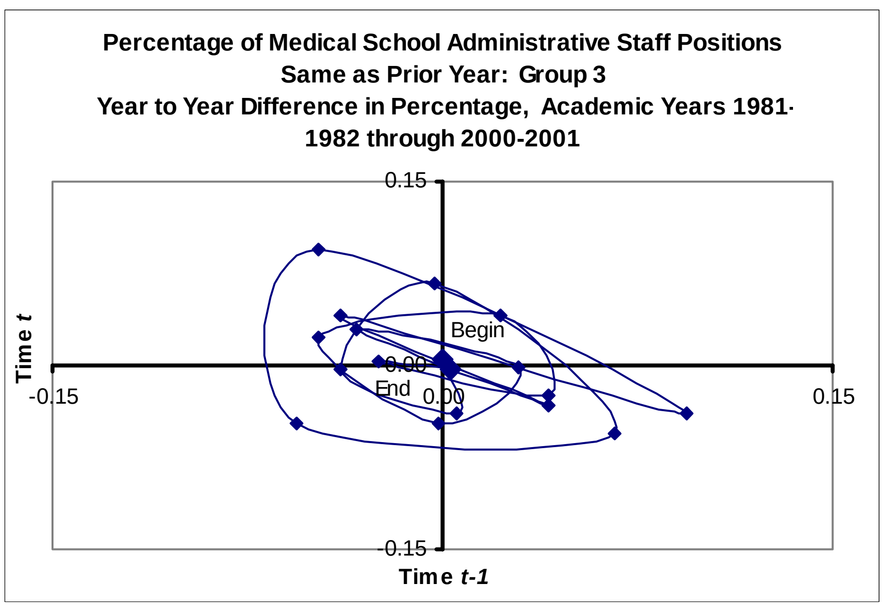

Figure 8-60

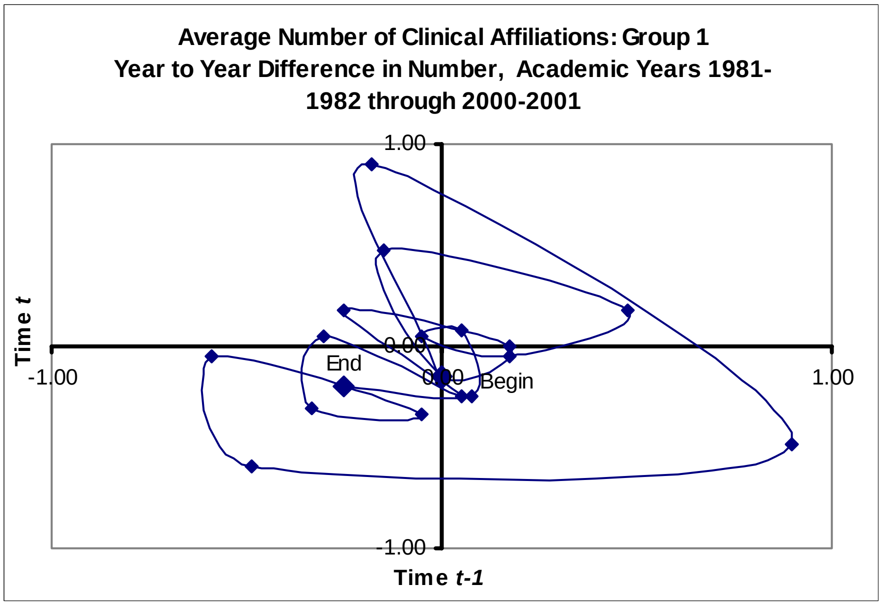

Figure 8-61

markets (Group 3) traced two increasingly larger orbits and then settled into a stable pattern near coordinate 0,0. Although the average number of clinical affiliations reported by schools in high managed care markets varied less than at schools in low and medium managed care markets, the size of the year-to-year changes in Group 3 schools was about the same as the other two groups.

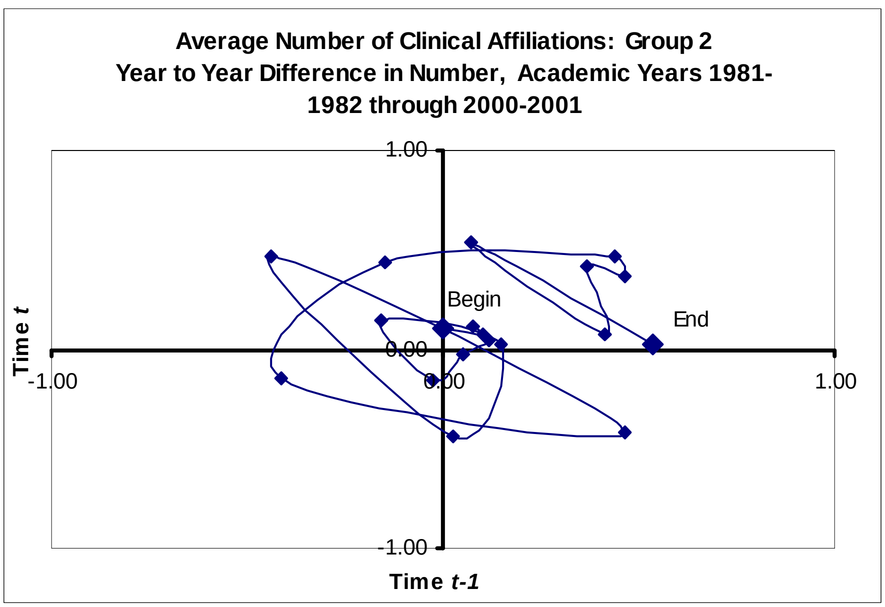

Figure 8-62

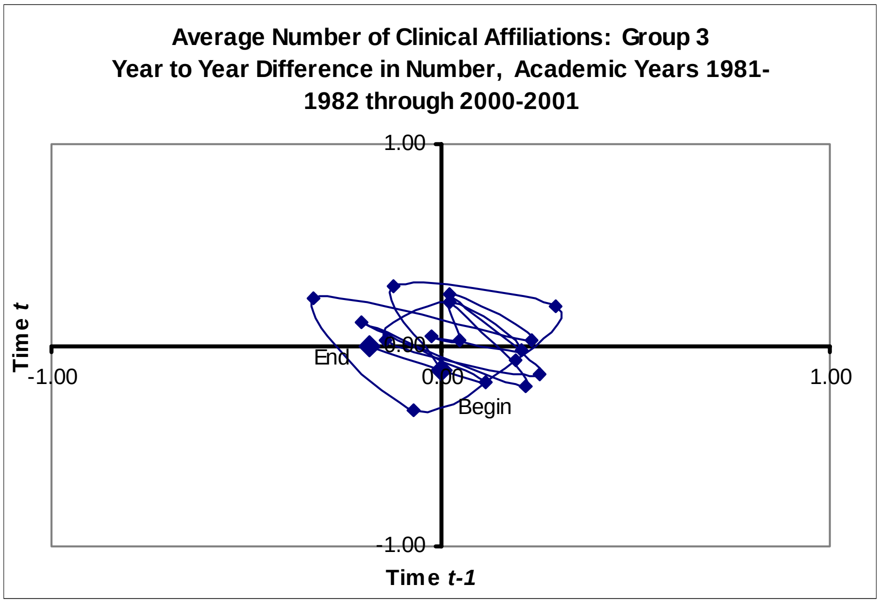

Figure 8-63

The phase portraits presented in the preceding sections added to the rich description of the AMC system by illuminating the qualitative nature of the underlying attractors that described the financial and institutional characteristics' study variables. The line graphs presented in chapters 6

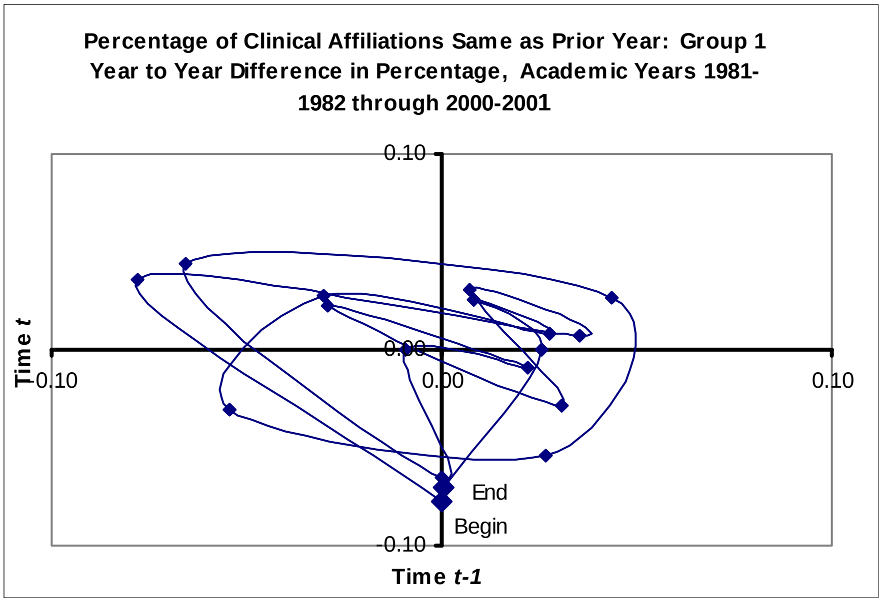

Figure 8-64

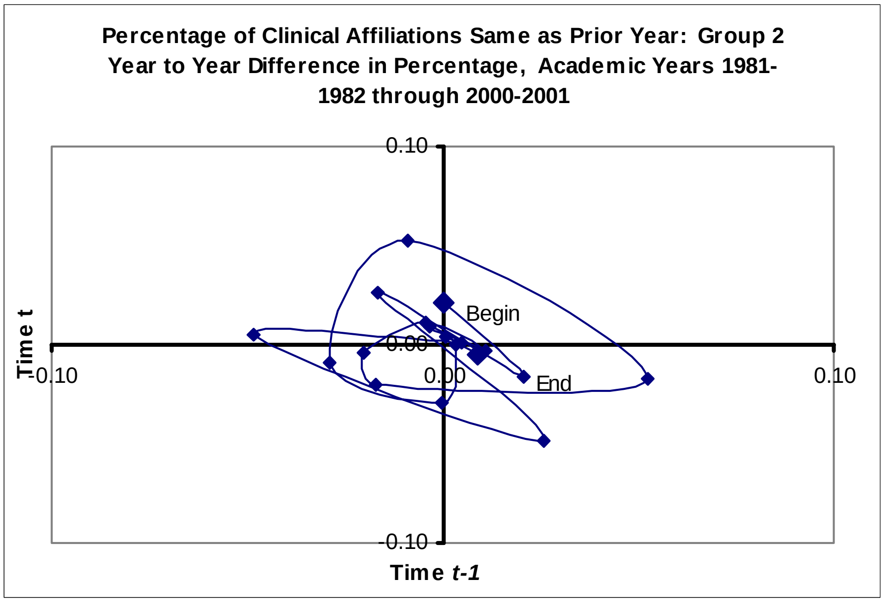

Figure 8-65

and 7 offered an indication that these variables were primarily nonlinear; the phase plane graphs here in chapter 8 offered an indication of the patterns of nonlinear behavior. Both types of graphs provided value to this research study by revealing different aspects of the AMC system: line

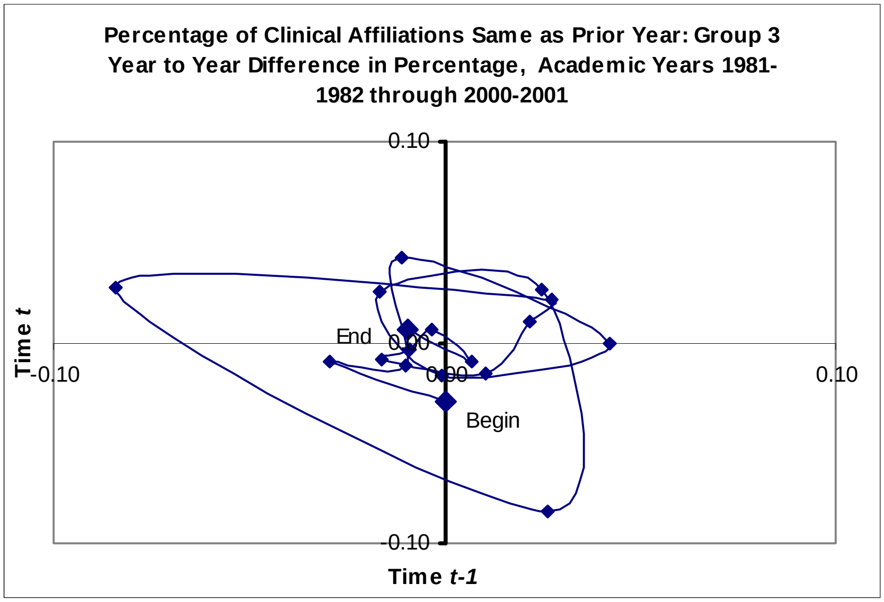

Figure 8-66

graphs helped establish the presence of nonlinearity, and phase portraits helped reveal the nature of the behavior, probable limits of behavior, and underlying structure of the system.

The phase portraits revealed that periodic attractors, i.e., trajectories that oscillated between diagonally opposite quadrants, were more common than point attractors, i.e., trajectories that settled down to one point. Both of these attractors implied stability in the system but the periodic attractor implied a more complex—a more nonlinear—system. The other notable result was that many of the attractors appeared to change over the study period. In particular, the attractors traced by the trajectories of a number of the variables appeared to change from periodic to chaotic, or vice versa. In some cases, the two kinds of attractors alternated during the twenty-year study period. This observation highlights the "messy" nature of real data and underscores the difficulty of long-term prediction in nonlinear dynamic systems.

The final section of this chapter presents the results of analyses designed to mathematically confirm the presence of nonlinearity in the variables describing the AMC system.

Nonlinear Mathematical Analyses

Preliminary indication that many of the variables in the study model exhibited nonlinearity was obtained by using Excel to fit a trend line to the data (see chapter 7). To confirm mathematically that the observed data were nonlinear and to obtain a specific mathematical description of the data, selected data series were analyzed using the MATLAB functions and program described in chapter 5 of this dissertation. Entering the data values for observed and predicted data from MATLAB to Excel and calculating the sum of squared differences between the two sets of data completed this confirmatory analysis.

The mathematical descriptions obtained in the MATLAB analyses provided a tool for generating predicted data. The data that were generated and compared to the observed data were generated for the same period of time as the observed data, but the same mathematical description could be used to predict values beyond the time period of observed data. The results of the phase plane graphical analyses serve as a caution that long-term prediction is likely to be incorrect—the probability of change in the underlying attractor or structure of the nonlinear dynamic system is too great to place much confidence in long term predictions.

Table 8-1, below, shows the values of the tuning parameter in the logistic equation that were obtained by analyzing each of the variables listed with the MATLAB program. Recall that the tuning parameter significantly influences the nature of the data that are predicted by the logistic equation, and that lower values of the tuning parameter imply system stability and higher values imply chaos.

Table 8-1

	High Managed Care Market (Group 3)	**Medium Managed Care Market (Group 2)**
Variable	**Tuning Parameter**	**Tuning Parameter**
Avg. number of residents trained	.1310	.1517
Avg. number of master's and doctoral students	.1320	.1115
Total teaching responsibility	.1161	.1277
Avg. number of clinical faculty	.2321	.2001
Avg. number of administrative staff	.1115	.1014
% Administrative staff same as prior year	.1001	.1001
Avg. number of clinical affiliations	.1001	.1001

Because the value of the tuning parameter describes system characteristics, the values of this parameter allow an additional way to evaluate the underlying attractors operating in the system. In the logistic equation, higher values of the tuning parameter represent system behavior that is closer to chaos than lower values of the parameter. The moderate values of the tuning parameter that were obtained in the mathematical analyses were consistent with the frequency with which periodic attractors were observed in the phase plane graphical analyses. That is, the values of the tuning parameter and the periodic attractors both imply a degree of stability. This interpretation of the moderate values is also based on the behavior of the standard phase portraits presented as examples in chapter 5, as the value of the tuning parameter was varied. It is also noteworthy that the variables that were most associated with the system changes and institutional behavior patterns that emerged over time had somewhat higher values.

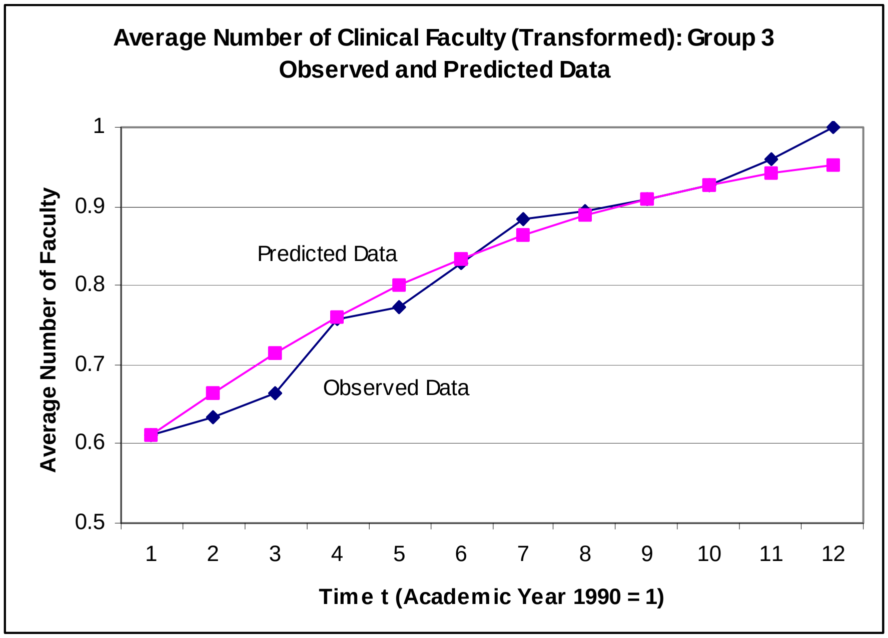

Figure 8-67

A pattern of increased research activity was observed in schools in high managed care markets, as evidenced by increased NIH research grant funding, more clinical faculty, and more master's and doctoral students. Values of the tuning parameter that described the trend data for the average number of master's and doctoral students and the average number of clinical faculty in Group 3 schools were higher than the values calculated for the same variables measured in Group 2 schools. The observed and predicted values of the average number of clinical faculty in Group 3 schools are shown in Figure 8-67. The sum of squared differences between the two sets of data (12 pairs of data points) was .0074, indicating that a good mathematical description was obtained from the MATLAB analysis. The goodness of fit, or level of prediction provided by the solution to the logistic equation provides a crucial piece of evidence regarding these data—their behavior can be unequivocally described as nonlinear.

The values of the tuning parameter were higher in the mathematical descriptions (i.e., the logistic equation) of the number of residents trained and total teaching responsibility in schools in medium (Group 2) managed care markets than for the same data from schools in high (Group 3) managed care markets. The observed and predicted values of the average number of residents in Group 2 schools are shown in Figure 8-68.

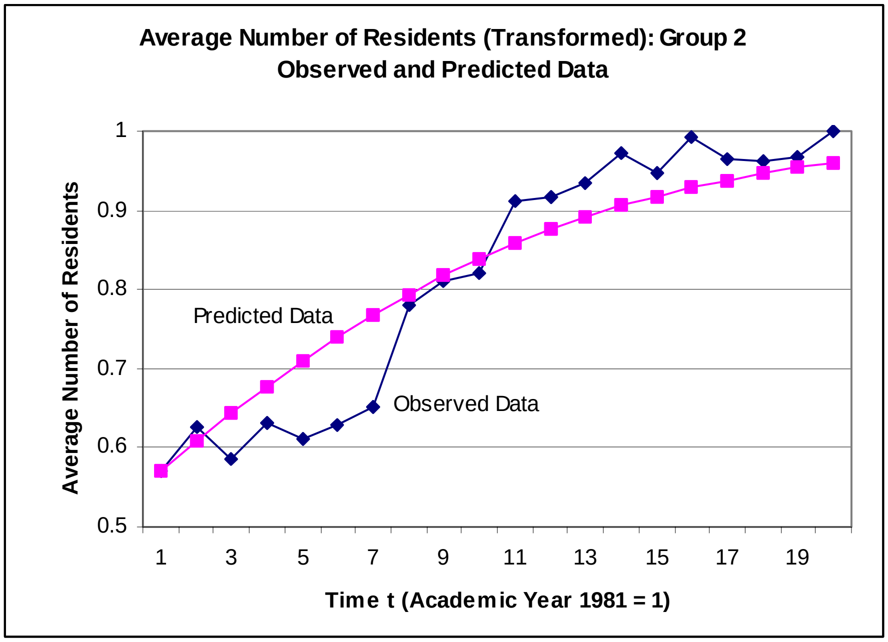

Figure 8-68

The sum of squared differences between the two sets of data (20 pairs of data points) was .0546, indicating that a good mathematical description was obtained, although not as good as the previous example, shown in Figure 8-67.

Although the phase plane portraits of the average number of clinical affiliations at schools in medium (Group 2) and high (Group 3) managed care markets look dissimilar, the values of the tuning parameter in the mathematical descriptions of the data were identical. The values of the parameter therefore suggested that the underlying structure, or attractors, might be similar for these two groups of medical schools for this variable.

In summary, graphical analysis provided an easy way to present and analyze a large amount of information about a nonlinear dynamic system. Phase portraits of each of the study variables showed the direction and magnitude of year-to-year changes in the variables. Unlike the analyses presented in chapters 6 and 7, the phase portraits provided a way to describe and evaluate the structure and behavior of the underlying attractors of the system. The shape of the attractor depicts the limits within which the system is likely to behave. The graphical analyses presented in this chapter also confirmed the structure or patterns of behavior that emerged over time in the groups of schools that were in medium and high managed care market areas.

The nonlinear mathematical analyses offered confirmation of the nonlinear nature of the AMC system, as represented by the constituent variables described in the study model. The values of the tuning parameters in the mathematical descriptions that were obtained from the MATLAB analyses were interpreted to suggest the nature of the underlying attractors. The intermediate values of the tuning parameters were consistent with the findings of the graphical analyses; i.e., the attractors described by the phase portraits were often periodic and only occasionally appeared to be chaotic. The presence of periodic attractors implies a degree of stability but not a stable equilibrium; a stable equilibrium would have appeared as a point attractor. A periodic attractor illustrated a system that was oscillating between two or perhaps four values as it moved through time. A chaotic or strange attractor illustrates a system that moves through time without ever repeating the same value.

The values of the tuning parameters could also be used to generate predicted values from the logistic equation for time periods beyond the available observed data. These predictions would need to be limited to the short term. The underlying attractors revealed in the phase portraits were observed to occasionally change during the study period—a graphic confirmation of the difficulty of predicting system behavior over the long term.

Chapter 9. Conclusions

General Comments

The purpose of this dissertation was to examine how complexity science might offer insight into large-scale social systems. In particular, I wanted to examine the behavior of a population of organizations comprised of large-scale networked organizational groups from the perspective of complexity theory. I also wanted to demonstrate the use of some of the graphical and mathematical tools that are associated with nonlinear dynamic systems to enrich our understanding of complex social systems. The choice of these tools was intended to position this research study in contrast to studies that metaphorically applied the concepts of complexity theory. To illustrate the enhanced understanding that can be obtained from the application of complexity theory and the tools associated with the study of nonlinear dynamic systems, I examined the changes in academic medical centers that were concurrent with the growth of the managed care health care delivery market. That is, academic medical centers were chosen as an illustrative example of a population of large-scale networked organizational groups.

Guiding the research study was a model of change in academic medical centers that proposed factors hypothesized to influence the functions and relationships among activities undertaken by medical schools and their associated institutions. The overarching independent variable was the managed care environment, a health care market that has favored the most efficient delivery of medical care. Changes in the fiscal environment of academic medical centers—changes influenced by federal policy and the health care delivery market—were hypothesized to be among the factors that mediated changes in the strategies used by academic medical centers to fulfill their missions of teaching, research, and patient care. Within the framework of complexity theory, I suggested that it might be fruitful to consider the networked academic medical centers as a complex adaptive system; in this way, the system itself could be seen to exhibit both nonlinearity and the emergence of patterned behaviors in response to the challenges of managed care. The theoretical framework of complexity science and the use of graphical and mathematical methods suggested insights into the nonlinear aspects of the AMC policy system—insights which would have been difficult to discern using methodologies based on linear assumptions.

Populations of organizations comprised of large-scale networked organizational groups have been studied from a variety of theoretical perspectives, including population ecology and institutional theory. These perspectives have tended to emphasize the normative, social, and legal forces in the environment that encourage movement toward stability. Quantitative analytic approaches are usually based on linear assumptions. While this dissertation was not intended to add to the development of these theoretical perspectives, it noted that while these perspectives have provided a basis from which to study populations of organizations, they are based on different assumptions than the complexity theory perspective.

The work of Scott et al. (2000), which used institutional theory to examine change over time in populations of health care delivery organizations and which was described in chapter 2, served as an example of an institutional approach to understanding the behavior of a population of organizations, and was based in part on a linear analysis of the data.[1] The two major concepts that Scott et al. applied to their research—the processes related to structuration and profound institutional change—appear to have counterparts in complexity science. Destructuration and restructuration appear to describe processes similar to self-organization and emergence, in which new emergent structures and patterns appear in complex systems without being imposed by an outside force. In both emergence and restructuration, old structures and patterns are replaced with new ones. Complexity theory would direct the researcher's attention to identifying the rules that govern the emergence of system structure from the interaction of simple components—rules on which the behavior of individual agents is based. The collective behavior of individual agents results in new patterns, which can be qualitatively different than the previous patterns. Identification of these rules may allow short term prediction of system behavior, although the exact point at which self-organization or emergence may occur probably cannot be predicted.

Profound change was described by Scott et al. as discontinuous—a characteristic of nonlinear dynamic systems that can be illustrated mathematically by varying the tuning parameter of a discrete logistic equation and plotting the results of a series of iterations of the equation.

[1] Scott et al., *Institutional Change and Health Care Organizations: From Professional Dominance to Managed Care*.

Behaviorally, profound change is qualitative, discontinuous, and most often occurs in systems that are becoming unstable and close to the edge of chaos. Graphical analysis using phase portraits can help researchers identify the occurrence of qualitative system changes and can direct their attention to variables involved in such changes.

Scott et al. also made two observations that must be considered here. First, they noted that it was difficult to identify the causal structure responsible for determining the direction and nature of change in organizations' structuration processes. This difficulty suggested the possibility that nonlinear relationships were present among the policy system elements examined by the authors. Second, they observed that organizational features exhibited an order that made some core characteristics more resistant to change than others. This observation suggested the possibility that these characteristics were expressions of underlying system attractors—structures that described the system's behavior and were not easily perturbed. Viewed in this way, the parameters of these core characteristics describe the bounds of probable system behavior.

The constructs used in institutional theory and complexity theory to describe similar phenomena are based on very different assumptions about system behavior: institutional theory adopts a linear perspective, while complexity theory focuses on nonlinear behavior. Large systems can be demonstrated to exhibit both linear and nonlinear behavior at different times or in different subsystems or variables at the same time. This suggests that the two approaches could be used in a complementary fashion to obtain a better understanding than either perspective alone could provide.

Complexity science literature, described in chapter 2, provided the primary set of concepts that informed the research study described in this dissertation. While complexity science is primarily the study of complex adaptive systems, it consists of a family of concepts that have evolved from research in the physical and biological sciences and from mathematical modeling. Some of the concepts that were drawn upon in this study of academic medical centers were nonlinearity, attractors, self-organization, and emergence. Examination of a population of organizations through the lens of complexity science appears to be an extension of the application of complexity theory to a new unit of analysis. Therefore, it was fitting to begin by asking whether it was appropriate to treat the population of academic medical schools as a complex adaptive system. Two hallmarks of complex adaptive systems are nonlinearity and the emergence of patterned behavior. Tools associated with complexity science—phase portraits and nonlinear mathematical analysis—were used to look for the presence of nonlinear behavior, underlying attractors, and the emergence of patterned behavior and self-organization. The complexity science literature served as a benchmark, and complexity science tools provided the means for determining the appropriateness of treating a population of networked organizations as a complex adaptive system.

The medical school literature, described in chapter 4, provided a qualitative underpinning to the rich and detailed quantitative description of changes in academic medical centers developed in this research study. The three traditional missions of medical schools—teaching, research, and patient care—served as organizing principles, for the multiple indicators used to operationalize the variables in the study model, and for identifying changes in clusters of variables that constituted patterns of behavior. A review of the literature on organizational strategies employed in response to increased managed care market penetration and other financial and policy changes also supported the notion that there was increased activity within this population of organizations with regard to resource allocation, organizational relationships, and market positioning. Legislation and public policy affecting teaching hospital revenues were also considered in the study model.

Importance of the Research

This dissertation is important for the application of complexity theory and the tools of nonlinear dynamic systems to the analysis of trend data describing a population of large-scale networked organizational groups. Although a small step, the dissertation provides a model for developing a conceptual framework that describes a nonlinear dynamic system, for specifying variables for which trend data can be obtained, and for applying graphical and nonlinear mathematical tools to the analysis of these data. It also provides a model for the application of specific methodological tools, rather than the metaphorical extension of concepts, to the study of social and policy systems from a complexity science perspective.

This dissertation is also important for furthering the understanding of the structure and functions of academic medical centers. To accomplish their missions, medical schools developed a complex set of relationships with teaching hospitals and other clinical facilities, allied health departments, and, often, a parent university. The transition to a more corporate model of health care delivery has prompted academic medical centers to take action, including increased change in clinical affiliations, in the relative composition of the faculty in basic science and clinical departments, in new physicians' choice of specialty, in their choices regarding types of students trained, and in the variety of medical school administrative staff positions. The rich description developed from the longitudinal data gathered for this research study provided a comprehensive and detailed account of these changes. Graphical analysis added an explanatory dimension to the rich description by illuminating and allowing interpretation of the underlying system attractors. The system attractors delineated in the phase portraits provided an indication of the boundaries or limits within which the system was likely to continue functioning. Mathematical analysis confirmed the nonlinear nature of the trend data that described the academic medical center system. The presence of emerging patterns of behavior, found by developing the rich description, and nonlinearity, demonstrated by the graphical and mathematical analysis, provided a basis for treating this population of large-scale networked organizational groups as a complex adaptive system.

This dissertation's research contributions, and other observations regarding the research study, are discussed as follows.

- Graphical analysis using phase portraits provided a novel method of examining the data, and facilitated the discovery and confirmation of the presence of patterned behavior. The qualitative dimensions of the system were displayed as trajectories on a two-dimensional Cartesian plane. This approach focused on the year-to-year changes in the system, both in size and direction, rather than the absolute values of the variables at one or more points in time. The dynamic nature of the system was captured and displayed, providing a visual representation of the evolving state of the system and the probable limits or bounds of system behavior, reflected in the shape of the attractors in the phase portraits, within which the system was likely to continue to function. This analysis revealed patterns and structure in aspects of the data that would otherwise have remained hidden had only linear methods of analysis been used. The nonlinear analysis tools used in this research study would be complementary to a linear approach to the analysis of these data.

- Mathematical analysis confirmed the presence of nonlinearity in the academic medical center system. Social systems are frequently characterized as nonlinear, usually by virtue of the fact that they are comprised of or driven by human behavior. Rarely is this assumption tested. This research study utilized a widely available analytical tool, MATLAB, and a logistic equation to mathematically describe the observed data well enough to conclude that the behavior of key variables in the study model (and the system) exhibited nonlinearity. The mathematical description that resulted from the analysis expressed the relationship of each succeeding value as a function of the immediately preceding value to a constant, the tuning parameter. The value of the tuning parameter indicated that the system was probably not predominantly chaotic, underscoring the fact that not all nonlinear dynamic systems exhibit chaos. Rather, the dominant type of attractor was a periodic attractor, which implied system stability (although not a stable equilibrium).

- Use of a logistic equation allowed calculation of predicted values that closely matched the observed values of variables over time, i.e., provided a good fit to the data. The most widely discussed logistic equation found in the chaos and complexity literature is the discrete form. For this research study, a continuous form of the equation was chosen because the study variables were typically continuous in nature. Although measurements were taken at discrete intervals, most variables were free to change continuously. For example, revenue streams accrued to AMCs throughout the year but were reported once per year. The mathematical description of the time series variables offers an opportunity to predict variable behavior for a limited time beyond the point at which data values are known. Because results of the phase plane graphical analyses indicated that attractors had sometimes changed over time, long-term prediction does not offer much hope of accuracy. This was certainly consistent with the character of nonlinear dynamic systems.

- The collection and examination of multiple indicators, guided by a study model, allowed development of a detailed, data-based rich description of the system of interest. Because I was looking for emerging patterns of behavior I looked across time and across many sources and types of data. Because this was a nonexperimental research study, examination of multiple dependent variables as a way of uncovering the role of independent variables was both appropriate and useful as strategy.

Conclusions

The research study described in this dissertation was exploratory and descriptive; it was not intended to result in prescription or recommendation. There are, however, several conclusions that may be of interest to those who are interested in the application of complexity theory to policy systems and populations of large networked organizations or who are responsible for managing the medical education enterprise.

The methodological tools of complexity science can be used to help understand the behavior of an entire population of organizations.

This research study served as a proof of concept of the notion of using the ideas of complexity science to develop a study model, to collect data, and to use the methodological tools of the theoretical framework of complexity science to describe and explain the observed behavior of a population of organizations. The development of rich descriptions of the academic medical center system revealed emerging patterns of system behavior, and an understanding of these patterns was augmented by graphical phase plane and nonlinear mathematical analyses. These analyses qualitatively described the system structure and underlying attractors, which helped identify the boundaries of likely behavior and which confirmed the nonlinear nature of the system. The application of the methodological tools of complexity science extended the description and comprehension of the academic medical center system beyond that which would have been obtained solely through the metaphorical application of complexity science concepts. Identification of the likely boundaries of system behavior through analysis of attractors in phase portraits is one example of the benefit of using graphical and nonlinear mathematical tools.

Another benefit of graphical analysis is that it would serve to direct the attention of a researcher or manager to certain aspects of the complex system. Complexity science may not assist in long-term prediction and may not, for example, tell a manager exactly what to do in response to a changing environment. However, periodic analysis of phase portraits of key system variables may serve as an early warning of qualitative changes in the underlying attractors of the system.

The presence of nonlinearity in the key data suggests the need to adopt a different way of thinking about system behavior.

The nonlinearity that was identified by the XY line graph analyses and confirmed by the mathematical analyses suggested that changes in the academic medical center system were not wholly the result of linear processes. That is, management and other decisions made at medical schools and teaching hospitals were likely not to have consistently resulted in effects or outputs that were proportional to investments or other system inputs. Outcomes may have been unusually dependent on the system's state at the time a decision was implemented, reflecting the sensitivity to initial conditions found in nonlinear dynamic systems. That is, the initial value or state of the system is a strong determinant of the future course of the system. Managers and administrators may not have experienced outcomes that they expected or predicted, and results may even have appeared to be random. In other words, actors at academic medical centers may have been operating under linear assumptions when in fact they were in the midst of a nonlinear dynamic system.

Nonlinear systems may be quite stable for long periods of time and may exhibit predictable performance. Conditions may effectively dampen or stabilize the underlying disorder. In academic medical centers, market pressures that limited demand for physicians, for example, also limited the medical education enterprise. These conditions may hide the nonlinear nature of the system from the managers and administrators. Once the possibility of nonlinearity is recognized, however, decision-supporting analytical techniques such as regression analysis are less valuable. The proportion of the data left unexplained by linear techniques may not be noise in the system—it may be the very information that can help explain system behavior and thereby support more effective planning and action. The use of the graphical and mathematical tools of complexity science can significantly augment understanding for individuals who work on a daily basis within organizations that are complex, nonlinear dynamic systems.

The presence of nonlinearity and the emergence of patterned behavior within schools grouped on the basis of their managed care market environment suggests that it is appropriate to treat the population of academic medical centers as a complex adaptive system.

The presence of nonlinearity suggests that the relationship between the establishment of managed care as the dominant form of health care delivery and changes in the activities and organization of academic medical centers was more subtle and indirect than otherwise might be expected on the basis of linear assumptions. The myriad decisions and actions taken at individual academic medical centers were based on local conditions and were likely to have had different effects in their local markets. It is almost certainly not the case that more managed care market penetration always prompted more of a certain action (e.g., recruiting more residents to be trained, or writing more research grant proposals), resulting in more of a particular outcome (more residents in training and more income from Medicare DGME payments; higher research grant funding). And yet, the aggregate result was a pattern that characterized academic medical centers more generally as leveraging their existing institutional strengths, and more specifically as focusing their actions on certain components of their missions depending on their history and managed care market environment. These patterns emerged without central direction, a hallmark of the self-organizing behavior of complex adaptive systems.

The treatment of a population of organizations as a complex adaptive system focuses our observation on aspects of the system that might be neglected in a linear perspective. The presence of nonlinearity is a key feature of a complex adaptive system, but not the only characteristic. Complex adaptive systems are nonlinearly dynamic and they are sensitively dependent on initial conditions. As a result, system outcomes are difficult to predict even though they are shaped by the system's history. Multiple feedback loops provide both positive and negative feedback. To fully understand a nonlinear dynamic system such as a complex adaptive system, both kinds of feedback loops should be identified. Complex adaptive systems are capable of self-organization; new structures or patterns can arise without central direction or control. This emergence of new system properties cannot be predicted by examining the individual components; the whole is greater than the sum of the parts. A manager who recognizes that he or she is working within a complex adaptive system might, for example, wish to provide resources to support self-organization as an alternative to a top-down approach to organizational change.

Academic medical centers have responded to the rise of managed care in the health care delivery marketplace by leveraging their institutional strengths.

One of the key findings with regard to academic medical centers was that schools in medium and high managed care markets appeared to have leveraged their institutional strengths as a way of responding to the increased market penetration of managed care. Schools that were in medium managed care markets were primarily teaching institutions that provided a significant amount of patient care. They had the highest average number of medical students, the highest average number of basic science faculty, and the highest average number of administrative staff positions. During the study period, they grew to become the group of schools with the highest average total teaching load (based on medical students, master's and doctoral students, and residents) and they did so by substantially increasing the number and proportion of residents trained. Residents receive primarily clinical training and they learn by practicing medicine at teaching hospitals and other affiliated clinical facilities. These schools had the highest average amount of revenues from hospital fees, and the number of their clinical affiliations increased two to four times as fast as clinical affiliations at other academic medical centers, so that by the end of the study period schools in medium managed care markets had the highest average number of clinical facilities. Schools in medium managed care markets maintained their commitment to training clinicians, and they maintained their patient care revenue by training more residents and establishing more affiliations with clinical facilities.

Schools in high managed care markets were distinguished by their research intensiveness. These schools were consistently the recipients of large amounts of federal and other research funding, primarily through the NIH. Associated with research funding was funding for research training. During the study period, schools in high managed care markets received an average of about

140% of the research funds awarded to the average medical school and over 150% of the amount of training funds awarded to the average medical school. During the last five years of the study period, the NIH saw an unprecedented doubling of its budget. Schools in high managed care markets were the recipients of much of the research and training made possible by grant support as a result of this budget increase. These schools also had the largest average number of clinical faculty and the highest ratio of faculty members to medical students throughout the study period. At the beginning of the study period, schools in high managed care markets were responsible for training the highest average number of residents; by the end of the study period this distinction had gone to schools in medium managed care markets. However, by the end of the study period, schools in high managed care markets assumed the lead role in teaching master's and doctoral students—students who, unlike most residents, participate in research.

Both of these groups of schools increased activity in areas in which they were most experienced and, presumably, successful. Many decisions by different individuals at different schools resulted in the emergence of similar patterns in schools that were in similar health care delivery marketplaces and which had similar histories of activities and of mission emphases.

Next Steps

The identification of nonlinear properties in the academic medical center system opened a new perspective with which to understand the behavior of an important population of networked organizations. One of the most important features of nonlinearity—that output may not be proportional to input—carries profound implications for managers, policy planners, and administrators. Until researchers and managers recognize the coexistence of nonlinear and linear processes in social systems, they will be studying and making decisions on the basis of incomplete information. Decisions regarding resource allocation, investments in capital improvements, staffing, and strategic and policy planning must include a consideration of the nonlinear aspects of the system within which the decisions are made. Moreover, the development of policy with regard to complex institutions such as AMCs, and to important sectors of the economy such as health care delivery, would also be better informed by recognition of the nonlinear aspects of these systems. Additional research will further develop the tools and interpretive concepts that will allow this important step forward in understanding and managing large-scale policy systems.

One potentially fruitful area of further research is an examination of the implications of the study results for decision-making and short-term prediction within a single academic medical center. The rich description of study variables–of their evolution over time within the three managed care market groups of schools–may suggest which data might be important to examine at a particular AMC. This research study might therefore suggest some ways in which those individuals responsible for managing AMCs might take a new approach to understanding their own institutions from a complexity perspective.

The next steps in the application of complexity research to social and policy systems should explore ways to systematically interpret the results of nonlinear mathematical analysis, both independently and in conjunction with the qualitative interpretation of the underlying system attractors revealed by phase portraits. Graphical and nonlinear mathematical tools will reveal characteristics of system activities that may be overlooked by more conventional linear methods. They can serve a very important role in identifying points in the system where the researcher should focus attention, but neither phase portraits nor nonlinear mathematical analysis will reveal *why* institutions behave as they do. Therefore, the methodological tools of nonlinear dynamic systems analysis will probably need to be combined with other quantitative and qualitative tools in order for us to more fully understand the behavior of social systems.

Although the results of this research study are not, and were not intended to be, prescriptive, there are nevertheless certain prescriptive implications that arise from this study. Once the presence of nonlinearity is recognized, it follows that its influence extends beyond general management to the arena of policy planning and management, including policy assessment. Strategic policy planning cannot be undertaken with the expectation of achieving outcomes or effects that are proportional to inputs. Randomly appearing or unexpected results should be examined with the purpose of trying to identify an underlying attractor, rather than dismissed as unexplained aberrations. Because of the effects of nonlinear processes on our ability to predict long-term outcomes, policy assessments should include a shortened horizon for collecting information, monitoring benchmarks, and assessing the effects of policies, particularly those that include interventions intended to change system behavior.

In this research study, I applied the tools of nonlinear system dynamics and complexity science to help formulate an understanding of changes in a population of organizations. The example to which I applied the theoretical perspective was academic medical centers; specifically, I examined organizational changes that were concurrent with major changes in the health care delivery sector. In contrast to metaphorical applications of the concepts of chaos and complexity, this research study demonstrated the application of methodological tools for understanding large-scale networked organizational groups as complex adaptive systems. While academic medical centers as a group have several distinctive characteristics, their experience with a newly challenging environment and this research study's approach to examination of their behavior may prove to be extensible to the strategic and policy analyses of other systems of organizations.

APPENDIX A

INSTITUTIONAL PROFILES

Medical School		**Enrollment**	697
University of Alabama School of Medicine		**Number of Graduates**	150
Birmingham		**% Primary Care Physicians**	27%
AL		**Clinical Faculty**	762
		Basic Science Faculty	179
Type of Control		**Total Faculty**	948
Public		**Total Teaching Load**	2,148
		Total Revenue	$369,430,295
Managed Care Market		**Total NIH Support**	$170,379,277
Managed Care-State	11%	**Number of Clinical Affiliations**	12
Managed Care-MSA	18%		
Average HMO market, 1995-2001	9%		

History

The University of Alabama School of Medicine is a continuation of medical training begun in Mobile more than a hundred years ago. The medical school was moved from the Tuscaloosa Campus to Birmingham in 1945 and expanded from a 2- to a 4-year school. Clinical campuses are located in Tuscaloosa, Huntsville, and Birmingham.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 1

Medical School			**Enrollment**	256
University of South Alabama College of Medicine			**Number of Graduates**	65
Mobile			**% Primary Care Physicians**	46%
AL			**Clinical Faculty**	119
			Basic Science Faculty	56
Type of Control			**Total Faculty**	178
Public			**Total Teaching Load**	589
			Total Revenue	$55,078,880
Managed Care Market			**Total NIH Support**	$11,670,068
Managed Care-State	11%		**Number of Clinical Affiliations**	3
Managed Care-MSA	N/A			
Average HMO market, 1995-2001	9%			

History

On August 19, 1969, the state legislature passed a resolution that a second medical school should be established in Alabama under the auspices of the University of South Alabama. On January 3, 1973, the charter class entered the University of South Alabama College of Medicine. The Basic Medical Sciences Building is located on the main university campus. Clinical teaching is conducted at the University of South Alabama Hospitals and numerous ambulatory facilities.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group	1	**ID**	2

Medical School	
University of Arizona College of Medicine	
Tucson	
AZ	
Type of Control	
Public	
Managed Care Market	
Managed Care-State	37%
Managed Care-MSA	57%
Average HMO market, 1995-2001	35%

Enrollment	412
Number of Graduates	102
% Primary Care Physicians	39%
Clinical Faculty	356
Basic Science Faculty	72
Total Faculty	433
Total Teaching Load	1,076
Total Revenue	$142,860,000
Total NIH Support	$56,208,437
Number of Clinical Affiliations	9

History

In 1961 the Board of Regents of the Universities and State College of Arizona authorized the University of Arizona to proceed with the establishment of a full 4-year College of Medicine on its campus in Tucson. In 1963 the state legislature appropriated funds for planning purposes, and active planning began in 1964. The first class of students was admitted in the fall of 1967 and graduated in June 1971.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 3

Medical School			**Enrollment**	563
University of Arkansas College of Medicine			**Number of Graduates**	136
Little Rock			**% Primary Care Physicians**	36%
AR			**Clinical Faculty**	509
			Basic Science Faculty	111
Type of Control			**Total Faculty**	627
Public			**Total Teaching Load**	1,136
			Total Revenue	$143,580,408
Managed Care Market			**Total NIH Support**	$32,998,157
Managed Care-State	16%		**Number of Clinical Affiliations**	28
Managed Care-MSA	36%			
Average HMO market, 1995-2001	11%			

History

The College of Medicine is part of the University of Arkansas for Medical Sciences, one of the five campuses of the University system. The college, founded in 1879, is the parent of 3 subsequent colleges: pharmacy, nursing, and health-related professions. Six area health education centers operate in the larger cities of the state as satellite centers of medical education.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 4

Medical School		**Enrollment**	406
University of California, Davis, School of Medicine		**Number of Graduates**	92
Davis		**% Primary Care Physicians**	35%
CA		**Clinical Faculty**	346
		Basic Science Faculty	35
Type of Control		**Total Faculty**	385
Public		**Total Teaching Load**	913
		Total Revenue	$117,282,221
Managed Care Market		**Total NIH Support**	$46,369,338
Managed Care-State	65%	**Number of Clinical Affiliations**	12
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	52%		

History

The Regents of the University of California authorized the development of a medical school on the Davis campus near Sacramento in 1963, and legislative funds were made available for planning and development in 1966. The school admitted an entering class of 48 freshmen in 1968. By the fall of 1971, the size of the entering class had more than doubled to 100 students. Currently, the school admits a freshman class of 93 students.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 5

Medical School 388

University of California, Irvine, College of Medicine
Irvine
CA

Type of Control
Public

Managed Care Market

Managed Care-State	65%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	52%

Number of Graduates	87
% Primary Care Physicians	38%
Clinical Faculty	470
Basic Science Faculty	70
Total Faculty	541
Total Teaching Load	1,078
Total Revenue	$145,245,575
Total NIH Support	$50,194,130
Number of Clinical Affiliations	7

History

Founded in 1898, the California College of Medicine became part of the University of California Irvine (UCI), one of nine campuses in the University of California System, in 1965. The college officially moved from Los Angeles to a 122-acre site on the Irvine campus in 1968. Today, the UCI College of Medicine provides teaching, research, and patient care facilities at the health sciences complex on the Irvine campus and at UCI Medical Center, the college's principal clinical facility, located in Orange.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 6

Medical School		**Enrollment**	715
University of California, Los Angeles, UCLA School of Medicine		**Number of Graduates**	164
Los Angeles		**% Primary Care Physicians**	29%
CA		1,097	
		Basic Science Faculty	116
Type of Control		**Total Faculty**	1,214
Public		**Total Teaching Load**	2,621
		Total Revenue	$721,616,028
Managed Care Market		**Total NIH Support**	$201,097,654
Managed Care-State	65%	**Number of Clinical Affiliations**	23
Managed Care-MSA	53%		
Average HMO market, 1995-2001	52%		

History

The medical school is in the UCLA Center for Health Sciences on the UCLA campus. The second oldest of the five medical schools in the University of California, it accepted its first class of medical students in 1951.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 7

Medical School

University of California, San Diego, School of Medicine
La Jolla
Public

Type of Control
Public

Managed Care Market

Managed Care-State	65%
Managed Care-MSA	52%
Average HMO market, 1995-2001	52%

Enrollment	486
Number of Graduates	112
% Primary Care Physicians	32%
Clinical Faculty	623
Basic Science Faculty	33
	661
Total Teaching Load	1,457
Total Revenue	$ 365,674,150
Total NIH Support	$163,944,593
Number of Clinical Affiliations	13

History

The Regents of the University of California voted in 1962 to establish a School of Medicine on the San Diego campus at La Jolla. The first class of medical students was matriculated in fall 1968. The Basic Science Building, Biomedical Library, Clinical Sciences Building, Center for Molecular Genetics, and the Veterans Administration Hospital are located on the La Jolla campus. Across the highway is a growing health sciences complex with a new eye center, general hospital, and ambulatory care center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 8

Medical School		**Enrollment**	620
University of California, San Francisco, School of Medicine	Related / proximate	**Number of Graduates**	152
San Francisco	No	**% Primary Care Physicians**	34%
CA	Medical school-based	**Clinical Faculty**	796
	Departmental plan	**Basic Science Faculty**	86
Type of Control	Part of university	**Total Faculty**	884
Public		**Total Teaching Load**	2,629
		Total Revenue	$ 740,638,647
Managed Care Market		**Total NIH Support**	$303,214,901
Managed Care-State	65%	**Number of Clinical Affiliations**	5
Managed Care-MSA	72%		
Average HMO market, 1995-2001	52%		

History

The School of Medicine at the University of California, San Francisco, dates from 1964 when it was founded as the Toland Medical College. In 1873 it was formally transferred to the Regents of the University of California.

Current Institutional Description

Relation to Parent University	Freestanding / state system
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 9

Medical School		**Enrollment**	674
Loma Linda University School of Medicine		**Number of Graduates**	168
Loma Linda	Related / proximate	**% Primary Care Physicians**	38%
CA	No	**Clinical Faculty**	594
	Medical school-based	**Basic Science Faculty**	83
Type of Control	Federated plan	**Total Faculty**	678
Private	Mixed	**Total Teaching Load**	1,485
		Total Revenue	$77,902,973
Managed Care Market		$9,326,212	
Managed Care-State	65%	**Number of Clinical Affiliations**	8
Managed Care-MSA	54%		
Average HMO market, 1995-2001	52%		

History

The medical school was founded in 1909 and was known as the College of Medical Evangelists until 1961. It is owned and operated by the Seventh Day Adventist church. The college was originally located in Loma Linda, CA, although after several years the clinical instruction was given in L.A. The clinical facilities at the White Memorial Medical Center and the L.A. County Hospital were used until 1966 when the entire medical school was consolidated at Loma Linda. This move was supported by the building of L.L.U. Medical Center, completed in 1967. In 1961 the name was changed to L.L.U. By this time the university had become a health sciences institution and included schools of medicine, dentistry, and other related health disciplines.

Current Institutional Description

Relation to Parent University	Freestanding		
Community-based School	No		
Practice Plan Organization	Medical school-based		
Practice Plan Typology	Federated plan		
Practice Plan Legal Structure	Separate not-for-profit		
Managed Care Market Group	3	**ID**	10

Medical School		**Enrollment**	652
Keck School of Medicine of the University of Southern California		**Number of Graduates**	159
Los Angeles		**% Primary Care Physicians**	23%
CA		**Clinical Faculty**	629
	Related / distant	**Basic Science Faculty**	123
Type of Control	No	**Total Faculty**	762
Private	Medical school-based	**Total Teaching Load**	2,125
	Federated plan	**Total Revenue**	$400,299,886
Managed Care Market	Part of university	$90,780,294	
Managed Care-State	65%	**Number of Clinical Affiliations**	21
Managed Care-MSA	53%		
Average HMO market, 1995-2001	52%		

History

The University of Southern California (USC) was founded in 1880 and is a private, nonprofit corporation. The School of Medicine became a division in 1885 and established its own campus in 1952 on 12 acres adjoining the Los Angeles County (LAC)-USC Medical Center, 7 miles from the main university campus. All medical instruction has been conducted on the health sciences campus since 1960.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 11

Medical School		**Enrollment**	456
Stanford University School of Medicine		**Number of Graduates**	99
Stanford		**% Primary Care Physicians**	19%
CA	Related / proximate	**Clinical Faculty**	579
	No	**Basic Science Faculty**	91
Type of Control	Medical school-based	**Total Faculty**	671
Private	Federated plan	**Total Teaching Load**	2,102
	Part of university	**Total Revenue**	$394,527,346
Managed Care Market		**Total NIH Support**	$192,654,400
Managed Care-State	65%	**Number of Clinical Affiliations**	6
Managed Care-MSA	72%		
Average HMO market, 1995-2001	52%		

History

The School of Medicine was established in 1908 when the properties and equipment of Cooper Medical College were transferred to Stanford. The medical school is part of the Stanford University Medical Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 12

Medical School		**Enrollment**	543
University of Colorado School of Medicine	Freestanding	**Number of Graduates**	128
Denver	No	**% Primary Care Physicians**	35%
CO	Hospital-based	**Clinical Faculty**	717
	Federated plan	**Basic Science Faculty**	162
Type of Control	Multiple professional corporation	**Total Faculty**	880
		$286,177,810	
Managed Care Market		**Total NIH Support**	$137,030,596
Managed Care-State	45%	**Number of Clinical Affiliations**	12
Managed Care-MSA	52%		
Average HMO market, 1995-2001	38%		

History

The University of Colorado School of Medicine was opened on the main campus in Boulder in 1883. The school was moved to downtown Denver in 1911 to be merged with the Denver and Gross College of Medicine. In 1922 a facility was built on a 17-acre site in a residential section of Denver, and the School of Medicine was moved there in 1924. The 1924 site has grown into the present 45-acre campus of the University of Colorado Health Sciences Center.

Current Institutional Description	
Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 13

Medical School	
University of Connecticut School of Medicine	
Farmington	
CT	
Type of Control	
Public	

Managed Care Market	
Managed Care-State	46%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	43%

Enrollment	337
Number of Graduates	79
% Primary Care Physicians	34%
Clinical Faculty	678
Basic Science Faculty	126
Total Faculty	805
Total Teaching Load	1,127
Total Revenue	$135,384,146
Total NIH Support	$37,535,852
Number of Clinical Affiliations	12

History

The University of Connecticut School of Medicine appointed its first faculty members in 1963 and admitted its first class in 1968. The University of Connecticut Health Center, 35 miles from the main university campus, includes the School of Medicine, School of Dental Medicine, Ambulatory Services, and John Dempsey Hospital.

Current Institutional Description	
Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 14

Medical School	
Yale University School of Medicine	
New Haven	
CT	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	46%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	43%

Enrollment	717
Number of Graduates	79
% Primary Care Physicians	20%
Clinical Faculty	699
Basic Science Faculty	140
Total Faculty	840
Total Teaching Load	2,515
Total Revenue	$423,949,573
Total NIH Support	$227,594,084
Number of Clinical Affiliations	16

History

The Medical Institution of Yale College was chartered in 1810, opened in 1813, and has been in continuous operation since that date. Yale College became Yale University in 1887; the current designation of the school was adopted in 1918.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 15

Medical School		**Enrollment**	615
George Washington University School of Medicine and Health Sciences		**Number of Graduates**	143
Washington		**% Primary Care Physicians**	26%
DC		**Clinical Faculty**	368
		Basic Science Faculty	82
Type of Control		**Total Faculty**	451
Private		**Total Teaching Load**	1,073
		Total Revenue	$118,593,922
Managed Care Market		**Total NIH Support**	$14,972,670
Managed Care-State	N/A	**Number of Clinical Affiliations**	16
Managed Care-MSA	36%		
Average HMO market, 1995-2001	33%		

History

The School of Medicine was founded in 1821 as the Medical Department of the Columbian College. In 1974 the name was changed to the School of Medicine and Health Sciences. The Walter G. Ross Hall of Health Sciences, Paul Himmelfarb Health Sciences Library, University Hospital, Burns Memorial Building and Ambulatory Care Center (Medical Faculty Associates), and Warwick Building are situated on the main campus and constitute the George Washington University Medical Center.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 16

Medical School		**Enrollment**	680
Georgetown University School of Medicine		**Number of Graduates**	172
Washington		**% Primary Care Physicians**	20%
DC		**Clinical Faculty**	870
		Basic Science Faculty	230
Type of Control		**Total Faculty**	1,102
Private		**Total Teaching Load**	1,581
		Total Revenue	$186,620,865
Managed Care Market		**Total NIH Support**	$54,170,891
Managed Care-State	N/A	**Number of Clinical Affiliations**	9
Average HMO market, 1995-2001	33%		

History

Georgetown University was founded in 1789, and the School of Medicine was established in 1851. Georgetown University Medical Center comprises four units: the School of Medicine, the School of Nursing, the Library, and the Georgetown University Hospital. The Medical Center is on the campus of Georgetown University.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 17

Medical School		**Enrollment**	440
Howard University College of Medicine		**Number of Graduates**	105
Washington		**% Primary Care Physicians**	34%
DC		**Clinical Faculty**	153
		Basic Science Faculty	80
Type of Control		**Total Faculty**	244
Private		**Total Teaching Load**	841
		Total Revenue	$103,587,261
Managed Care Market		**Total NIH Support**	$20,928,018
Managed Care-MSA	36%	**Number of Clinical Affiliations**	9
Average HMO market, 1995-2001	33%		

History

The College of Medicine had its beginning as the Medical Department of Howard University when it was chartered by Congress in March 1867. Instruction in the department began in November 1868. In 1882, formalized instruction in dentistry and pharmacy warrant the division of the Medical Department into the medical, dental, and pharmaceutical colleges. The name of the department was changed to the School of Medicine in 1907, and its component parts were named the College of Medicine, the College of Dentistry, and the College of Pharmacy. The Colleges of Medicine and Dentistry are now autonomous units within the Howard University Center for the Health Sciences.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 18

Medical School

University of Florida College of Medicine

Gainesville

FL

Type of Control

Public

Managed Care Market

Managed Care-State	37%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	33%

Enrollment	475
Number of Graduates	120
% Primary Care Physicians	27%
Clinical Faculty	818
Basic Science Faculty	118
Total Faculty	947
Total Teaching Load	1,593
Total Revenue	$237,293,248
Total NIH Support	$60,072,222
Number of Clinical Affiliations	5

History

The College of Medicine accepted its first class in September 1956. It is an integral part of the University of Florida and is located on the university campus. The medical school is part of the J. Hillis Miller Health Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 19

Medical School

University of Miami School of Medicine
Miami
FL

Type of Control

Private

Managed Care Market

Managed Care-State	37%
Managed Care-MSA	43%
Average HMO market, 1995-2001	33%

Enrollment	606
Number of Graduates	147
% Primary Care Physicians	23%
Clinical Faculty	973
Basic Science Faculty	158
Total Faculty	1,144
Total Teaching Load	1,568
Total Revenue	$270,868,000
Total NIH Support	$75,191,856
Number of Clinical Affiliations	10

History

The University of Miami School of Medicine was founded in 1952 and is located in the University of Miami-Jackson Memorial Hospital Medical Center, approximately 8 miles from the University of Miami Coral Gables campus. The Rosenstiel Medical Sciences Building, which serves as the center of the school's educational activities, opened in 1969.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 20

Medical School

University of South Florida College of Medicine
Tampa
FL

Type of Control
Public

Managed Care Market

Managed Care-State	37%
Managed Care-MSA	41%
Average HMO market, 1995-2001	33%

Enrollment	395
Number of Graduates	90
% Primary Care Physicians	31%
Clinical Faculty	142
Basic Science Faculty	52
Total Faculty	197
Total Teaching Load	1,068
Total Revenue	$118,212,128
Total NIH Support	$23,993,436
Number of Clinical Affiliations	8

History

The College of Medicine was opened for the instruction of students in 1971. It is an integral part of the University of South Florida (USF) and is located on the campus. The medical school is part of the University of South Florida Health Sciences Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 21

Medical School		**Enrollment**	452
Emory University School of Medicine		**Number of Graduates**	109
Atlanta		**% Primary Care Physicians**	26%
GA		**Clinical Faculty**	1,307
		Basic Science Faculty	106
Type of Control		**Total Faculty**	1,420
Private		**Total Teaching Load**	1,662
		Total Revenue	$355,997,765
Managed Care Market		**Total NIH Support**	$122,823,991
Managed Care-State	23%	**Number of Clinical Affiliations**	8
Managed Care-MSA	39%		
Average HMO market, 1995-2001	18%		

History

The history of the school began with the chartering of Atlanta Medical College in 1854. This was the first of a series of institutions that eventually consolidated in 1913 and became the School of Medicine of Emory University in 1915. Since 1917 the school has operated and developed both in the downtown area and on the main university campus in Druid Hills. The medical school is part of the Robert W. Woodruff Health Sciences Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 22

Medical School

Medical College of Georgia School of Medicine
Augusta
GA

Type of Control
Public

Managed Care Market

Managed Care-State	23%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	18%

Enrollment	720
Number of Graduates	179
% Primary Care Physicians	32%
Clinical Faculty	450
Basic Science Faculty	73
Total Faculty	523
Total Teaching Load	1,153
Total Revenue	$139,741,984
Total NIH Support	$23,295,227
Number of Clinical Affiliations	11

History

A unit of the University System of Georgia, the Medical College of Georgia was originally chartered in 1828 under the name Medical Academy of Georgia. In 1833 the name was changed to the Medical College of Georgia and was again changed in 1933 to the University of Georgia School of Medicine. In 1950 the present name was restored.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 23

Medical School

Mercer University School of Medicine

Macon

GA

Type of Control

Private

Managed Care Market

Managed Care-State	23%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	18%

Enrollment	196
Number of Graduates	52
% Primary Care Physicians	52%
Clinical Faculty	266
Basic Science Faculty	35
Total Faculty	309
Total Teaching Load	448
Total Revenue	$62,411,429
Total NIH Support	$616,029
Number of Clinical Affiliations	11

History

The Mercer University School of Medicine was founded in June of 1972 and graduated its charter class in June of 1986. The School of Medicine is located on the main campus of Mercer University.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 24

Medical School		**Enrollment**	176
Morehouse School of Medicine		**Number of Graduates**	32
Atlanta		**% Primary Care Physicians**	37%
GA		**Clinical Faculty**	144
		Basic Science Faculty	57
Type of Control		**Total Faculty**	206
Private		**Total Teaching Load**	304
		Total Revenue	$60,061,998
Managed Care Market		**Total NIH Support**	$26,126,925
Managed Care-State	23%	**Number of Clinical Affiliations**	5
Managed Care-MSA	39%		
Average HMO market, 1995-2001	18%		

History

The Morehouse School of Medicine is a private, independent medical school which admitted its first class of 24 students in September 1978 and a component of Morehouse College. In 1981 the school became independent of the college and converted to M.D. degree-granting status. The first M.D. degree was awarded in May 1985. The mission of the school emphasizes the primary health care needs of the underserved. An active biomedical research program tied together by an emphasis on disease processes that disproportionately affect minority communities supports a Ph.D. and an M.D. - Ph.D. program.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 25

Medical School		Enrollment	239
University of Hawaii at Manoa John A. Burns School of Medicine		Number of Graduates	55
Honolulu		% Primary Care Physicians	31%
HI		Clinical Faculty	102
		Basic Science Faculty	46
Type of Control		Total Faculty	149
Public		Total Teaching Load	544
		Total Revenue	$50,651,734
Managed Care Market		Total NIH Support	$4,629,687
Managed Care-State	49%	Number of Clinical Affiliations	21
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	34%		

History

The School of Medicine was established in 1965 and functioned as a 2-year school until 1973. At that time expansion to a full M.D. degree-granting program was approved. The first class graduated in 1975.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group	2	**ID**	26

Medical School	
Univ. of Chicago Div. of the Biol. Sciences Pritzker School of Medicine	
Chicago	
IL	

Enrollment	420
Number of Graduates	127
% Primary Care Physicians	23%
Clinical Faculty	606
Basic Science Faculty	97
Total Faculty	714
Total Teaching Load	1,404
Total Revenue	$262,535,746
Total NIH Support	$114,333,527
Number of Clinical Affiliations	4

Type of Control

Private

Managed Care Market	
Managed Care-State	25%
Managed Care-MSA	30%
Average HMO market, 1995-2001	24%

History

The School of Medicine of the University of Chicago was established in 1927. In 1968 it was renamed the Pritzker School of Medicine.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group	1	**ID**	27

Medical School	
Finch University of Health Sciences/Chicago Medical School	
North Chicago	
IL	

Type of Control

Private

Managed Care Market	
Managed Care-State	25%
Managed Care-MSA	30%
Average HMO market, 1995-2001	24%

Enrollment	746
Number of Graduates	187
% Primary Care Physicians	26%
Clinical Faculty	139
Basic Science Faculty	59
Total Faculty	202
Total Teaching Load	1,017
Total Revenue	$71,922,793
Total NIH Support	$5,270,346
Number of Clinical Affiliations	8

History

The Chicago Medical School was founded in 1912 as the Chicago Hospital College of Medicine. In 1919 the name of the institution was changed to the Chicago Medical School and in 1980 it completed a move to North Chicago in 1980. In 1967, with the establishment of the University of Health Sciences, the academic programs were broadened to include the School of Graduate and Postdoctoral Studies and the School of Related Health Sciences in addition to the Chicago Medical School. In 1993 the university was renamed Finch University of Health Sciences.

Current Institutional Description			
Relation to Parent University	Freestanding		
Community-based School	No		
Practice Plan Organization	Medical school-based		
Practice Plan Typology	Multi-specialty plan		
Practice Plan Legal Structure	Part of university		
Managed Care Market Group	1	**ID**	28

Medical School	
University of Illinois at Chicago College of Medicine	
Chicago	
IL	
Type of Control	
Public	

Enrollment	1,200
Number of Graduates	264
% Primary Care Physicians	30%
Clinical Faculty	555
Basic Science Faculty	173
Total Faculty	766
Total Teaching Load	2,672
Total Revenue	$199,729,683
Total NIH Support	$61,681,558
Number of Clinical Affiliations	30

Managed Care Market	
Managed Care-State	25%
Managed Care-MSA	30%
Average HMO market, 1995-2001	24%

History
Founded in 1881 as the College of Physicians and Surgeons of Chicago, the school affiliated with the University of Illinois in 1897 and became known as the University of Illinois College of Medicine in 1900. The Office of the Dean is located on the campus of the University of Illinois at Chicago, 135 miles from the Urbana-Champaign campus of the university. In 1970 the college was regionalized to include programs of medical education in Chicago, Peoria, Rockford, and Urbana-Champaign.

Current Institutional Description	
Relation to Parent University	Related / distant
Community-based School	N/A
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 29

Medical School

Loyola University of Chicago Stritch School of Medicine
Maywood
IL

Type of Control
Private

Managed Care Market

Managed Care-State	25%
Managed Care-MSA	30%
Average HMO market, 1995-2001	24%

Enrollment	518
Number of Graduates	125
% Primary Care Physicians	30%
Clinical Faculty	542
Basic Science Faculty	58
Total Faculty	607
Total Teaching Load	1,213
Total Revenue	$129,139,029
Total NIH Support	$23,648,919
Number of Clinical Affiliations	10

History

Loyola University of Chicago's School of Medicine was established in 1909. In 1948, it was renamed the Stritch School of Medicine. In 1969, the Loyola University Medical Center opened on a suburban site 12 miles west of Chicago's Loop district. The Medical Center's 70-acre campus, adjacent to the Hines Veterans Administration Medical Center, is home to the Medical School, McGaw Hospital, the Mulcahy Outpatient Center, the Cardinal Bernardin Cancer Center, a Level I trauma facility for children and adults, and the Ronald McDonald Children's Hospital.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit
Managed Care Market Group	1

ID 30

Medical School	
Northwestern University Medical School	
Chicago	
IL	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	25%
Managed Care-MSA	30%
Average HMO market, 1995-2001	24%

Enrollment	697
Number of Graduates	165
% Primary Care Physicians	21%
Clinical Faculty	1,138
Basic Science Faculty	179
Total Faculty	1,346
Total Teaching Load	1,694
Total Revenue	$263,196,327
Total NIH Support	$81,892,848
Number of Clinical Affiliations	8

History

Northwestern University Medical School was organized in 1859 as the Medical Department of Lind University. In 1863, it continued under the name of Chicago Medical College. In 1879 the college was affiliated with Northwestern University. Together with the schools of dentistry, law, and continuing education division, Northwestern University Medical School has been located on the Chicago campus of the university since 1926.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group	1	**ID**	31

Medical School		**Enrollment**	480
Rush Medical College of Rush University		**Number of Graduates**	112
Chicago		**% Primary Care Physicians**	32%
IL		**Clinical Faculty**	495
		Basic Science Faculty	103
Type of Control		**Total Faculty**	600
Private		**Total Teaching Load**	1,167
		Total Revenue	$146,980,797
Managed Care Market		**Total NIH Support**	$0
Managed Care-State	25%	**Number of Clinical Affiliations**	16
Managed Care-MSA	30%		
Average HMO market, 1995-2001	24%		

History

Rush Medical College was chartered in 1837 and was associated with the University of Chicago from 1898 to 1942. The Presbyterian Hospital, founded in 1884 as its major teaching hospital, subsequently was affiliated with the University of Illinois until 1971. The Presbyterian-St. Luke's Hospital, created in 1958 by a merger with the St. Luke's Hospital, founded in 1864, merged with the Rush Medical College Corporation in 1969 to form Rush-Presbyterian-St. Luke's Medical Center with admitted first- and third-year students in September 1971.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Hospital-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group	1	**ID**	32

Medical School

Southern Illinois University School of Medicine
Springfield
IL

Type of Control
Public

Managed Care Market

Managed Care-State	25%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	24%

Enrollment	288
Number of Graduates	69
% Primary Care Physicians	41%
Clinical Faculty	238
Basic Science Faculty	48
Total Faculty	315
Total Teaching Load	586
Total Revenue	$71,355,900
Total NIH Support	$4,132,895
Number of Clinical Affiliations	3

History

Southern Illinois University School of Medicine was established in 1969. Teaching facilities are located on the campus of Southern Illinois University at Carbondale and in Springfield, Illinois.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 33

Medical School		**Enrollment**	1,120
Indiana University School of Medicine		**Number of Graduates**	261
Indianapolis		**% Primary Care Physicians**	32%
IN		**Clinical Faculty**	889
		Basic Science Faculty	170
Type of Control		**Total Faculty**	1,126
Public		**Total Teaching Load**	2,359
		Total Revenue	$268,119,910
Managed Care Market		**Total NIH Support**	$82,149,258
Managed Care-State	23%	**Number of Clinical Affiliations**	6
Managed Care-MSA	25%		
Average HMO market, 1995-2001	17%		

History

The Indiana University School of Medicine was organized in Bloomington in 1903 through a series of mergers of various medical schools. In 1958 the school was consolidated and located at Indianapolis with the exception of the Medical Sciences Program, which remains on the Bloomington campus. In 1971 the school's programs were expanded by the addition of basic medical science centers at Evansville, Fort Wayne, Gary, Lafayette, Muncie, South Bend, and Terre Haute.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Multiple professional corporation

Managed Care Market Group 1 **ID** 34

Medical School		Enrollment	680
University of Iowa College of Medicine		Number of Graduates	181
Iowa City		% Primary Care Physicians	37%
IA		Clinical Faculty	630
		Basic Science Faculty	101
Type of Control		Total Faculty	742
Public		Total Teaching Load	1,541
		Total Revenue	$291,176,645
Managed Care Market		Total NIH Support	$129,456,504
Managed Care-State	18%	Number of Clinical Affiliations	15
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	12%		

History

The College of Medicine originated as the Medical Department of the University of Iowa in 1850. In 1870 the Medical Department was moved from Keokuk to the campus at Iowa City and adopted its present name.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 35

Medical School

University of Kansas School of Medicine
Kansas City
KS

Type of Control

Public

Managed Care Market

Managed Care-State	26%
Managed Care-MSA	42%
Average HMO market, 1995-2001	18%

Enrollment	706
Number of Graduates	168
% Primary Care Physicians	37%
Clinical Faculty	328
Basic Science Faculty	120
Total Faculty	452
Total Teaching Load	1,296
Total Revenue	$138,239,863
Total NIH Support	$32,299,640
Number of Clinical Affiliations	10

History

The University of Kansas established a "preparatory medical course" in 1880, and began to offer a 4-year medical curriculum in 1906. The School of Medicine is part of the University of Kansas Medical Center, which began to develop its current site in Kansas City, Kansas, in 1924. In 1971, the School of Medicine established a campus in Wichita, where a portion of each class receives its clinical training in the last 2 years.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Mixed

Managed Care Market Group 3

ID 36

Medical School		**Enrollment**	389
University of Kentucky College of Medicine		**Number of Graduates**	103
Lexington		**% Primary Care Physicians**	40%
KY		**Clinical Faculty**	438
		Basic Science Faculty	123
Type of Control		**Total Faculty**	562
Public		**Total Teaching Load**	1,179
		Total Revenue	$166,582,491
Managed Care Market		**Total NIH Support**	$50,550,017
Managed Care-State	44%	**Number of Clinical Affiliations**	15
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	28%		

History

The College of Medicine opened in September 1960. It is one of the units of the University of Kentucky, A.B. Chandler Medical Center, which also includes the colleges of dentistry, nursing, pharmacy, and allied health professions; the University Hospital; the Kentucky Clinic, with its off-site facilities; the Medical Library; and the University Student Health Services.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	N/A
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 37

Medical School

University of Louisville School of Medicine

Louisville

KY

Type of Control

Public

Managed Care Market

Managed Care-State	44%
Managed Care-MSA	34%
Average HMO market, 1995-2001	28%

Enrollment	588
Number of Graduates	147
% Primary Care Physicians	30%
Clinical Faculty	449
Basic Science Faculty	78
Total Faculty	528
Total Teaching Load	1,434
Total Revenue	$118,619,313
Total NIH Support	$23,944,158
Number of Clinical Affiliations	12

History

Medical education in Louisville began on February 2, 1833, with the granting of a charter for the Louisville Medical Institute. The first class of 80 students convened in 1837. The Louisville Medical Institute became the Medical Department of the University of Louisville by charter on April 23, 1846. In 1908 the Medical Department of Kentucky University, the Medical Department of the University of Louisville, the Hospital College of Medicine and the Louisville Medical College merged, forming the Medical Department of the University of Louisville. The medical school is part of the Health Sciences Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Multiple professional corporation

Managed Care Market Group 2 **ID** 38

Medical School		**Enrollment**	700
Louisiana State University School of Medicine in New Orleans		**Number of Graduates**	171
New Orleans		**% Primary Care Physicians**	26%
LA		**Clinical Faculty**	418
		Basic Science Faculty	99
Type of Control		**Total Faculty**	530
Public		**Total Teaching Load**	1,424
		Total Revenue	$153,279,806
Managed Care Market		**Total NIH Support**	$25,793,624
Managed Care-State	27%	**Number of Clinical Affiliations**	10
Managed Care-MSA	24%		
Average HMO market, 1995-2001	20%		

History

The Louisiana State University School of Medicine in New Orleans was established on October 1, 1931. The main campus of the parent university, Louisiana State University, is located in Baton Rouge. The School of Medicine is one of 5 professional schools in the Louisiana State University Health Sciences Center.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 39

Medical School	
Louisiana State University School of Medicine in Shreveport	
Shreveport	
LA	

Type of Control

Public

Managed Care Market

Managed Care-State	27%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	20%

Enrollment	400
Number of Graduates	93
% Primary Care Physicians	30%
Clinical Faculty	343
Basic Science Faculty	70
Total Faculty	431
Total Teaching Load	795
Total Revenue	$79,848,471
Total NIH Support	
Number of Clinical Affiliations	7

History

Established in 1965-66 by acts of the Louisiana Legislature, the School of Medicine in Shreveport graduated its first class of students in 1973. In 1975 the School of Medicine complex was completed, and a class enrollment of 100 students per year was approved. The medical school is part of the Louisiana State University Health Sciences Center.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 40

Medical School	
Tulane University School of Medicine	
New Orleans	
LA	

Type of Control

Private

Managed Care Market	
Managed Care-State	27%
Managed Care-MSA	24%
Average HMO market, 1995-2001	20%

Enrollment	589
Number of Graduates	158
% Primary Care Physicians	20%
Clinical Faculty	401
Basic Science Faculty	87
Total Faculty	493
Total Teaching Load	1,540
Total Revenue	$107,385,121
Total NIH Support	$16,774,555
Number of Clinical Affiliations	19

History

Founded in 1834 as the Medical College of Louisiana, the School of Medicine was incorporated into the University of Louisiana at its establishment in 1847. It has been called Tulane University since 1884. The medical school is part of the Tulane Medical Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 41

Medical School	
Johns Hopkins University School of Medicine	
Baltimore	
MD	

Type of Control

Private

Managed Care Market	
Managed Care-State	41%
Managed Care-MSA	33%
Average HMO market, 1995-2001	40%

Enrollment	475
Number of Graduates	120
% Primary Care Physicians	25%
Clinical Faculty	1,506
Basic Science Faculty	266
Total Faculty	1,792
Total Teaching Load	2,323
Total Revenue	$519,077,543
Total NIH Support	$337,267,718
Number of Clinical Affiliations	6

History

The School of Medicine was opened for instruction of students in October 1893, four years after the opening of the Johns Hopkins Hospital.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 42

Medical School
University of Maryland School of Medicine
Baltimore
MD

Type of Control
Public

Managed Care Market

Managed Care-State	41%
Managed Care-MSA	33%
Average HMO market, 1995-2001	40%

Enrollment	569
Number of Graduates	131
% Primary Care Physicians	33%
Clinical Faculty	770
Basic Science Faculty	176
Total Faculty	982
Total Teaching Load	1,627
Total Revenue	$326,326,590
Total NIH Support	$87,688,914
Number of Clinical Affiliations	16

History

The University of Maryland School of Medicine was founded in 1807 as the College of Medicine of Maryland. Davidge Hall, its first building, was constructed in 1812 and is the oldest building in North America, used continuously for medical education. The school became part of the University of Maryland System in 1920, when the professional schools in Baltimore merged with the Maryland State College of Agriculture in College Park. The School of Medicine is one of 6 professional schools that comprise the university's campus in downtown Baltimore.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 43

Medical School		Enrollment	670
Uniformed Services University of the Health Sciences F. Edward Hebert School of Medicine		Number of Graduates	151
Bethesda		% Primary Care Physicians	29%
MD		Clinical Faculty	834
		Basic Science Faculty	167
Type of Control		Total Faculty	1,005
Public		Total Teaching Load	2,970
		Total Revenue	$178,535,959
Managed Care Market		Total NIH Support	$162,460
Managed Care-State	41%	Number of Clinical Affiliations	4
Managed Care-MSA	36%		
Average HMO market, 1995-2001	40%		

History

Upon enactment in 1972 of the Uniformed Services Health Professions Revitalization Act, the Congress authorized establishment of the Uniformed Services University of the Health Sciences. The governing Board of Regents planned and developed the School of Medicine as the initial academic component within the university. The first class of 32 medical officer candidates enrolled on October 12, 1976.

Current Institutional Description

Relation to Parent University	Federal government / freestanding		
Community-based School	No		
Practice Plan Organization	N/A		
Practice Plan Typology	N/A		
Practice Plan Legal Structure	N/A		
Managed Care Market Group	3	**ID**	44

Medical School	
Boston University School of Medicine	
Boston	
MA	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	54%
Managed Care-MSA	57%
Average HMO market, 1995-2001	52%

Enrollment	618
Number of Graduates	146
% Primary Care Physicians	26%
Clinical Faculty	775
Basic Science Faculty	165
Total Faculty	944
Total Teaching Load	1,633
Total Revenue	$308,538,082
Total NIH Support	
Number of Clinical Affiliations	22

History

In 1873 Boston University established the School of Medicine by merging with the New England Female Medical College, which had been founded in 1848 as the first medical college for women in the world. In 1962 the School of Medicine became a constituent member of the Boston University Medical Center. It is located approximately 2 miles from the Charles River campus of Boston University, the parent university. The school celebrated its sesquicentennial in 1998.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Hospital-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 45

Medical School			**Enrollment**	730
Harvard Medical School			**Number of Graduates**	164
Boston			**% Primary Care Physicians**	19%
MA			**Clinical Faculty**	5,000
			Basic Science Faculty	508
Type of Control			**Total Faculty**	5,509
Private			**Total Teaching Load**	1,219
			Total Revenue	$1,410,872,197
Managed Care Market			**Total NIH Support**	$134,627,918
Managed Care-State	54%		**Number of Clinical Affiliations**	17
Managed Care-MSA	57%			
Average HMO market, 1995-2001	52%			

History

On September 19, 1782, the President and Fellows of Harvard College officially adopted a plan for instituting medical instruction. The school's present buildings opened in 1906 and are located in Boston across the Charles River from the university in Cambridge.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Hospital-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Mixed

Managed Care Market Group 3 **ID** 46

Medical School	
University of Massachusetts Medical School	
Worcester	
MA	

Enrollment	420
Number of Graduates	96
% Primary Care Physicians	40%
Clinical Faculty	472
Basic Science Faculty	125
Total Faculty	600
Total Teaching Load	1,239
Total Revenue	$176,132,190
Total NIH Support	$82,396,949
Number of Clinical Affiliations	4

Type of Control

Public

Managed Care Market

Managed Care-State	54%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	52%

History

The Medical School was established by an act of the General Court in 1962. The teaching hospital is UMass Memorial Medical Center. The first freshman class was admitted in the fall of 1970.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 47

Medical School		**Enrollment**	684
Tufts University School of Medicine		**Number of Graduates**	176
Boston		**% Primary Care Physicians**	27%
MA		**Clinical Faculty**	805
		Basic Science Faculty	142
Type of Control		**Total Faculty**	948
Private		**Total Teaching Load**	1,804
		Total Revenue	$300,255,681
Managed Care Market		**Total NIH Support**	$39,565,615
Managed Care-State	54%	**Number of Clinical Affiliations**	10
Managed Care-MSA	57%		
Average HMO market, 1995-2001	52%		

History

Tufts University School of Medicine is located in downtown Boston, two blocks south and east of historic Boston Common. Established in 1893 as one of the component schools of Tufts College, its name was changed from Tufts College Medical School to its present title in 1955 when the original Tufts College, founded in 1852, changed to its university status. The medical and dental schools, the USDA Human Nutrition Research Center on Aging, and the Sackler School of Graduate Biomedical Sciences are located in Boston. The university's undergraduate campus is in Medford, just north of Boston.

Current Institutional Description	
Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	N/A
Practice Plan Typology	No practice plan
Practice Plan Legal Structure	N/A

Managed Care Market Group	3	**ID**	48

Medical School		**Enrollment**	445
Michigan State University College of Human Medicine		**Number of Graduates**	103
East Lansing		**% Primary Care Physicians**	45%
MI		**Clinical Faculty**	150
		Basic Science Faculty	34
Type of Control		**Total Faculty**	203
Public		**Total Teaching Load**	741
		Total Revenue	$66,151,415
Managed Care Market		**Total NIH Support**	$5,127,102
Managed Care-State	32%	**Number of Clinical Affiliations**	17
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	27%		

History

In 1960, there was a societal demand for more physicians, nationally and within the state. The College of Human Medicine thus began in 1964 with expectations that the college would place strong emphasis on training primary care physicians. Issues of minority admissions, affirmative action, educational supports for disadvantaged students, and medical care for the poor are preeminent in the fabric of the college.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 49

Medical School		**Enrollment**	679
University of Michigan Medical School		**Number of Graduates**	163
Ann Arbor		**% Primary Care Physicians**	22%
MI		**Clinical Faculty**	1,235
		Basic Science Faculty	139
Type of Control		**Total Faculty**	1,387
Public		**Total Teaching Load**	1,814
		Total Revenue	$391,090,532
Managed Care Market		**Total NIH Support**	$203,254,062
Managed Care-State	32%	**Number of Clinical Affiliations**	8
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	27%		

History

The University of Michigan Medical School admitted its first class of 91 entering students in 1850. Women were admitted as early as 1870. In 1880 the course was lengthened to 3 years and in 1890 to 4 years.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 50

Medical School		**Enrollment**	1,043
Wayne State University School of Medicine		**Number of Graduates**	236
Detroit		**% Primary Care Physicians**	29%
MI		**Clinical Faculty**	863
		Basic Science Faculty	179
Type of Control		**Total Faculty**	1,062
Public		**Total Teaching Load**	2,464
		Total Revenue	$244,364,311
Managed Care Market		**Total NIH Support**	$55,887,920
Managed Care-State	32%	**Number of Clinical Affiliations**	19
Managed Care-MSA	33%		
Average HMO market, 1995-2001	27%		

History

The School of Medicine was founded in 1868 as the Detroit Medical College. It was the first established school of what was to become, in 1956, Wayne State University. It is one of the largest, single-campus medical schools in the country and is affiliated with the Detroit Medical Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Mixed

Managed Care Market Group 2 **ID** 51

Medical School	
Mayo Medical School	
Rochester	
MN	

Type of Control

Private

Managed Care Market

Managed Care-State	39%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	37%

Enrollment	170
Number of Graduates	40
% Primary Care Physicians	25%
Clinical Faculty	1,493
Basic Science Faculty	135
Total Faculty	1,640
Total Teaching Load	1,457
Total Revenue	$159,599,000
Total NIH Support	$0
Number of Clinical Affiliations	7

History

Mayo Medical School, founded in 1972, is part of the Department of Education Services of Mayo Foundation. Also included in the Department of Education Services are the Mayo Graduate School of Medicine, founded in 1915; the Mayo Graduate School, formalized in 1989; the Mayo School of Health-Related Sciences, formalized in 1972; and the Mayo School of Continuing Medical Education, established in 1977.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 52

Medical School		**Enrollment**	106
University of Minnesota-Duluth School of Medicine		**Number of Graduates**	0
Duluth		**% Primary Care Physicians**	Missing
MN		**Clinical Faculty**	2
		Basic Science Faculty	30
Type of Control		**Total Faculty**	33
Public		**Total Teaching Load**	142
		Total Revenue	$14,092,502
Managed Care Market		**Total NIH Support**	$0
Managed Care-State	39%	**Number of Clinical Affiliations**	4
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	37%		

History

The University of Minnesota-Duluth School of Medicine admitted its first class in 1972 with the mission of educating future rural family physicians. After successful completion of the first 2 years of study, students are guaranteed transfer to the University of Minnesota, Twin Cities campus, in Minneapolis.

Current Institutional Description	
Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	N/A
Practice Plan Typology	No practice plan
Practice Plan Legal Structure	N/A

Managed Care Market Group 2 **ID** 53

Medical School

University of Minnesota Medical School-Minneapolis
Minneapolis
MN

Type of Control
Public

Managed Care Market

Managed Care-State	39%
Managed Care-MSA	47%
Average HMO market, 1995-2001	37%

Enrollment	865
Number of Graduates	220
% Primary Care Physicians	43%
Clinical Faculty	680
Basic Science Faculty	185
Total Faculty	873
Total Teaching Load	2,600
Total Revenue	$278,741,807
Total NIH Support	$111,000,943
Number of Clinical Affiliations	6

History

The Medical School, founded in 1888, is a major unit of the Academic Health Center of the University of Minnesota. The buildings of the Medical School, the Fairview-University Medical Center, University Campus, and the other units of the Academic Health Center are located on the east bank portion of the Twin Cities campus of the University of Minnesota in Minneapolis.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 54

Medical School

University of Mississippi School of Medicine
Jackson
MS

Type of Control
Public

Managed Care Market

Managed Care-State	5%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	2%

Enrollment	400
Number of Graduates	84
% Primary Care Physicians	39%
Clinical Faculty	419
Basic Science Faculty	105
Total Faculty	525
Total Teaching Load	826
Total Revenue	$119,646,355
Total NIH Support	$11,755,779
Number of Clinical Affiliations	7

History

The University of Mississippi School of Medicine was established at Oxford in 1903 as a 2-year school. In 1955, it was moved to the University of Mississippi Medical Center in Jackson and expanded to a 4-year program. The first degrees were awarded in 1957.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Multiple professional corporation

Managed Care Market Group 1

ID 55

Medical School		**Enrollment**	382
University of Missouri-Columbia School of Medicine		**Number of Graduates**	99
Columbia		**% Primary Care Physicians**	35%
MO		**Clinical Faculty**	293
		Basic Science Faculty	75
Type of Control		**Total Faculty**	389
Public		**Total Teaching Load**	799
		Total Revenue	$86,230,920
Managed Care Market		**Total NIH Support**	$12,017,980
Managed Care-State	44%	**Number of Clinical Affiliations**	9
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	34%		

History

Founded in 1841, the University of Missouri School of Medicine offered only a 2-year basic sciences program for much of its early existence. The present 4-year program dates from 1956 when the University Hospital opened. Part of the University of Missouri Health Care, the School of Medicine is located on the Columbia campus.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 56

Medical School

University of Missouri-Kansas City School of Medicine
Kansas City
MO

Type of Control
Public

Managed Care Market

Managed Care-State	44%
Managed Care-MSA	42%
Average HMO market, 1995-2001	34%

Enrollment	749
Number of Graduates	72
% Primary Care Physicians	27%
Clinical Faculty	425
Basic Science Faculty	22
Total Faculty	452
Total Teaching Load	726
Total Revenue	$56,517,961
Total NIH Support	$4,605,968
Number of Clinical Affiliations	9

History

The School of Medicine is part of a 4-campus university system in Missouri that includes Kansas City, Columbia, St. Louis, and Rolla. It is one of 4 health science schools in Kansas City. The medical school offers a 6-year combined B.A.-M.D. program. The first class enrolled in the fall of 1971.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 57

Medical School		**Enrollment**	600
Saint Louis University School of Medicine		**Number of Graduates**	141
St. Louis		**% Primary Care Physicians**	33%
MO		**Clinical Faculty**	405
		Basic Science Faculty	123
Type of Control		**Total Faculty**	530
Private		**Total Teaching Load**	1,100
		Total Revenue	$63,915,675
Managed Care Market		**Total NIH Support**	$22,684,821
Managed Care-State	44%	**Number of Clinical Affiliations**	7
Managed Care-MSA	40%		
Average HMO market, 1995-2001	34%		

History

The first faculty in medicine of the university was appointed in 1836. The present School of Medicine dates from 1903 when the Marion Sims-Beaumont College of Medicine came under the direction of the university. The medical school is part of the Saint Louis University Health Sciences Center, which is located 1 mile from the university proper.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 58

Medical School		**Enrollment**	576
Washington University School of Medicine		**Number of Graduates**	123
St. Louis		**% Primary Care Physicians**	21%
MO		**Clinical Faculty**	765
		Basic Science Faculty	146
Type of Control		**Total Faculty**	953
Private		**Total Teaching Load**	1,834
		Total Revenue	$485,201,051
Managed Care Market		**Total NIH Support**	$289,518,114
Managed Care-State	44%	**Number of Clinical Affiliations**	8
Managed Care-MSA	40%		
Average HMO market, 1995-2001	34%		

History

Medical education began at Washington University in 1891 by affiliation between the university and the St. Louis Medical College. Today the medical school is part of the Washington University Medical Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group	3	**ID**	59

Medical School	
Creighton University School of Medicine	
Omaha	
NE	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	13%
Managed Care-MSA	28%
Average HMO market, 1995-2001	12%

Enrollment	440
Number of Graduates	106
% Primary Care Physicians	28%
Clinical Faculty	171
Basic Science Faculty	60
Total Faculty	237
Total Teaching Load	820
Total Revenue	$44,393,967
Total NIH Support	$4,042,380
Number of Clinical Affiliations	8

History

Creighton University was founded on September 2, 1878, in accordance with the wishes of Edward and Mary Creighton, under the name of Creighton College. On August 14, 1879, the trust created was surrendered to a new corporation, the Creighton University. The Creighton University School of Medicine was opened on October 1, 1892, and became the first professional school of the university. The Creighton University Health Sciences Center includes the schools of medicine, dentistry, nursing, pharmacy, and allied health professions. Saint Joseph Hospital and the Boys Town National Research Hospital are located on a single campus with the remainder of the university community.

Current Institutional Description

Relation to Parent University	Related / proximate		
Community-based School	No		
Practice Plan Organization	Medical school-based		
Practice Plan Typology	Federated plan		
Practice Plan Legal Structure	Part of university		
Managed Care Market Group	1	**ID**	60

Medical School		**Enrollment**	488
University of Nebraska College of Medicine		**Number of Graduates**	122
Omaha		**% Primary Care Physicians**	35%
NE		**Clinical Faculty**	281
		Basic Science Faculty	87
Type of Control		**Total Faculty**	393
Public		**Total Teaching Load**	970
		Total Revenue	$154,493,219
Managed Care Market		**Total NIH Support**	$26,556,108
Managed Care-State	13%	**Number of Clinical Affiliations**	24
Managed Care-MSA	28%		
Average HMO market, 1995-2001	12%		

History

The Omaha Medical College was incorporated in 1881. When it became part of the University of Nebraska in 1902, basic sciences years were taught in Lincoln and the clinical years in Omaha. In 1913 a new campus was established in Omaha for all medical education. The medical school is part of the University of Nebraska Medical Center.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 61

Medical School	
University of Nevada School of Medicine	
Las Vegas	
NV	
Type of Control	
Public	
Managed Care Market	
Managed Care-State	30%
Managed Care-MSA	31%
Average HMO market, 1995-2001	24%

Enrollment	206
Number of Graduates	50
% Primary Care Physicians	36%
Clinical Faculty	163
Basic Science Faculty	40
Total Faculty	219
Total Teaching Load	505
Total Revenue	$55,594,143
Total NIH Support	$10,209,772
Number of Clinical Affiliations	3

History

The School of Medicine was originally approved in 1969 as a 2-year school of basic sciences. In 1977 the university's Board of Regents and the Nevada State Legislature approved the school's conversion to a 4-year degree granting school. The first doctor of medicine degrees were awarded in 1980. The School of Medicine is a university-based, community integrated medical school with the basic science campus located on the University of Nevada, Reno campus and clinical campuses in Reno and Las Vegas. Present enrollment at the School of Medicine is 52 students per class.

Current Institutional Description

Relation to Parent University	Related / proximate		
Community-based School	Yes		
Practice Plan Organization	Medical school-based		
Practice Plan Typology	Multi-specialty plan		
Practice Plan Legal Structure	Separate not-for-profit		
Managed Care Market Group	2	**ID**	62

Medical School	
Dartmouth Medical School	
Hanover	
NH	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	39%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	38%

Enrollment	309
Number of Graduates	64
% Primary Care Physicians	34%
Clinical Faculty	554
Basic Science Faculty	82
Total Faculty	639
Total Teaching Load	873
Total Revenue	$109,612,169
Total NIH Support	$49,025,793
Number of Clinical Affiliations	16

History

Dartmouth Medical School, founded as the medical department of Dartmouth College, opened with its first lecture on November 22, 1797. The Medical School is a component of the Dartmouth-Hitchcock Medical Center and has facilities on the campus of Dartmouth College and at the medical center in Lebanon, NH.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group	2	**ID**	63

Medical School

UMDNJ-New Jersey Medical School
Newark
NJ

Type of Control

Public

Managed Care Market

Managed Care-State	38%
Managed Care-MSA	37%
Average HMO market, 1995-2001	35%

Enrollment	680
Number of Graduates	169
% Primary Care Physicians	24%
Clinical Faculty	544
Basic Science Faculty	134
Total Faculty	679
Total Teaching Load	1,518
Total Revenue	$160,470,054
Total NIH Support	$38,082,852
Number of Clinical Affiliations	5

History

The UMDNJ-New Jersey Medical School was incorporated on August 6, 1954, as the Seton Hall College of Medicine and Dentistry and in November of that year was granted a charter by the New Jersey Department of Education. In 1965 Seton Hall College of Medicine and Dentistry became the New Jersey College of Medicine and Dentistry, a state supported institution. The New Jersey Medical School is one of 8 schools that compose the statewide UMDNJ (University of Medicine and Dentistry of New Jersey), established in July 1970 under a single board of trustees.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 64

Medical School

UMDNJ-Robert Wood Johnson Medical School
New Brunswick
NJ

Type of Control
Public

Managed Care Market

Managed Care-State	38%
Managed Care-MSA	48%
Average HMO market, 1995-2001	35%

Enrollment	600
Number of Graduates	146
% Primary Care Physicians	25%
Clinical Faculty	359
Basic Science Faculty	92
Total Faculty	452
Total Teaching Load	1,473
Total Revenue	$181,680,427
Total NIH Support	$46,654,907
Number of Clinical Affiliations	5

History

UMDNJ-Robert Wood Johnson Medical School has campuses in Piscataway, New Brunswick and Camden, New Jersey. Established at Rutgers Medical School, it had its name changed to Robert Wood Johnson Medical School in 1986.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 65

Medical School
University of New Mexico School of Medicine
Albuquerque
NM

Type of Control
Public

Managed Care Market

Managed Care-State	42%
Managed Care-MSA	58%
Average HMO market, 1995-2001	30%

Enrollment	280
Number of Graduates	71
% Primary Care Physicians	34%
Clinical Faculty	535
Basic Science Faculty	61
Total Faculty	606
Total Teaching Load	840
Total Revenue	$149,587,293
Total NIH Support	$34,516,581
Number of Clinical Affiliations	8

History

The establishment of the School of Medicine at the University of New Mexico was authorized by the Board of Regents in 1961. The first entering class enrolled in the fall of 1964. The School of Medicine is situated on the university campus and is a part of the University of New Mexico Health Sciences Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 66

Medical School

Albany Medical College

Albany

NY

Type of Control

Private

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	51%
Average HMO market, 1995-2001	38%

Enrollment	513
Number of Graduates	128
% Primary Care Physicians	26%
Clinical Faculty	493
Basic Science Faculty	74
Total Faculty	576
Total Teaching Load	1,006
Total Revenue	$55,868,093
Total NIH Support	$10,234,906
Number of Clinical Affiliations	8

History

The Albany Medical College, chartered by the legislature of New York, was opened on January 2, 1839. The Medical College is part of the Albany Medical Center.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 67

Medical School		**Enrollment**	747
Albert Einstein College of Medicine of Yeshiva University		**Number of Graduates**	192
Bronx		**% Primary Care Physicians**	24%
NY		**Clinical Faculty**	2,017
		Basic Science Faculty	306
Type of Control		**Total Faculty**	2,346
Private		**Total Teaching Load**	3,252
		Total Revenue	$276,388,061
Managed Care Market		**Total NIH Support**	$121,537,936
Managed Care-State	45%	**Number of Clinical Affiliations**	11
Managed Care-MSA	37%		
Average HMO market, 1995-2001	38%		

History

The Albert Einstein College of Medicine admitted its first class in fall 1955. The College of Medicine is approximately seven miles from the main campus of the university.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 68

Medical School			**Enrollment**	611
Columbia University College of Physicians and Surgeons			**Number of Graduates**	149
New York			**% Primary Care Physicians**	20%
NY			**Clinical Faculty**	2,074
			Basic Science Faculty	345
Type of Control			**Total Faculty**	2,422
Private			**Total Teaching Load**	2,589
			Total Revenue	$532,951,000
Managed Care Market			**Total NIH Support**	$196,690,246
Managed Care-State	45%		**Number of Clinical Affiliations**	25
Managed Care-MSA	37%			
Average HMO market, 1995-2001	38%			

History

Columbia University began as King's College, which was founded in 1754 by royal grant of George II, King of England. In 1814 the medical faculty of Columbia College was merged with the College of Physicians and Surgeons. In 1860 the College of Physicians and Surgeons became the Medical Department of Columbia College. In 1891 the college was incorporated as an integral part of the university. The medical school is part of the Columbia-Presbyterian Medical Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Mixed

Managed Care Market Group	2	**ID**	69

Medical School	
Cornell University Joan and Sanford I. Weill Medical College and Graduate School of Medical Sciences	
New York	
NY	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	45%
Managed Care-MSA	37%
Average HMO market, 1995-2001	38%

Enrollment	415
Number of Graduates	89
% Primary Care Physicians	22%
Clinical Faculty	1,557
Basic Science Faculty	186
Total Faculty	1,750
Total Teaching Load	2,480
Total Revenue	$315,081,686
Total NIH Support	$92,342,400
Number of Clinical Affiliations	20

History

Cornell University Medical College was established in 1898 and the Graduate School of Medical Sciences in 1952 by the Trustees of Cornell University in order to take advantage of New York City's opportunities for clinical instruction. The Medical College moved to its present location in 1932 as the research and educational component of the New York Hospital-Cornell Medical Center. In 1998, the Medical College and Graduate School were renamed.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university
Managed Care Market Group	2

ID 70

Medical School

Mount Sinai School of Medicine of New York University
New York
NY

Type of Control
Private

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	37%
Average HMO market, 1995-2001	38%

Enrollment	451
Number of Graduates	110
% Primary Care Physicians	20%
Clinical Faculty	664
Basic Science Faculty	156
Total Faculty	841
Total Teaching Load	1,696
Total Revenue	$301,725,442
Total NIH Support	$121,964,497
Number of Clinical Affiliations	16

History

The School of Medicine was granted a provisional charter by the Board of Regents of the State University of New York in 1963 and an absolute charter on May 24, 1968, to establish a medical school on the campus of the Mount Sinai Hospital. The school matriculated its first students in September 1968. In July 1999, Mount Sinai School of Medicine formally affiliated with New York University.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 71

Medical School	
New York Medical College	
Valhalla	
NY	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	45%
Managed Care-MSA	37%
Average HMO market, 1995-2001	38%

Enrollment	778
Number of Graduates	204
% Primary Care Physicians	24%
Clinical Faculty	1,002
Basic Science Faculty	73
Total Faculty	1,089
Total Teaching Load	2,259
Total Revenue	$183,227,941
Total NIH Support	$19,456,256
Number of Clinical Affiliations	5

History

New York Medical College was founded by William Cullen Bryant and received its charter from the legislature of New York State in April 1860. New York Medical College is a health sciences university in the Catholic tradition that includes two graduate schools--the Graduate School of Basic Medical Sciences and Graduate School of Health Sciences. For over 100 years the college was located in New York City. During the late 1970s the College moved to its present location in Westchester County.

Current Institutional Description			
Relation to Parent University	Freestanding		
Community-based School	No		
Practice Plan Organization	Hospital-based		
Practice Plan Typology	Federated plan		
Practice Plan Legal Structure	Multiple professional corporation		
Managed Care Market Group	2	**ID**	72

Medical School

New York University School of Medicine
New York
NY

Type of Control

Private

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	37%
Average HMO market, 1995-2001	38%

Enrollment	678
Number of Graduates	163
% Primary Care Physicians	25%
Clinical Faculty	608
Basic Science Faculty	229
Total Faculty	860
Total Teaching Load	1,925
Total Revenue	$255,545,887
Total NIH Support	$95,963,065
Number of Clinical Affiliations	11

History

The New York University School of Medicine admitted its first class in 1841. The parent university is a private institution, receiving no tax support and having no geographic restriction on its student body. The medical school is part of the New York University Medical Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 73

Medical School

University of Rochester School of Medicine and Dentistry
Rochester
NY

Type of Control
Private

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	68%
Average HMO market, 1995-2001	38%

Enrollment	414
Number of Graduates	85
% Primary Care Physicians	35%
Clinical Faculty	799
Basic Science Faculty	141
Total Faculty	969
Total Teaching Load	1,525
Total Revenue	$228,346,608
Total NIH Support	$108,164,571
Number of Clinical Affiliations	8

History

The School of Medicine and Dentistry was founded in 1920 and accepted its first class in 1925. The Medical Center adjoins the university's River Campus with its programs in arts and sciences and major intellectual disciplines.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 74

Medical School	
State University of New York Health Science Center at Brooklyn College of Medicine	
Brooklyn	
NY	
Type of Control	
Public	

Enrollment	759
Number of Graduates	198
% Primary Care Physicians	21%
Clinical Faculty	555
Basic Science Faculty	105
Total Faculty	676
Total Teaching Load	1,709
Total Revenue	$223,856,762
Total NIH Support	$23,540,464
Number of Clinical Affiliations	30

Managed Care Market	
Managed Care-State	45%
Managed Care-MSA	37%
Average HMO market, 1995-2001	38%

History

The College of Medicine was founded in 1860 as the teaching division of the Long Island College Hospital in Brooklyn. In 1930 it was incorporated as the Long Island College of Medicine, and in 1950 is was merged with the State University of New York to become the first unit of the Downstate Medical Center. In January of 1986, the full name of the College of Medicine's campus was changed to State University of New York Health Science Center at Brooklyn.

Current Institutional Description

Relation to Parent University	Freestanding / state system
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Multiple professional corporation
Managed Care Market Group	2

ID 75

Medical School

State University of New York at Buffalo School of Medicine and Biomedical Sciences

Buffalo

NY

Type of Control

Public

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	64%
Average HMO market, 1995-2001	38%

Enrollment	540
Number of Graduates	134
% Primary Care Physicians	28%
Clinical Faculty	618
Basic Science Faculty	133
Total Faculty	753
Total Teaching Load	1,663
Total Revenue	$206,760,248
Total NIH Support	$22,587,515
Number of Clinical Affiliations	8

History

The University of Buffalo School of Medicine was founded in 1846 and in 1898 absorbed the Medical Department of Niagara University. In September 1962 the University at Buffalo was merged with and became a unit of the State University of New York.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Mixed

Managed Care Market Group 3

ID 76

Medical School		**Enrollment**	417
State University of New York at Stony Brook Health Sciences Center		**Number of Graduates**	96
Stony Brook		**% Primary Care Physicians**	29%
NY		**Clinical Faculty**	549
		Basic Science Faculty	115
Type of Control		**Total Faculty**	665
Public		**Total Teaching Load**	1,014
		Total Revenue	$187,474,917
Managed Care Market		**Total NIH Support**	$38,242,153
Managed Care-State	45%	**Number of Clinical Affiliations**	5
Managed Care-MSA	37%		
Average HMO market, 1995-2001	38%		

History

The School of Medicine at the State University of New York at Stony Brook is one of five schools in the Health Sciences Center, which is located on the university campus. The first students were accepted to the medical school for the 1971-72 academic year. Instruction takes place in the University Hospital at Stony Brook and at institutions affiliated with the Health Sciences Center.

Current Institutional Description			
Relation to Parent University	Related / proximate		
Community-based School	No		
Practice Plan Organization	Medical school-based		
Practice Plan Typology	Federated plan		
Practice Plan Legal Structure	Federated plan		
	Mixed		
Managed Care Market Group	2	**ID**	77

Medical School

State University of New York Upstate Medical University
College of Medicine

Syracuse

NY

Type of Control

Public

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	25%
Average HMO market, 1995-2001	38%

Enrollment	622
Number of Graduates	151
% Primary Care Physicians	33%
Clinical Faculty	363
Basic Science Faculty	61
Total Faculty	439
Total Teaching Load	1,178
Total Revenue	$99,120,305
Total NIH Support	$12,710,110
Number of Clinical Affiliations	9

History

The College of Medicine traces its history back to 1834, when it was organized as the Medical Department of Geneva College. The college remained in Geneva until 1872, when it moved to Syracuse as the College of Medicine of Syracuse University. It became part of the State University of New York (SUNY) in 1950 and was renamed the Upstate Medical Center. In 1986 it was renamed the SUNY Health Science Center. The main campus is located in Syracuse, and a satellite clinical campus is in Binghamton. The main office of the State University of New York is located in Albany.

Current Institutional Description

Relation to Parent University	Freestanding / state system
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Mixed
Managed Care Market Group	2

ID 78

Medical School	
Duke University School of Medicine	
Durham	
NC	

Type of Control

Private

Managed Care Market	
Managed Care-State	25%
Managed Care-MSA	32%
Average HMO market, 1995-2001	19%

Enrollment	401
Number of Graduates	91
% Primary Care Physicians	16%
Clinical Faculty	1,306
Basic Science Faculty	195
Total Faculty	1,514
Total Teaching Load	1,558
Total Revenue	$432,461,181
Total NIH Support	$203,561,371
Number of Clinical Affiliations	11

History

The Duke University School of Medicine, which is part of the Duke University Medical Center, is located on the campus of Duke in Durham. The hospital was opened in 1930, and the first medical students were admitted in October of that year.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 79

Medical School	
The Brody School of Medicine at East Carolina University	
Greenville	
NC	

Type of Control

Public

Managed Care Market	
Managed Care-State	25%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	19%

Enrollment	302
Number of Graduates	68
% Primary Care Physicians	35%
Clinical Faculty	266
Basic Science Faculty	62
Total Faculty	328
Total Teaching Load	365
Total Revenue	$75,242,733
Total NIH Support	$5,332,246
Number of Clinical Affiliations	4

History

In 1972 East Carolina University enrolled students in a one-year program in medical education. The present 4-year school was established in 1975.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 80

Medical School	
University of North Carolina at Chapel Hill School of Medicine	
Chapel Hill	
NC	

Enrollment	630
Number of Graduates	151
% Primary Care Physicians	33%
Clinical Faculty	846
Basic Science Faculty	234
Total Faculty	1,135
Total Teaching Load	2,332
Total Revenue	$366,592,647
Total NIH Support	$170,782,162
Number of Clinical Affiliations	16

Type of Control

Public

Managed Care Market	
Managed Care-State	25%
Managed Care-MSA	32%
Average HMO market, 1995-2001	19%

History

The School of Medicine of the University of North Carolina was established in 1879. It is located on the campus of the University of North Carolina at Chapel Hill.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Multiple professional corporation

Managed Care Market Group	2	**ID**	81

Medical School

Wake Forest University School of Medicine

Winston-Salem

NC

Type of Control

Private

Managed Care Market

Managed Care-State	25%
Managed Care-MSA	32%
Average HMO market, 1995-2001	19%

Enrollment	452
Number of Graduates	107
% Primary Care Physicians	30%
Clinical Faculty	479
Basic Science Faculty	182
Total Faculty	672
Total Teaching Load	1,198
Total Revenue	$168,359,333
Total NIH Support	$90,303,296
Number of Clinical Affiliations	4

History

The School of Medicine, established in 1902, operated as a 2-year medical school until 1941, when it was expanded to a 4-year medical college. At that time it was renamed the Bowman Gray School of Medicine of Wake Forest College. The medical school and the North Carolina Baptist Hospitals, Inc., were formally organized as the Medical Center of Bowman Gray School of Medicine and North Carolina Baptist Hospital in 1974. The medical center organization became a corporation in 1976. The name of the School was changed to the Wake Forest University School of Medicine in 1997.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 82

Medical School

University of North Dakota School of Medicine and Health Sciences

Grand Forks

ND

Type of Control

Public

Managed Care Market

Managed Care-State	5%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	N/A

Enrollment	235
Number of Graduates	54
% Primary Care Physicians	42%
Clinical Faculty	60
Basic Science Faculty	32
Total Faculty	112
Total Teaching Load	445
Total Revenue	$35,001,953
Total NIH Support	$5,863,429
Number of Clinical Affiliations	9

History

The University of North Dakota School of Medicine was founded in 1905 as a 2-year school of basic science. The expansion to an M.D. degree-granting program was approved in 1973, and the first class graduated in 1976. The first two years of medical education are provided in Grand Forks, while the third year and fourth years are provided in Bismarck, Fargo, Grand Forks, Minot, and other communities across the state. The school's name was changed in 1996, to the UND School of Medicine and Health Sciences to reflect the diversity of educational and research activities that occur at the school.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit
Managed Care Market Group	1

ID 83

Medical School

Case Western Reserve University School of Medicine
Cleveland
OH

Type of Control
Private

Managed Care Market

Managed Care-State	31%
Managed Care-MSA	32%
Average HMO market, 1995-2001	26%

Enrollment	580
Number of Graduates	150
% Primary Care Physicians	29%
Clinical Faculty	920
Basic Science Faculty	234
Total Faculty	1,155
Total Teaching Load	2,310
Total Revenue	$422,700,413
Total NIH Support	$174,096,211
Number of Clinical Affiliations	4

History

The school was organized in 1843 as the Cleveland Medical College in cooperation with Western Reserve College, then located at Hudson, Ohio. The School of Medicine is now legal successor to all of the regular medical schools that have existed from time to time in Cleveland and is located on the Case Western Reserve University campus.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Hospital-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Multiple professional corporation

Managed Care Market Group 2

ID 84

Medical School	
University of Cincinnati College of Medicine	
Cincinnati	
OH	

Type of Control
Public

Managed Care Market	
Managed Care-State	31%
Managed Care-MSA	37%
Average HMO market, 1995-2001	26%

Enrollment	623
Number of Graduates	154
% Primary Care Physicians	33%
Clinical Faculty	726
Basic Science Faculty	120
Total Faculty	852
Total Teaching Load	1,881
Total Revenue	$271,985,102
Total NIH Support	$74,957,038
Number of Clinical Affiliations	10

History

The College of Medicine is the descendant of the Medical College of Ohio, which was chartered in 1819. In 1896 this college became the medical department of the University of Cincinnati by incorporation into that institution. The medical college is part of the University of Cincinnati Medical Center.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	N/A
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Multiple professional corporation

Managed Care Market Group 2 **ID** 85

Medical School

Medical College of Ohio
Toledo
OH

Type of Control

Public

Managed Care Market

Managed Care-State	31%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	26%

Enrollment	569
Number of Graduates	151
% Primary Care Physicians	33%
Clinical Faculty	205
Basic Science Faculty	62
Total Faculty	273
Total Teaching Load	944
Total Revenue	$86,962,041
Total NIH Support	$10,694,448
Number of Clinical Affiliations	4

History

Toledo State College of Medicine was created by the General Assembly of the state of Ohio on December 18, 1964. In 1967 the General Assembly changed the official designation of the college to the Medical College of Ohio at Toledo, effective November of that year. The Medical College of Ohio falls directly within the purview of the Ohio Board of Regents. Although not administratively affiliated, there are cooperative programs between the Medical College, the University of Toledo, Bowling Green State University, and other nearby institutions of higher learning. The first class was admitted in the fall of 1969.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	For-profit corp
Managed Care Market Group	1

ID 86

Medical School		**Enrollment**	413
Northeastern Ohio Universities College of Medicine		**Number of Graduates**	97
Rootstown		**% Primary Care Physicians**	30%
OH		**Clinical Faculty**	194
		Basic Science Faculty	35
Type of Control		**Total Faculty**	230
Public		**Total Teaching Load**	1,110
		Total Revenue	$68,936,319
Managed Care Market		**Total NIH Support**	$1,239,189
Managed Care-State	31%	**Number of Clinical Affiliations**	18
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	26%		

History

The Northeastern Ohio Universities College of Medicine (NEOUCOM) is a community-based, state medical school established in November 1973. NEOUCOM awards the M.D. degree and, through consortial relationships with the University of Akron, Kent State University, and Youngstown State University, offers a combined B.S.-M.D. degree. The administration, basic sciences, and community-health sciences are located in the Rootstown campus, and the clinical sciences are community-based in hospitals in Akron, Canton, Youngstown, and the 17-county area of NE Ohio.

Current Institutional Description

Relation to Parent University	Consortium
Community-based School	Yes
Practice Plan Organization	N/A
Practice Plan Typology	No practice plan
Practice Plan Legal Structure	N/A

Managed Care Market Group 1 **ID** 87

Medical School	
Ohio State University College of Medicine and Public Health	
Columbus	
OH	
Type of Control	
Public	

Managed Care Market	
Managed Care-State	31%
Managed Care-MSA	30%
Average HMO market, 1995-2001	26%

Enrollment	919
Number of Graduates	205
% Primary Care Physicians	34%
Clinical Faculty	426
Basic Science Faculty	88
Total Faculty	536
Total Teaching Load	1,635
Total Revenue	$218,341,633
Total NIH Support	$58,679,624
Number of Clinical Affiliations	15

History

The College of Medicine and Public Health of the Ohio State University was established in 1914 by an act of the Ohio legislature.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Multiple professional corporation

Managed Care Market Group	1	**ID**	88

Medical School

Wright State University School of Medicine
Dayton
OH

Type of Control

Public

Managed Care Market

Managed Care-State	31%
Managed Care-MSA	34%
Average HMO market, 1995-2001	26%

Enrollment	370
Number of Graduates	87
% Primary Care Physicians	46%
Clinical Faculty	220
Basic Science Faculty	44
Total Faculty	268
Total Teaching Load	892
Total Revenue	$89,990,593
Total NIH Support	$7,136,294
Number of Clinical Affiliations	8

History

Wright State University was first established in 1964 as a campus of the Ohio University System operated conjointly by the Ohio State University and Miami University of Ohio; in 1967 independent status as one of 12 state-assisted universities was conferred. The School of Medicine was authorized in 1973 by the state of Ohio. The administration and the basic sciences departments are located in the parent university campus in Fairborn, a suburb of Dayton. The clinical sciences departments are community-based in seven affiliated hospitals in the Dayton area. The charter class matriculated in September 1976.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 89

Medical School
University of Oklahoma College of Medicine
Oklahoma City
OK

Type of Control
Public

Managed Care Market

Managed Care-State	22%
Managed Care-MSA	25%
Average HMO market, 1995-2001	16%

Enrollment	588
Number of Graduates	140
% Primary Care Physicians	34%
Clinical Faculty	473
Basic Science Faculty	114
Total Faculty	589
Total Teaching Load	1,399
Total Revenue	$136,808,149
Total NIH Support	$23,981,086
Number of Clinical Affiliations	14

History
The College of Medicine is one of seven health professions colleges that make up the University of Oklahoma Health Sciences Center, located 20 miles from the main campus in Norman. The College of Medicine was established in 1900 as a two-year preclinical college and merged in 1910 with the Epworth Medical College in Oklahoma City to become a four-year degree-granting college. The University of Oklahoma College of Medicine-Tulsa was established by legislative action in 1973. Up to 35 students each year may transfer from Oklahoma City to Tulsa after their sophomore year to complete their clinical education.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 1 **ID** 90

Medical School

Oregon Health Sciences University School of Medicine
Portland
OR

Type of Control
Public

Managed Care Market

Managed Care-State	50%
Managed Care-MSA	52%
Average HMO market, 1995-2001	43%

Enrollment	400
Number of Graduates	104
% Primary Care Physicians	39%
Clinical Faculty	678
Basic Science Faculty	153
Total Faculty	846
Total Teaching Load	1,261
Total Revenue	$221,339,401
Total NIH Support	$102,913,908
Number of Clinical Affiliations	23

History
The University of Oregon School of Medicine in Portland, Oregon, was established in 1887. In 1913 it was merged with the medical department of Willamette University in Salem, and all students were transferred to Portland. In 1974 the schools of medicine, dentistry, and nursing were combined into the University of Oregon Health Sciences Center. The center was renamed Oregon Health Sciences University in November 1981.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 91

Medical School

Jefferson Medical College of Thomas Jefferson University
Philadelphia
PA

Type of Control

Private

Managed Care Market

Managed Care-State	50%
Managed Care-MSA	48%
Average HMO market, 1995-2001	38%

Enrollment	900
Number of Graduates	215
% Primary Care Physicians	29%
Clinical Faculty	492
Basic Science Faculty	179
Total Faculty	676
Total Teaching Load	1,955
Total Revenue	$216,128,877
Total NIH Support	$74,700,748
Number of Clinical Affiliations	19

History

Jefferson Medical College was established in 1824; classes have been graduated annually since 1826. It is privately controlled, nondenominational, and coeducational. On July 1, 1969, Thomas Jefferson University was established with the Jefferson Medical College was one of its colleges.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 92

Medical School

MCP Hahnemann School of Medicine

Philadelphia

PA

Type of Control

Private

Managed Care Market

Managed Care-State	50%
Managed Care-MSA	48%
Average HMO market, 1995-2001	38%

Enrollment	966
Number of Graduates	245
% Primary Care Physicians	Missing
Clinical Faculty	1,073
Basic Science Faculty	94
Total Faculty	1,168
Total Teaching Load	1,834
Total Revenue	Missing
Total NIH Support	$15,821,224
Number of Clinical Affiliations	20

History

MCP Hahnemann School of Medicine was formed through the consolidation of the Medical College of Pennsylvania and Hahnemann University in 1994-95. The Medical College of Pennsylvania was incorporated in 1850 as the Female Medical College of Pennsylvania, changing its name in 1867 to the Women's Medical College of Pennsylvania and, in 1970, to the Medical College of Pennsylvania. Hahnemann University School of Medicine was formed through the successive union of several institutions, the oldest of which was founded in 1848. On November 11, 1998 the School of Medicine became part of the newly established MCP Hahnemann University, managed by Drexel University, Philadelphia. In addition to the School of Medicine, the University is also composed of the College of Nursing and Health Professions and the School of Public Health.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university
Managed Care Market Group	3

ID 93

Medical School

Pennsylvania State University College of Medicine
Hershey
PA

Type of Control
Private

Managed Care Market

Managed Care-State	50%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	38%

Enrollment	641
Number of Graduates	99
% Primary Care Physicians	33%
Clinical Faculty	420
Basic Science Faculty	99
Total Faculty	524
Total Teaching Load	1,077
Total Revenue	$119,582,077
Total NIH Support	$40,463,926
Number of Clinical Affiliations	3

History

The Milton S. Hershey Medical Center of the Pennsylvania State University was established in August 1963 and admitted the first class of medical students in 1967. Located on a 549-acre campus on the western edge of Hershey, the medical center is 12 miles from the state capital, Harrisburg, and approximately 105 miles from the university's main campus at University Park.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 94

Medical School
University of Pennsylvania School of Medicine
Philadelphia
PA

Type of Control
Private

Managed Care Market

Managed Care-State	50%
Managed Care-MSA	48%
Average HMO market, 1995-2001	38%

Enrollment	590
Number of Graduates	158
% Primary Care Physicians	23%
Clinical Faculty	1,836
Basic Science Faculty	238
Total Faculty	2,075
Total Teaching Load	1,842
Total Revenue	$515,781,914
Total NIH Support	$318,796,754
Number of Clinical Affiliations	15

History

Founded in 1765, the School of Medicine of the University of Pennsylvania has the distinction of being the oldest medical school in the United States. It is located on the campus of the university in west Philadelphia.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 95

Medical School		**Enrollment**	590
University of Pittsburgh School of Medicine		**Number of Graduates**	150
Pittsburgh		**% Primary Care Physicians**	29%
PA		**Clinical Faculty**	1,507
		Basic Science Faculty	118
Type of Control		**Total Faculty**	1,626
Private		**Total Teaching Load**	1,826
		Total Revenue	$438,342,278
Managed Care Market		**Total NIH Support**	$195,113,781
Managed Care-State	50%	**Number of Clinical Affiliations**	16
Managed Care-MSA	56%		
Average HMO market, 1995-2001	38%		

History

The School of Medicine was originally chartered in 1886 as the Western Pennsylvania Medical College and, in 1892, became affiliated with the Western University of Pennsylvania. In 1908 its name was changed to the School of Medicine of the University of Pittsburgh. The University of Pittsburgh became a state-related institution in 1966. The medical school is located on the university campus, which is in the Oakland district of Pittsburgh.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 96

Medical School
Temple University School of Medicine
Philadelphia
PA

Type of Control
Private

Managed Care Market

Managed Care-State	50%
Managed Care-MSA	48%
Average HMO market, 1995-2001	38%

Enrollment	740
Number of Graduates	182
% Primary Care Physicians	33%
Clinical Faculty	247
Basic Science Faculty	94
Total Faculty	345
Total Teaching Load	1,403
Total Revenue	$111,006,859
Total NIH Support	$28,819,857
Number of Clinical Affiliations	18

History
The School of Medicine was opened as a department of Temple University in 1901.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 97

Medical School		**Enrollment**	227
Universidad Central del Caribe School of Medicine		**Number of Graduates**	47
Bayamon		**% Primary Care Physicians**	31%
PR		**Clinical Faculty**	97
		Basic Science Faculty	21
Type of Control		**Total Faculty**	119
Private		**Total Teaching Load**	310
		Total Revenue	$20,703,631
Managed Care Market		**Total NIH Support**	$2,242,622
Managed Care-State	N/A	**Number of Clinical Affiliations**	5
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	N/A		

History

The School of Medicine of Universidad Central del Caribe started operations in September 1976. All basic science and clinical facilities are located on the grounds of the Dr. Ramon Ruiz Arnau University Hospital at Bayamon, Puerto Rico. The new Basic Sciences Building started operations in August 1990.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 98

Medical School		**Enrollment**	262
Ponce School of Medicine		**Number of Graduates**	66
Ponce		**% Primary Care Physicians**	27%
PR		**Clinical Faculty**	25
		Basic Science Faculty	31
Type of Control		**Total Faculty**	60
Private		**Total Teaching Load**	392
		Total Revenue	$11,158,944
Managed Care Market		**Total NIH Support**	$4,436,455
Managed Care-State	N/A	**Number of Clinical Affiliations**	12
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	N/A		

History

The Ponce School of Medicine was established in 1977 by the Catholic University of Puerto Rico but since 1980 has been operated independently under the auspices of the private not-for-profit foundation, the Ponce Medical School Foundation Inc. The administration and basic sciences are located in a series of modern facilities inaugurated on January 1995 in the southern part of the city of Ponce, PR. The clinical sciences are community based in eight different affiliated hospital in the southern area of Puerto Rico. The charter class graduated in May 1981.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 99

Medical School		**Enrollment**	445
University of Puerto Rico School of Medicine		**Number of Graduates**	113
San Juan		**% Primary Care Physicians**	27%
PR		**Clinical Faculty**	229
		Basic Science Faculty	69
Type of Control		**Total Faculty**	299
Public		**Total Teaching Load**	910
		Total Revenue	$53,951,289
Managed Care Market		**Total NIH Support**	$15,906,366
Managed Care-State	N/A	**Number of Clinical Affiliations**	9
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	N/A		

History

The University of Puerto Rico School of Medicine accepted its first class in August 1950. The School of Medicine developed originally from the School of Tropical Medicine of the university (which had been established under joint auspices with Columbia University in 1924). Since 1972 the School of Medicine has been located on the Medical Sciences Campus on the grounds of the Puerto Rico Medical Center, two miles from the main university campus at Rio Piedras.

Current Institutional Description

Relation to Parent University	Related / distant
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 100

Medical School	
Brown University School of Medicine	
Providence	
RI	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	53%
Managed Care-MSA	56%
Average HMO market, 1995-2001	36%

Enrollment	320
Number of Graduates	80
% Primary Care Physicians	29%
Clinical Faculty	489
Basic Science Faculty	80
Total Faculty	571
Total Teaching Load	1,141
Total Revenue	$284,128,218
Total NIH Support	$30,825,479
Number of Clinical Affiliations	7

History

Brown University was founded in 1764. Its first MD program, initiated in 1811, was temporarily suspended in 1827. The master of medical science program was begun in 1963, and the MD-conferring program started in 1973. The first class of physicians was graduated in June 1975. The School of Medicine operates in conjunction with 7 hospitals in the Providence metropolitan area.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Hospital-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 3 **ID** 101

Medical School		**Enrollment**	570
Medical University of South Carolina College of Medicine		**Number of Graduates**	136
Charleston		**% Primary Care Physicians**	32%
SC		**Clinical Faculty**	611
		Basic Science Faculty	198
Type of Control		**Total Faculty**	810
Public		**Total Teaching Load**	1,312
		Total Revenue	$205,716,687
Managed Care Market	17%	**Total NIH Support**	$56,167,734
Managed Care-State	N/A	**Number of Clinical Affiliations**	14
Managed Care-MSA	N/A		
Average HMO market, 1995-2001			

History

Founded in 1824, the Medical College of South Carolina graduated its first class in 1825. In 1969 the name was changed to the Medical University of South Carolina.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 102

Medical School

University of South Carolina School of Medicine
Columbia
SC

Type of Control
Public

Managed Care Market

Managed Care-State	17%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	11%

Enrollment	295
Number of Graduates	71
% Primary Care Physicians	34%
Clinical Faculty	152
Basic Science Faculty	48
Total Faculty	217
Total Teaching Load	633
Total Revenue	$46,632,681
Total NIH Support	$2,229,815
Number of Clinical Affiliations	5

History

The University of South Carolina School of Medicine was authorized by the South Carolina state legislature in June 1973 and is established under the Veterans Administration Medical School Assistance and Health Manpower Training Act of 1972. The new School of Medicine campus, located approximately four and one-half miles from the main campus of the University of South Carolina, was completed in 1983 and houses basic science departments, administrative offices, and the medical library. Most clinical departments are located at affiliated hospitals in the Columbia area.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university
Managed Care Market Group	1

ID 103

Medical School			**Enrollment**	200
University of South Dakota School of Medicine			**Number of Graduates**	49
Sioux Falls			**% Primary Care Physicians**	44%
SD			**Clinical Faculty**	93
			Basic Science Faculty	42
Type of Control			**Total Faculty**	144
Public			**Total Teaching Load**	335
			Total Revenue	$25,321,047
Managed Care Market			**Total NIH Support**	$4,633,345
Managed Care-State	9%		**Number of Clinical Affiliations**	10
Managed Care-MSA	N/A			
Average HMO market, 1995-2001	11%			

History

Medical course work began at the University of South Dakota in 1907 with the organization of the College of Medicine offering the first two years of the standard four-year medical degree program. The program was expanded in 1974 to degree-granting status and graduated the first class in 1977. The school has a community-based philosophy and clinical training (Years 3 and 4) is conducted in the community facilities affiliated with the program throughout South Dakota.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 104

Medical School

East Tennessee State University James H. Quillen College of Medicine

Johnson City

TN

Type of Control

#REF!

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	34%

Enrollment	244
Number of Graduates	55
% Primary Care Physicians	44%
Clinical Faculty	162
Basic Science Faculty	45
Total Faculty	220
Total Teaching Load	423
Total Revenue	$52,896,543
Total NIH Support	$3,243,837
Number of Clinical Affiliations	14

History

The James H. Quillen College of Medicine of East Tennessee State University was authorized by the legislature of the state of Tennessee in March 1974 and its established under the Veterans Administration Medical School Assistance and Health Manpower Training Act of 1972. The College of Medicine is located on the grounds of the Veterans Affairs Medical Center. Departments active in the first-year curriculum plus the departments of family medicine and psychiatry remain on the adjacent campus of East Tennessee State University.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit
Managed Care Market Group	2

ID 105

Medical School	
Meharry Medical College School of Medicine	
Nashville	
TN	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	45%
Managed Care-MSA	40%
Average HMO market, 1995-2001	34%

Enrollment	368
Number of Graduates	77
% Primary Care Physicians	28%
Clinical Faculty	130
Basic Science Faculty	63
Total Faculty	196
Total Teaching Load	611
Total Revenue	$65,063,260
Total NIH Support	$18,428,826
Number of Clinical Affiliations	10

History

Meharry Medical College was organized in 1876 as the Medical Department of Central Tennessee College. In 1900 Central Tennessee College was reorganized as Walden University, and the Medical Department became known as Meharry Medical College of Walden University. Later a separate corporate existence was sought, and in 1915 a new charter was granted by the state of Tennessee. Through contributions from a variety of sources, property was acquired in northwest Nashville, and the present school and hospital were erected in 1930-31. The School of Medicine is the oldest and largest of the College's four schools.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 106

Medical School

University of Tennessee, Health Science Center, College of Medicine

Memphis

TN

Type of Control

Public

Managed Care Market

Managed Care-State	45%
Managed Care-MSA	47%
Average HMO market, 1995-2001	34%

Enrollment	683
Number of Graduates	152
% Primary Care Physicians	40%
Clinical Faculty	835
Basic Science Faculty	140
Total Faculty	984
Total Teaching Load	1,663
Total Revenue	$135,340,494
Total NIH Support	$42,303,110
Number of Clinical Affiliations	13

History

The University of Tennessee College of Medicine was established in 1851 as the Medical Department of the University of Nashville. Later, by mergers and agreements, it became part of the University of Tennessee and was moved to Memphis in 1911. It is one of six colleges comprising the University of Tennessee, Health Science Center, and has programs in Chattanooga, Jackson, Knoxville, and Nashville as well as in Memphis.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit
Managed Care Market Group	3

ID 107

Medical School	
Vanderbilt University School of Medicine	
Nashville	
TN	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	45%
Managed Care-MSA	40%
Average HMO market, 1995-2001	34%

Enrollment	421
Number of Graduates	104
% Primary Care Physicians	21%
Clinical Faculty	854
Basic Science Faculty	239
Total Faculty	1,158
Total Teaching Load	1,690
Total Revenue	$236,782,061
Total NIH Support	$137,583,802
Number of Clinical Affiliations	7

History

Vanderbilt University issued its first MD degrees in 1875. During a reorganization in 1925, the medical school was moved to the main campus of Vanderbilt University. The medical school is part of the Vanderbilt University Medical Center.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 3 **ID** 108

Medical School		**Enrollment**	666
Baylor College of Medicine		**Number of Graduates**	170
Houston		**% Primary Care Physicians**	24%
TX		**Clinical Faculty**	1,378
		Basic Science Faculty	386
Type of Control		**Total Faculty**	1,766
Private		**Total Teaching Load**	2,533
		Total Revenue	$440,825,513
Managed Care Market		**Total NIH Support**	$220,109,790
Managed Care-State	28%	**Number of Clinical Affiliations**	17
Managed Care-MSA	39%		
Average HMO market, 1995-2001	21%		

History

The University of Dallas Medical Department was organized in 1900 and in 1903 allied itself with Baylor University of Waco, Texas. The medical college moved to its present site in 1943 to become the first institution in the Texas Medical Center. The college separated from Baylor University and was incorporated as an independent institution in 1969.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Departmental plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 109

Medical School		**Enrollment**	270
The Texas A&M University System Health Science Center College of Medicine		**Number of Graduates**	63
College Station		**% Primary Care Physicians**	32%
TX		**Clinical Faculty**	796
		Basic Science Faculty	107
Type of Control		**Total Faculty**	908
Public		**Total Teaching Load**	627
		Total Revenue	$54,320,345
Managed Care Market		**Total NIH Support**	$13,828,204
Managed Care-State	28%	**Number of Clinical Affiliations**	4
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	21%		

History

The Texas A&M University College of Medicine was authorized by the Texas Legislature in 1971. The first class was graduated in June 1981. In January 1991, the Board of Regents of the Texas A&M University System created the Texas A&M University Health Science Center, of which the College is an integral part. The College is located on the main campus of the parent university with clinical facilities in affiliated institutions.

Current Institutional Description

Relation to Parent University	Related / proximate		
Community-based School	Yes		
Practice Plan Organization	Medical school-based		
Practice Plan Typology	Departmental plan		
Practice Plan Legal Structure	Mixed		
Managed Care Market Group	1	**ID**	110

Medical School	
Texas Tech University Health Sciences Center School of Medicine	
Lubbock	
TX	
Type of Control	
Public	

Enrollment	480
Number of Graduates	120
% Primary Care Physicians	30%
Clinical Faculty	369
Basic Science Faculty	58
Total Faculty	450
Total Teaching Load	1,040
Total Revenue	$104,967,337
Total NIH Support	$5,066,949
Number of Clinical Affiliations	22

Managed Care Market	
Managed Care-State	28%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	21%

History

In May 1969, the 61st Texas Legislature and the governor authorized the establishment of an MD degree-granting School of Medicine on the campus of Texas Tech University in Lubbock, Texas. The school is governed by the Board of Regents of Texas Tech University and the Texas Tech University Health Sciences Center, which meets in separate sessions for each institution. Each is subject to the supervision and regulations of the Coordinating Board, Texas College and University System. The medical school, with regional academic health centers in Amarillo, El Paso, and Odessa, is part of the Texas Tech UHSC.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university
Managed Care Market Group	1

ID 111

Medical School		**Enrollment**	800
University of Texas Southwestern Medical Center at Dallas Southwestern Medical School		**Number of Graduates**	205
Dallas		**% Primary Care Physicians**	27%
TX		**Clinical Faculty**	1,090
		Basic Science Faculty	214
Type of Control		**Total Faculty**	1,311
Public		**Total Teaching Load**	2,192
		Total Revenue	$369,100,596
Managed Care Market		**Total NIH Support**	$144,649,172
Managed Care-State	28%	**Number of Clinical Affiliations**	17
Managed Care-MSA	37%		
Average HMO market, 1995-2001	21%		

History

The University of Texas Southwestern Medical Center at Dallas was founded as Southwestern Medical College in 1943, affiliated with the University of Texas System in 1949, and was given health center form in 1972. The 3 components of the Southwestern Medical Center are Southwestern Medical School, Graduate School of Biomedical Sciences, and Allied Health Sciences School.

Current Institutional Description

Relation to Parent University	Freestanding / state system		
Community-based School	No		
Practice Plan Organization	Health system-based		
Practice Plan Typology	Multi-specialty plan		
Practice Plan Legal Structure	Part of university		
Managed Care Market Group	2	**ID**	112

Medical School

University of Texas Medical Branch University of Texas Medical School at Galveston

Galveston

TX

Type of Control

Public

Managed Care Market

Managed Care-State	28%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	21%

Enrollment	820
Number of Graduates	153
% Primary Care Physicians	31%
Clinical Faculty	398
Basic Science Faculty	269
Total Faculty	673
Total Teaching Load	1,708
Total Revenue	$230,827,844
Total NIH Support	$61,685,911
Number of Clinical Affiliations	9

History

The University of Texas Medical Branch at Galveston was established in 1881 as a branch of the University of Texas and accepted its first class in 1891. In addition to the medical school, the campus includes the Graduate School of Biomedical Sciences, the School of Allied Health Sciences, the School of Nursing, the Marine Biomedical Institute, and the Institute for the Medical Humanities.

Current Institutional Description

Relation to Parent University	Freestanding / state system
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university
Managed Care Market Group	1

ID 113

Medical School		**Enrollment**	800
University of Texas - Houston Medical School		**Number of Graduates**	182
Houston		**% Primary Care Physicians**	34%
TX		**Clinical Faculty**	603
		Basic Science Faculty	91
Type of Control		**Total Faculty**	701
Public		**Total Teaching Load**	1,733
		Total Revenue	$205,433,369
Managed Care Market		**Total NIH Support**	$57,310,479
Managed Care-State	28%	**Number of Clinical Affiliations**	8
Managed Care-MSA	N/A		
Average HMO market, 1995-2001	21%		

History

The University of Texas Medical School at Houston was authorized by the Texas Legislature in May 1969 as a component of the University of Texas System. With the cooperation of the other three University of Texas medical schools, the first class enrolled in September 1970. The first class was graduated in 1973. The Medical School is a part of the University of Texas Health Science Center at Houston with schools of dentistry, public health, nursing, allied health, and the Graduate School of Biomedical Sciences.

Current Institutional Description

Relation to Parent University	Freestanding / state system
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Part of university
Managed Care Market Group	2

ID 114

Medical School		**Enrollment**	800
University of Texas Medical School at San Antonio		**Number of Graduates**	201
San Antonio		**% Primary Care Physicians**	39%
TX		**Clinical Faculty**	554
		Basic Science Faculty	80
Type of Control		**Total Faculty**	636
Public		**Total Teaching Load**	1,824
		Total Revenue	$212,532,074
Managed Care Market		**Total NIH Support**	$62,117,253
Managed Care-State	28%	**Number of Clinical Affiliations**	11
Managed Care-MSA	31%		
Average HMO market, 1995-2001	21%		

History

The University of Texas Medical School at San Antonio was established in 1959 by the Texas Legislature as a separate component unit of the University of Texas System. The Medical School opened at its present site in September 1968. In October 1972 the Board of Regents directed the establishment of the University of Texas Health Science Center at San Antonio. The Medical School is an integral part of the center, which also houses the Dental School, Graduate School of Biomedical Sciences, School of Nursing, School of Allied Health Sciences, and Institute of Biotechnology.

Current Institutional Description

Relation to Parent University	Freestanding / state system		
Community-based School	No		
Practice Plan Organization	Medical school-based		
Practice Plan Typology	Multi-specialty plan		
Practice Plan Legal Structure	Part of university		
Managed Care Market Group	2	**ID**	115

Medical School		**Enrollment**	400
University of Utah School of Medicine		**Number of Graduates**	98
Salt Lake City		**% Primary Care Physicians**	32%
UT		**Clinical Faculty**	660
		Basic Science Faculty	166
Type of Control		**Total Faculty**	827
Public		**Total Teaching Load**	1,235
		Total Revenue	$200,858,456
Managed Care Market		**Total NIH Support**	$81,797,128
Managed Care-State	51%	**Number of Clinical Affiliations**	11
Managed Care-MSA	39%		
Average HMO market, 1995-2001	39%		

History

Founded as a 2-year school in 1905, the College of Medicine was expanded to a 4-year program in 1943. In 1965 it became completely integrated into the university with the completion of the University of Utah Medical Center on the upper main campus. In 1981 the name was changed formally to the University of Utah School of Medicine.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 116

Medical School	
University of Vermont College of Medicine	
Burlington	
VT	

Type of Control

Public

Managed Care Market

Managed Care-State	29%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	20%

Enrollment	375
Number of Graduates	91
% Primary Care Physicians	32%
Clinical Faculty	263
Basic Science Faculty	107
Total Faculty	371
Total Teaching Load	787
Total Revenue	$88,998,770
Total NIH Support	$51,783,240
Number of Clinical Affiliations	4

History

Instruction in what was to become the University of Vermont College of Medicine was initiated in 1803 when Dr. John Pomeroy was appointed to the staff to teach chirurgery (surgery) and anatomy. The first full and regular course of medical lectures, however, was not offered until fall 1822. In 1836 the medical department was forced to close because of lack of students and professors. The school was reorganized and reopened in 1853. In 1899 the medical college became a coordinate department of the university under the control of the Board of Trustees. In 1911 the College of Medicine became an integral part of the university.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 117

Medical School	
Eastern Virginia Medical School of the Medical College of Hampton Roads	
Norfolk	
VA	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	26%
Managed Care-MSA	27%
Average HMO market, 1995-2001	22%

Enrollment	620
Number of Graduates	104
% Primary Care Physicians	38%
Clinical Faculty	228
Basic Science Faculty	37
Total Faculty	266
Total Teaching Load	429
Total Revenue	$70,207,709
Total NIH Support	$5,690,809
Number of Clinical Affiliations	18

History

Eastern Virginia Medical School is governed by the Medical College of Hampton Roads Board of Visitors and was established by the General Assembly of the Commonwealth of Virginia in 1964. In September 1976 the medical school graduated 23 physicians in its first class. With the support of the communities of Norfolk, Virginia Beach, Chesapeake, Hampton, Portsmouth, Newport News, Suffolk and other cities and counties throughout eastern Virginia, the medical school gained recognition as an academic health center. The basic medical science building, Lewis Hall, was occupied in 1978; the clinical science education building, Hofheimer Hall, was occupied in June 1985. As a result of a 1987 enactment by the General Assembly, the name of the governing body was changed from Eastern Virginia Medical Authority to the Medical College of Hampton Roads.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	Yes
Practice Plan Organization	N/A
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Mixed
Managed Care Market Group	1

ID 118

Medical School	
Virginia Commonwealth University School of Medicine	
Richmond	
VA	
Type of Control	
Public	
Managed Care Market	
Managed Care-State	29%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	20%

Enrollment	672
Number of Graduates	172
% Primary Care Physicians	36%
Clinical Faculty	686
Basic Science Faculty	140
Total Faculty	843
Total Teaching Load	1,589
Total Revenue	$216,681,435
Total NIH Support	$49,770,960
Number of Clinical Affiliations	10

History

The Medical College of Virginia was established in 1838 as a department of Hampden-Sydney and was conducted as such until 1860 when it became a state institution. In 1913 it was consolidated with the University College of Medicine, and in 1914 all students were transferred to the Medical College of Virginia. In 1969 General Assembly of Virginia created, as of July 1, 1968, Virginia Commonwealth University through a combination of Richmond Professional Institute and the Medical College of Virginia. The official school name is now the Virginia Commonwealth University School of Medicine.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit
Managed Care Market Group	3

ID 119

Medical School		**Enrollment**	555
University of Virginia School of Medicine		**Number of Graduates**	130
Charlottesville		**% Primary Care Physicians**	35%
VA		**Clinical Faculty**	683
		Basic Science Faculty	137
Type of Control		**Total Faculty**	851
Public		**Total Teaching Load**	1,636
		Total Revenue	$213,676,700
Managed Care Market		**Total NIH Support**	$103,697,502
Managed Care-State	26%	**Number of Clinical Affiliations**	11
Managed Care-MSA	27%		
Average HMO market, 1995-2001	22%		

History

According to Thomas Jefferson, medical education was to become part of the curriculum and of general education at the University of Virginia. A School of Anatomy and Medicine was one of the original 8 schools authorized by the General Assembly on January 25, 1819. The school opened on March 7, 1825, and is located on the grounds of the University of Virginia. The medical school is part of the University of Virginia Health System.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Health system-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 120

Medical School

University of Washington School of Medicine
Seattle
WA

Type of Control
Public

Managed Care Market

Managed Care-State	27%
Managed Care-MSA	37%
Average HMO market, 1995-2001	24%

Enrollment	738
Number of Graduates	177
% Primary Care Physicians	44%
Clinical Faculty	849
Basic Science Faculty	205
Total Faculty	1,062
Total Teaching Load	3,354
Total Revenue	$672,522,467
Total NIH Support	$222,507,127
Number of Clinical Affiliations	27

History

The University of Washington School of Medicine was established in 1945 as a unit of the Division of Health Sciences and an integral part of the total university campus. The school serves the 5-state WWAMI (Washington, Wyoming, Alaska, Montana, and Idaho) region.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 121

Medical School	
Joan C. Edwards School of Medicine at Marshall University	
Huntington	
WV	
Type of Control	
Public	
Managed Care Market	
Managed Care-State	14%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	11%

Enrollment	195
Number of Graduates	52
% Primary Care Physicians	46%
Clinical Faculty	128
Basic Science Faculty	28
Total Faculty	157
Total Teaching Load	387
Total Revenue	$28,511,151
Total NIH Support	$2,658,303
Number of Clinical Affiliations	6

History

The Joan C. Edwards School of Medicine at Marshall University was developed under the Veterans Administration Medical School Assistance and Health Manpower Training Act, enacted in 1972. The first class of 24 medical students enrolled in January 1978. The School of Medicine received full accreditation in 1981, and the charter class was graduated in May of that year. The School of Medicine's administrative and clinical facility is adjacent to Cabell Huntington Hospital and the school has educational facilities at the Veterans Affairs Medical Center. Community hospitals in Huntington provide additional educational and clinical facilities.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	Yes
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit
Managed Care Market Group	1

ID 122

Medical School	
West Virginia University School of Medicine	
Morgantown	
WV	

Type of Control

Public

Managed Care Market	
Managed Care-State	14%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	11%

Enrollment	354
Number of Graduates	91
% Primary Care Physicians	33%
Clinical Faculty	377
Basic Science Faculty	81
Total Faculty	474
Total Teaching Load	889
Total Revenue	$71,836,601
Total NIH Support	$9,665,326
Number of Clinical Affiliations	12

History

West Virginia University has offered the first 2 years of the medical curriculum since 1902. In 1960 it became a 4-year medical school. In 1972, the Charleston Division of the WVU Health Science Center, located in Charleston, WV, was established. Since 1988, a 376-bed Ruby Memorial replacement hospital, a 70-bed comprehensive psychiatric hospital, the Mary Babb Randolph Cancer Center, a physician office center, and a 60-bed rehabilitation hospital have opened on the WVU Health Sciences Center campus in Morgantown.

Current Institutional Description	
Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 1 **ID** 123

Medical School	
Medical College of Wisconsin	
Milwaukee	
WI	
Type of Control	
Private	
Managed Care Market	
Managed Care-State	38%
Managed Care-MSA	39%
Average HMO market, 1995-2001	33%

Enrollment	807
Number of Graduates	191
% Primary Care Physicians	31%
Clinical Faculty	785
Basic Science Faculty	119
Total Faculty	920
Total Teaching Load	1,624
Total Revenue	$194,437,381
Total NIH Support	$71,638,967
Number of Clinical Affiliations	20

History

The Medical College of Wisconsin originated in 1913 as the Medical Department of Marquette University. In 1918 a corporation was chartered by the state of Wisconsin to operate the Marquette University School of Medicine as a component of Marquette University. In 1967 the School of Medicine separated from Marquette and was reorganized to become a totally freestanding corporation. In 1970 the name of the college was changed to the Medical College of Wisconsin.

Current Institutional Description

Relation to Parent University	Freestanding
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Federated plan
Practice Plan Legal Structure	Part of university

Managed Care Market Group 2 **ID** 124

Medical School

University of Wisconsin Medical School

Madison

WI

Type of Control

Public

Managed Care Market

Managed Care-State	38%
Managed Care-MSA	N/A
Average HMO market, 1995-2001	33%

Enrollment	600
Number of Graduates	143
% Primary Care Physicians	36%
Clinical Faculty	565
Basic Science Faculty	166
Total Faculty	733
Total Teaching Load	1,480
Total Revenue	$253,147,123
Total NIH Support	$99,297,948
Number of Clinical Affiliations	9

History

The Medical School is located on the Madison campus of the University of Wisconsin in clinical facilities, occupied since April 1, 1979, adjoining the Madison Veterans Administration Hospital. The school was established in 1907, offering a 2-year program. With the construction of Wisconsin General Hospital in 1925, a 4-year program was initiated. The first 4-year class graduated in 1927.

Current Institutional Description

Relation to Parent University	Related / proximate
Community-based School	No
Practice Plan Organization	Medical school-based
Practice Plan Typology	Multi-specialty plan
Practice Plan Legal Structure	Separate not-for-profit

Managed Care Market Group 2 **ID** 125

APPENDIX B

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M.S., Psychology, Virginia Polytechnic Institute & State University, 1973
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PROFESSIONAL EXPERIENCE

Macro International Inc., 1988-present
Senior Vice President (2001-present).
General manager of QRC Division, responsible for division operation and staff of 110 information technology and research professionals; profit/loss responsibility; development and implementation of marketing strategy; participation in corporate governance. Project director on projects for the National Institutes of Health, National Science Foundation, and National Academy of Science.
Vice President, Quantum Research Corporation/Macro International Inc., 1992-2000
Research Associate, Quantum Research Corporation, 1988-1992

University of Maryland, Research Faculty, 1983-1988
Established and operated flow cytometry facility at United States Department of Agriculture (USDA) Agricultural Research Service in Beltsville, MD; responsible for facility operation and data analysis and presentation.

Lawrence Livermore National Laboratory, Research Associate, 1977-1981
Managed dedicated flow cytometry research laboratory; served as liaison between instrument development teams and biomedical research teams.

PUBLICATIONS

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