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### Economic Evolution And Structure: The Impact Of Complexity On The U.S. Economic System

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## Complexity in the economy

I wished a simple life for me.  
The web I see is too complex to be.  
I wish that I might un-  
    wind this web I've made.  
The knot is twisted and hard.  
To cut it would destroy  
    the whole and make discord.  
This cannot be.  
Spinning tighter and tighter until it breaks.  
This life I have begun to  
Make.

Alberta Bontemps

Our society is becoming more complex, not just our personal lives. These two developments stem from many of the same causes, and reversing such trends does not seem feasible in either sphere. Indeed, with solemn mien politicians, preachers, futurists, and fanatics have told us so often that the world, in general, is becoming more complex that the idea seems commonplace. Nevertheless, in particular situations the meaning of this idea is often obscure: What do such pronouncements concretely mean, for instance, regarding the economy? Under what specific circumstances is the assertion true? Most importantly, how does it affect our daily lives?

I have written this book because I believe that the concept of complexity is crucial for understanding the evolution of the U.S. economic system. Defined precisely and used as a tool of quantitative research, it leads us to ask new questions about the economy, as well as to give us new answers to many old questions. It allows us to see how the population is becoming more heterogeneous, an important factor underlying the decline of social cohesiveness in the United States. It provides perspective about the long-term rising unemployment rate in the economy. It leads us to explore more carefully than before whether volatility in the economy is increasing. It suggests to us some important clues for understanding the changing business strategies by large corporations. It forces us to look, in a quite different manner, at the changing international competitiveness of particular American industries. It shows us more clearly how the government sector has both responded to, and created, the

increasing complexity of the economic system. It guides us to greater understanding about a number of processes underlying economic growth. It permits us to see more clearly the direction in which the institutions of the economy have been changing and to make predictions about the future evolution of the economy in a more disciplined manner. Complexity, let me emphasize, is not a theory but a perspective; it is not an ideology, but an approach to help us see how a number of seemingly different changes in the economy are related.<sup>1</sup>

In analyzing the structural complexity of the economic system, three quite different phenomena must be considered: the structure itself, the processes generating the complexity of this structure, and the impact of this complexity on the operation of the system. The first question is primarily descriptive and requires the development of a set of quantitative indicators. The second question is both descriptive and analytic. The descriptive task involves following the indicators of structural complexity over time; the analytic task involves exploration of those mechanisms that have created the changing complexity. The third question involves linking particular aspects of the behavior of the economic system to its structural components. In some cases, this can be carried out in a rigorously deductive fashion; in other cases, more intuitive methods of inference must be employed. In both cases, however, I do not rest with the theory but attempt to test the propositions empirically. It is this link between theory and behavior that, in turn, allows us to say something about the future of the economic system in an organized fashion. It is this link upon which I focus in this book; the policy prescriptions must be left for others.

The first task of this chapter is to explore the meaning of the term *complexity*, especially since it is used in a number of different ways in the social science literature. This is followed by a discussion of some of the major results in the rest of the book that show how an increase in complexity of the economic system influences the behavior of the economy. The final two sections of the chapter explore how complexity can be measured and the motives that guide my approach. In order to maintain continuity in both this chapter and the rest of the book, I present detailed evidence on a variety of particular points in a series of appendices. Although annoying for those wishing to pursue all aspects of the argument in depth, this procedure lessens the burden on those who are willing give the author the benefit of doubt at particular points of the

1. Complexity of the economy is the central focus of a book by Warsh (1984) and, under other rubrics, of a number of articles by others. While sharing a common vision about the importance of complexity in understanding the operations of economic systems, these authors have applied the concept in much different ways than I. Of course, predictions about increasing complexity are common to all these studies. Nevertheless, it is what the analyst does with the concept for developing understanding of the operation of the economy that is crucial. Much closer to the approach taken in this book is an analysis of the structural complexity of exchange systems in tribal and peasant societies by Stodder (1995).

argument. Above all, this book is not aimed at the specialist in particular fields, but rather to those who wish to see how the specialized knowledge in one branch of economics is related to that in another branch.

### The meaning of structural complexity

As I will discuss in greater detail in Appendix Note 1.1, the concept of complexity has several different but related meanings. In this study I use the term only in the sense of structural complexity, which relates to the organization of a system at a single point in time. Structural complexity is, of course, a concept that can be employed to describe many different phenomena and we have only to look around us to find examples. In the field of technology, for instance, the original turbojet engine of the 1930s had a few parts, of which only one moved; by 1990 jet engines had a much superior performance but, at the same time, had almost 20,000 parts.<sup>2</sup> In the field of business organization, the division of labor has increased so that the number of interactions within a firm have greatly increased. Or, as I show in Chapter 2, the population has become increasingly heterogeneous and this, in turn, increases difficulties of governance.

Problems arise in trying to understand the concept of structural complexity because particular investigators have employed different definitions tailored to their own analytical tasks. In some cases the definition is highly abstract, for instance, Herbert Simon characterizes a complex system in terms of a large number of parts interacting in a nonsimple way.<sup>3</sup> For our investigation of the evolution of the economic system, it is difficult to employ this definition empirically. Others have defined complexity in a very narrow fashion, for instance, in terms of the number of distinct units within a system. This does not easily serve our purposes either.

Our analytic problems are compounded because the various phenomena we are studying can be examined from different perspectives so that the concept of complexity can be applied in different ways and can yield seemingly contradictory results. That is, according to one perspective, complexity might be increasing; but according to another perspective, it may be decreasing. Such difficulties are not confined to economics. For instance, the biologist George C. Williams points out that in some respects, such as with brain

2. Arthur (1993).

3. Simon (1969), p. 86. In other sciences these conceptual problems also appear. For instance, Murray Gell-Mann (1994), a Nobel laureate in physics, derives a highly abstract definition of structural complexity that is useful for his purposes but is difficult to apply to many problems in the physical sciences. Gell-Mann's approach toward complexity is sufficiently different from that of Ilya Prigogine, a Nobel laureate in chemistry, that he does not even mention the latter in his survey of complexity.

structure, a mammal is structurally more complex than any fish.<sup>4</sup> But in other respects, such as the integumentary histology of the species, the average fish is much more complex than any mammal. Both perspectives are useful, even if the conclusions appear at odds. The definition of complexity, as Nobel laureate Murray Gell-Mann is wise to remind us, is necessarily context dependent.

The definition of structural complexity used throughout this book starts with the notion that complexity relates either directly or indirectly to the information necessary for those in the system to function effectively. Three different but related sets of indicators capture this notion: the direct information requirements, the elaborateness of the internal configuration of the system and the accompanying interactions, and the heterogeneity of the elements of the system. Each of these three indicators captures at least one facet of the concept of complexity used in ordinary discourse.

#### *Direct information requirements*

Any system requiring more immediate information for a person to function effectively is more complex. In the economic system as a whole, this greater demand for information is due, in part, to the rising level of technology; and it is reflected in the greater specialization of labor and a higher per capita income. The latter, in turn, is accompanied by greater information requirements on the consumer side that reflect the greater number of products and product attributes: We not only have a number of different types of VCRs on the market from which to choose, but each has a wide number of different features. Advanced technology has also lowered costs of communication and transportation, a major factor in the expansion of the size of individual markets. All of these aspects of the increasing informational requirements of the system have influenced not only how institutions are structured, but the strategies they pursue to survive.

Unfortunately, measurement problems to capture aspects of this type of complexity are severe. Although information requirements or knowledge per se are difficult to measure from the output side, they have often been investigated by measuring the inputs – especially the labor force – used in gathering, analyzing, and disseminating information. The latter approach is obviously imperfect. Measurements of the size of markets and the degree to which additional information must be taken into account are also difficult. If market prices are the only information producers consider in their decisions, the size of markets would make no difference. But if producers base their decisions on richer information than price, then an increase in exports and imports places a greater information burden on them.

4. Williams (1966), p. 43. The next reference is to Gell-Mann (1994), p. 33.

Industry or department	Situation 1				Situation 2				Situation 3			
	A	B	C	D	A	B	C	D	A	B	C	D
A	X				X	X	X	X	X	X	X	X
B		X				X	X	X	X	X	X	X
C			X				X	X	X	X	X	X
D				X				X	X	X	X	X

X = for organizations, an order sent from a department listed in a row to a department listed in a column; for an economy, a flow of products sent from an industry listed in the column rows to an industry listed in the heads for further processing.

The meaning of these diagrams is discussed in the text. The structural complexity of situation 1 is less than structural complexity of situation 2 that, in turn, is less than the structural complexity of situation 3. Situation 2 represents an arrangement of the rows and columns such that the Xs are “triangulated” completely.

Figure 1.1 Intrafirm or inraeconomy interactions.

*More elaborate interactions or internal configuration*

As the internal organizations of economic units within the economy increase in specialization and interdependence, more elaborate internal interactions occur. In certain cases an increase in scale also gives rise to more internal interactions. A simple but unrealistic case arises when an organization requires every individual to be in contact with every other individual. In this situation, when the number of employees increases one unit from  $n - 1$  to  $n$ , the number of interrelations between employees rises by  $n - 1$  units. More realistically, a larger organization often has more hierarchical levels and, to the extent that this signifies a greater volume of interrelations between all levels, structural complexity increases. If, however, department B within the organization deals only with department A above it and with department C below it, then in a meaningful sense the complexity faced by the members is only slightly greater than if the department were self-contained and dealt exclusively with a market. If, however, a department B must also deal with departments C and D below it and also with department A above it, and if A, C, and D must also deal with each other, then complexity has increased considerably in this particular structural sense.

This idea can be easily graphed by creating a matrix with every industry or department on both the vertical and horizontal axes. In the first example, the letters stand for departments within an organization, the rows indicate the department giving orders, and the columns indicate the department receiving them. An X is placed in the matrix if department A sends orders to department B. Within a department orders are both sent to and received by department members, so there is always an X in the diagonal element. This matrix, shown in Figure 1.1, can have different configurations. In Situation 1, the matrix is

completely decomposable and each department is self-contained. In Situation 2, the matrix can be triangulated; that is, department A sends orders to all other departments, department B to all departments but A, and so forth. In Situation 3 the matrix is totally undecomposable. If complexity is defined in terms of internal interactions, then the increasing structural complexity in moving from Situation 1 to Situation 3 should be readily apparent.

Such an approach can also be used to examine one aspect of the complexity of the economy as a whole. In such a case, instead of considering the axes to be different departments, we define them as different industries, with the Xs indicating one industry sending products to another for use as inputs in further processing. The final use of these products (consumption, investment, government purchases, and exports) and the factor inputs (labor, land, and capital) and imports are not included. If they were, we would have an input–output table; such tables are available for many countries and over a considerable period of time. As I'll show in the following section, some simple measurements can be developed from such a matrix that allow us to generalize about the changing complexity of the interindustry flows of the U.S. economy.

#### *Greater differentiation or heterogeneity of units*

As the particular units of the economy become more differentiated, diverse, or heterogeneous, more information is required to understand the system. Inequality of income for example, is one type of diversity. For policy makers, a system with quite similar units is much easier to deal with than a system with quite different units. In the former case, one policy might be suitable for all units; in the latter case, different policies may be required to deal with dissimilar units. For instance, it requires less information for a government to make policy where the incomes of the population are roughly equal than if there is great inequality.

A summary of these three meanings of structural complexity and various examples to illustrate them are presented in Table 1.1. I discuss each example in detail in later chapters. Let me repeat that all three aspects of structural complexity – increasing direct information requirements of the system, increasing interactions within the system, and increasing heterogeneity of the units within the system – reflect the increasing information requirements necessary for us to function effectively in the system and, on a personal level, deal with the increasing complications of life.

#### **Impacts of structural complexity**

In the final chapter of this book I will examine various scenarios for the development of capitalism in the United States in the light of the four most impor-

Table 1.1. *Meaning and examples of increasing structural complexity*


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Increasing direct information requirements of the system:

- Skill levels (and information processing) of the labor force rises (Chapter 3)
- Share of labor force engaged in creation, processing, and interpreting information increases (Chapter 3)
- Sizes of markets and variety of products increases (Chapters 6, 8)
- Businesses take into account more governmental regulations (Chapter 9)

Increasing interactions within the system:

- Interrelations between various sectors of the economy become more extensive (Chapter 1)
- Larger share of individual wealth is created directly by the government or through government institutions (Chapter 5)
- Financial interrelations become more intricate as ratio of financial to tangible assets rises (Chapter 5)

Increasing heterogeneity of the economic system:

- Ethnic differences within the population become more important (Chapter 2)
  - Differences in income and wealth become greater (Chapter 2)
  - Differences in the size distribution of firms become greater (Chapter 6)
- 
- 

tant – and interrelated – trends that I believe are driving change in the society. Two of these trends are economic – increasing structural complexity of the economic system and increasing internationalization of the economy; and two are social-cultural – a decreasing social cohesiveness and an enervation in the capitalist spirit. The exact impact of structural complexity on the operation of the economy is controversial and is a major concern of this study.

In recent years some have used the complexity approach as a telescope to examine entire economic systems at a single glance. In such analyses it is often an article of faith that greater complexity leads either to a greater chance of a malfunctioning of the system or a greater volatility of behavior. An analogy is often drawn with the frequency of breakdown of complex machinery. More careful scholars generally confine their generalizations to a relatively narrow range of phenomena and phrase their proposition more cautiously.<sup>5</sup> In some cases this argument is also tied to decelerating growth because coordination costs to avoid such breakdowns are rising faster than other costs. For instance, G. J. Mulgan tells us that “... as institutions, economies, and soci-

5. For instance, Gell-Mann (1994), p. 28, notes that complex ecosystems are apparently less resilient to changes in the external environment than comparatively simple ones, but that this is still a matter of controversy among specialists. If the general linkage between increasing structural complexity and volatility or lack of resiliency is true, then under certain conditions limits are placed on the general increase of complexity. The next reference is to Mulgan (1991), p. 2.



eties grow and become more complex, the costs of coordination and control tend to rise faster than their material capacities.”

This type of systemic approach toward complexity can be easily abused and from such global propositions about the relation between structural complexity and greater fragility of the system as a whole, we can “prove” the proposition by selecting a few vivid examples. For instance, in July 1993 an obscure plant of the Sumitomo Chemical Company in Nihama, Japan, blew up and destroyed 65 percent of the world’s capacity for producing an epoxy resin, cresol novolac, used to seal most computer chips into their plastic packages. Shortly thereafter spot prices for computer memory soared. Other “choke-points” can be specified in the manufacture of computer chips or of equipment making the chips as well.<sup>6</sup> Orio Giarini approaches the global proposition about increased fragility in a different manner by arguing that since both insurance costs and accident prevention costs have grown much faster than production, this must reflect increases in the vulnerability of the system to breakdowns. Unfortunately such evidence is insufficient to prove this proposition.

Those interested in general systems theory have also used the concept of complexity to speculate about the general deceleration of growth in industrialized nations in the last few decades. According to this argument, increased complexity of an economy requires more resources devoted to information gathering, processing, and analysis; which means that fewer resources can be devoted to investment. For example, a measure of the information required for a market system to function might be the production of those sectors such as wholesale and retail trade plus finance and real estate, where the primary function is to serve as an intermediary between buyers and sellers. In the period between 1950 and 1990, the share of the GDP originating from these sectors rose from 25 to 39 percent (1982 prices).<sup>7</sup>

Although this kind of telescopic approach toward complexity is interesting, it is usually much too grandiose. For instance, the linkage between resources devoted and investment and to the information sector is far from clear. As shown in Chapter 4, measurement of the information sector is considerably more complicated than the use of such simple data might suggest; and more careful measures yield much less dramatic results. Nevertheless, the telescopic approach does yield useful results if we are more careful with both the theory and the evidence than is usually the case. For example, a fruitful study by Abhijet V. Banerjee and Michael Spagal uses an interesting mathematical model to argue that the increasing structural complexity, measured by a trian-

6. *The Wall Street Journal*, August 27, 1993, p. 1. The citation in the next sentence comes from Giarini (1985).

7. The data come from U.S. Department of Commerce, Bureau of Economic Analysis (1986), pp. 254–5; and *Survey of Current Business*, 73, No. 5 (May 1993), p. 54. The series are spliced using 1977 as the pivot.

gularized input–output table (see Figure 1.1) accompanying an increase of per capita income, makes central planning increasingly difficult and the economy more prone to supply breakdowns. This leads to the proposition that the centrally planned economies manifested a greater deceleration of growth than market economies, a prediction supported by empirical evidence.<sup>8</sup>

In studying changes in structural complexity, the microscope is often a more useful instrument than the telescope and this is an approach adhered to in much of the following discussion. I start with relatively concrete problems, draw upon empirical studies of my own and of others, and attack the complexity problem from the ground up. In some cases where an acceptable theory is lacking, I adopt an inductive approach. For instance, in my study of economic volatility, I compute indicators of the actual volatility of a large number of financial and production indicators over a forty-year period to see what has actually happened. Only then do my speculations about the future begin. Although definite answers are not always possible, the attempt to match the various conjectures and propositions against data advances our understanding because we can remove a clutter of irrelevant theoretical models from the table.

Chapters 2 through 4 deal with the population and the labor force. As shown in Chapter 2, the complexity of the population structure, as measured by various indicators of heterogeneity, has increased over the last forty years. Under certain conditions, such heterogeneity leads to greater problems of governance, long-run planning, and higher government expenditures (Chapter 9).<sup>9</sup> It appears to be an important factor in the decline of social cohesiveness. Some aspects of this population heterogeneity also have a direct impact on the determinants of economic growth.

As discussed in Chapter 3, the complexity of the structure of the labor force also has increased in two senses: the overall level of skill required for the various jobs is higher and the heterogeneity of the jobs has increased. An important consequence is that structural unemployment has become more important over the years, in major part because of imbalances in the supply and demand for unskilled workers. A crucial indicator is the ratio of earnings of skilled and unskilled workers, which has widened in the last decade and a half. In one respect, however, structural complexity in the labor force has declined. This is in the area of labor-management relations, where labor unions have declined in importance. Such a change has a number of implications and I present evidence that these include a decline in fringe benefits and greater wage inequality.

Chapters 5 and 6 deal with the financial structure and the structure of production. The former chapter documents a rising structural complexity defined in terms of the structure of physical and financial assets. Discussion focuses

8. Banerjee and Spagal (1991). Pryor (1994b) provides the empirical evidence for the proposition.
9. Kirby (1985) argues the proposition about governance; Michael (1968) discusses governmental expenditures.

on the empirical evidence that such increasing complexity has led to greater financial distress, for instance, bank failures and bankruptcies, but not greater volatility, a result with some important implications for monetary policy. Chapter 6 documents an increasing structural complexity defined in terms of the informational burden on productive units, the heterogeneity of productive establishments and enterprises, and also the separation of ownership and control. The chapter begins with an analysis of a survey on the various strategies used by enterprises to deal with the increasing complexity of the economic environment in which they must operate. I then investigate evidence from a large number of empirical studies that ownership and control of U.S. corporations are becoming increasingly separated and that this separation has an important impact on executive compensation and also on firm profits.

Chapters 7 and 8 deal respectively with the behavior of markets for U.S. and foreign products. Chapter 7 explores the increase in domestic competition that has come about by the extension of the market – one indicator of structural complexity – arising from a greater amount of foreign trade. The chapter shows how the increase in complexity of domestic markets has acted against the law of one price so that the expected price convergence in different domestic markets has not occurred. It also documents how volatility of prices of raw materials has increased, largely because of the increase in the volatility of exchange rates. Chapter 8 shows how the increase in openness of the U.S. economy has increased in the past at a rapid rate, and how it probably will not continue in the future. It also examines the sources of U.S. competitiveness on the world market and the particular role played by products that are technologically advanced or that require highly skilled workers.

Chapter 9 deals with the government sector. It analyzes the differential growth of particular governmental expenditures to demonstrate how, in this respect, the government responds to changes in structural complexity. It also shows how the government has generated structural complexity in markets through an extension of its regulatory activities. Finally it documents how rising structural complexity has increased the difficulty of setting both micro- and macroeconomic policies. As the economy becomes more differentiated and heterogeneous, the goals of policy may increase in number because of the varied demands of the different groups. The greater heterogeneity and competing demands increase information requirements of the system and, in addition, lengthen decision-making lags of policy. At the same time, the policy tools available to the government for influencing the course of the economy may diminish as markets increase in scope and the nation becomes more integrated into the international economy.

Chapter 10 presents in detail the argument that increasing structural complexity is one of four major interrelated trends that are shaping the evolution of the society along with increasing internationalization of the economy, decreasing social cohesiveness, and enervation of the capitalist spirit. The

manner in which these trends interact with each other and are countered by particular policy actions are analyzed with the aid of a scenario analysis that sketches five possible futures of the economic system. The two extremes of course, are, no change and exhaustion of the system; the other three scenarios provide more interesting possibilities.

### Measurements of structural complexity

Before ending this introduction, two methodological issues deserve brief discussion. The first is the actual measurement of complexity which, given my emphasis on confronting theories with data, is a crucial problem. Edward O. Wilson, a leading biologist, once remarked:<sup>10</sup> "It is not difficult to recognize complexity ... The difficulty comes in how you measure it." Depending upon the phenomena under investigation, it is possible to use several different measures of complexity since each of the three different approaches for defining complexity has several dimensions.

An example of this multidimensionality of structural complexity can be given for the economy as a whole in terms of the definition focusing on the elaborateness of the internal configuration of the system. One approach to the problem uses input–output tables for the United States in 1947 and 1977, employing two simple measurements of structural complexity that come to mind:

- The first is the ratio of the interindustry flows of production to final use of the products: For any given level of GDP, the greater the flows of production from one industry to the other, rather than the end-user, the greater the structural complexity. This measure of complexity shows no essential change in the U.S. economy during the postwar era.
- Another measure focuses on the degree to which the interindustry matrix can be triangulated. By systematically moving the rows and corresponding columns around, we can try to increase the sum of the interindustry flows above the diagonal and decrease the sum below (as shown in Figure 1.1, Situation 2). In this case, the measure of complexity is the ratio of below-diagonal to above-diagonal flows. For the United States between 1947 and 1977, the ratio slowly increased from .317 to .325 when highly aggregated input–output tables are used; this indicates that structural complexity has slowly increased.<sup>11</sup> Since the input–output table of developing nations contain many more zeros than industrialized nations, this type of com-

10. Cited by Lewin (1992), p. 136.

11. I triangulated comparable 23 by 23 transaction matrices of the 1947 and 1977 input–output matrices of the United States (from Miller and Blair, 1985, Appendix B). A fuller description of the calculation is presented in Pryor (1994).

plexity must have increased much faster at lower stages of the industrialization process, a phenomenon receiving some exploration in the economic literature.<sup>12</sup>

The two different measurements of complexity of the U.S. production structure lead to different conclusions, but this should not cause alarm if we bear in mind that complexity is multidimensional; indeed, still other measures of structural complexity based on the input–output tables can be devised as well. In the specific case under consideration, it can be easily shown that the two particular measurements of structural complexity lead to different behavioral properties of the system, so that the multidimensional procedure is justified. Indeed, any satisfactory theory about complexity must explain the behavior implications of each measure.

In many cases, structural complexity is most usefully measured by indicators adopted for the occasion with a particular theory in mind. For instance, in the examination of complexity of the organization of labor in a factory, it is generally believed that higher levels of skill are tied to more complicated interactions between the parts of the system. In this case we can use the general level of skill of the work force as a measure of this type of complexity. For studying the complexity of the financial system, it is generally believed that the relative size of financial to real assets is an important indicator of financial interactions with the system; therefore, appropriate indicators can be easily devised (see Chapter 5).

Although these ad hoc measures of complexity are useful, we cannot stop at this point. Given the importance of information flows in the general definition of structural complexity, we can draw upon some simple ideas from information theory to obtain a more general measure of complexity. The *Theil statistic* turns out to have the properties needed to measure structural complexity from an information standpoint. For those unfamiliar with this statistic, it is discussed in greater detail in Appendix Note 1.2.

For our purposes the *Theil coefficient* (designated  $H$ ) can be used in many different ways. It can be employed to measure both heterogeneity and inequality, although these two aspects of structural complexity are quite different. If we wish to compare complexity calculations from different types of data sets, it is often convenient to normalize the coefficients by the highest value that  $H$  can take so that the homogeneous–heterogeneous scale or the inequality–equality scale run from 0 to 1. I call this the *relative Theil statistic*. The Theil statistic also can be decomposed easily so that the impact of the individual parts can be examined. This means, for example, that in studying the distribu-

12. Lamet, Richter, and Teufelsbauer (1972) have the most extensive discussion. They, as well as Yan and Ames (1965), discuss alternative indicators of structural complexity using input–output tables.

tion of income, we can determine what part of the total inequality is due to inequality within particular classes defined by race or gender and what part of the inequality is due to differences in average income between these groups.

### Final remarks on methodology

The last methodological issue concerns the approach, in general, and my motives for selecting and attacking the various problems in the manner that I have chosen. For the most part the method of analysis of structural complexity represents a more general application of the paradigm followed by specialists in industrial organization relating behavior to market structure, or by biologists relating anatomical structures to the adaptiveness of the plants or animals. As such, it requires little justification.

I do not try to make an exhaustive study of the evolution of the economic system. Instead, I select a series of issues to discuss that provide insight into important problems of economic institutions and, at the same time, illustrate different aspects of changing structural complexity in the post-World War II era. While it would be possible to study changing structural complexity for a longer period, I prefer to sacrifice temporal depth for a greater breadth of coverage. It also is possible to explore the evolution of behavior at a lower level (for instance, at the level of the individual firm) but this also must be left for others.<sup>13</sup> The analysis of both structural complexity and evolution can deal with many different aspects of the economy, but this study focuses primarily on the institutional structure of the system as a whole. This means, for instance, that although many problems of developing technology have an impact on structural complexity and the evolution of the economy in different ways, I deal primarily with those impinging on the system.

It also might be satisfying to develop an abstract theory about complexity and the functioning of an economic system, but this is not my aim. Herbert Simon posed a deep question when he asked,<sup>14</sup> "Is there anything nontrivial, yet quite general, that can be said about complexity?" With regard to complexity in the structural or morphological sense, I suspect that the answer is "not a great deal" and that Simon himself has well covered the field. Unfortunately, most purely theoretical discussions about complexity in the social sphere suffer from tediousness, pomposity, or both. Moreover, the level of abstraction is sufficiently high that the relation of the resulting theory to

13. One first-rate piece of work along these lines is by Nelson and Winter (1982), but their book explores the economic evolution at a different level of abstraction and asks quite different questions than this study, which is more concerned with institutional structure. The same may be said about studies such as Arthur (1994) or other analyses briefly mentioned in Appendix Note 1.1 or in an extremely useful study by Nelson (1995).

14. Simon (1977), p. 170.

real-world phenomena is tenuous at best and nonexistent at worse. Such theorizing, which can be carried out easily in the comfort of one's armchair, has the advantage of avoiding the hard work necessary for concrete economic research; but it hardly serves to advance our state of knowledge.

My purpose is much different: to use the various concepts of complexity to examine in an empirical fashion different aspects of the evolving U.S. economic system. Unlike some observers, I do not see the U.S. economic system evolving in the next few decades into some type of postcapitalist economy that is qualitatively so different from that to which we are accustomed that all we need to do is to sketch its major outlines.<sup>15</sup> Moreover, unlike many, I do not believe that societal and historical change is accelerating in the world today. Rather, I believe that we are evolving slowly and that it is necessary to be as specific as possible in our discussion of the future, particularly to avoid general propositions with dubious empirical relevance. Given the constraints of space, the disadvantage of my approach is that only a few problems in the various areas of the economy can be discussed. I hope, however, that the particular economic problems receiving attention will serve to stimulate others to employ the approach to analyze problems that they believe are important.

Since I am concerned not just with the past but also with the future of the economic system, let me add yet another caveat. We must follow Talleyrand's maxim that above all we must avoid overenthusiasm ("*surtout pas trop de zèle*"). Therefore, I try to abstain from the uncritical and irresponsible gusto of many practitioners of futurology, especially the wishful thinking, the confusion of the "will be" and the "ought to be," and the sermonizing. I also try to adopt work habits quite different from futurologists who, like theorists of complexity, are also addicted to sitting in their armchairs and, on the basis of miscellaneous anecdotes and statistics picked up during the day, letting their imaginations freely roam. Without feeling it necessary to examine systematically all the available data, these futurologists can generate all sorts of "interesting" predictions but, as Bertrand Russell once remarked in a different context, this type of scholarly endeavor has all of the advantages of theft over honest toil. Also it is unfortunate that the writings of many who believe they are blessed with the gift of prophesy are so breathless, pretentious, smug, and moralistic that the literature is an ordeal to read; I also try to avoid these traps.

An old Chinese proverb tells us that prediction is difficult, especially about the future. Most forecasts are actually observations about what has happened in the past and present, and which trends in this period are likely to have an impact on tomorrow. Thus, our knowledge of the present and the future is inextricably mixed. Since our comprehension of the present is in continual

15. Carnevale (1993), Drucker (1993), and Toffler (1981) are typical of those believing that we are evolving into a qualitatively different economic system. Attali (1991), p. 3 is typical of those asserting that social change is accelerating.

flux, we can understand one important meaning of Paul Valéry's oft-cited aphorism, "The Future is not what it used to be." And we also understand why a thorough understanding of the present is necessary for prediction.

Despite the pitfalls, the complexity approach has several advantages in studying the future. It forces the analysis to be sufficiently specific about what is happening in the present so that meaningful predictions can be made. It also provides an alternative to most of the current economic studies of the future that focus on such problems as the future level of the GDP, population, pollution, raw material stocks, or the forthcoming discoveries and innovations that allegedly will alter our lives. Instead, it directs our attention to a much different set of problems concerning the changes in economic institutions and in policies that influence their behavior.

To avoid confusion about my aims and methods, let me also explain briefly what I do not argue in this book:

- I do not believe that complexity of the economy always increases and, in this case, we can find an analogy in the field of biology. Although it has been part of the conventional biological wisdom from Charles Darwin and Herbert Spencer to the present that life is becoming more complex, some biologists and geologists have argued recently that in important dimensions, this is not the case. In a survey of these issues Daniel V. McShea shows that it is not only difficult to measure complexity but that decreases in biological complexity are common.<sup>16</sup> This should serve as a warning to social scientists, where it is part of the conventional wisdom that societies relentlessly and continuously evolve into more complex forms.
- I also do not argue that complexity is some type of exogenous phenomenon that "just happens." Often the degree of complexity of an

16. Some of the types of evidence in this debate are useful to note. McShea (1991) examines three different measures of the complexity of the vertebrae of four classes of aquatic animals and compares the results with similar measures for surrogates of their terrestrial ancestors. He finds a drift away from complexity, not toward it, in most cases. Boyajian and Lutz (1992) show an increase in the complexity of ammonoids (an extinct class of swimming, shelled mollusks), as measured by the lobes and saddles of their internal chambers, for about 200 million years; thereafter, this measure of complexity levels off. Bonner (1988) points out that complexity is often related to size and he makes a case for a generalized version of Cope's rule (over geological time organisms generally increase in size). But he also points out numerous exceptions to this rule. Moreover, he shows that although a positive relationship between size of animals and certain measures of complexity such as number of cell types exists, the relationship is weak. Attempts to link complexity, as measured by the size of the genome or the coding DNA per genome, to some types of gross measures reflecting the hierarchy of the species give rise to even more problems (Bonner, 1988, p. 123; Smith, 1988, p. 220). Some recent studies suggest that the increasing ability for information processing of the brains of certain mammals, which is yet another sign of increasing structural complexity, appears an exception, rather than a rule of nature (Lewin, 1992, Chapter 7)



economy is a function of policies taken by governments or private individuals that can be reversed. For instance, complexity in the financial system, as manifested by a high ratio of financial to physical assets, is in large measure a function of governmental regulation of financial intermediaries. In some cases, as I argue in detail in Chapter 9, the government creates structural complexity through its regulatory activities. In still other situations institutions develop that allow complexity to be reduced in certain dimensions, for instance, the market.<sup>17</sup>

- Moreover, I do not believe that economic or social problems necessarily increase with complexity. For instance, although no ethnic problems occur when the population is ethnically homogeneous, the most severe ethnic problems may not be most acute with the maximum heterogeneity, but somewhere between the two extremes. More specifically, such problems may be most acute, not in a situation where the population is evenly divided among two ethnic groups, but in a situation where one is 15 percent and the other is 85 percent. In the latter case, the predominance of one group may give rise to inappropriate behavior on its part toward the other group (for instance, the activities of the Hutu in Rwanda) that would never occur either where the ethnic groups are 50–50 or where the minority group has only 1 or 2 percent of the population. Similarly, ethnic tensions may be much higher when there are few ethnic groups than when there are many.<sup>18</sup>
- I do not use the complexity perspective for normative purposes – to argue for or against particular governmental policies or to provide advice on how best an individual can face the future. Rather, this is

From the discussion of Gell-Mann (1994), pp. 227–31 and 244–46, three additional considerations become important to take into account: First, we must not confuse the average complexity of the entire population with the complexity of a particular species. Second, certain types of complexity can increase simply as a result of a random genetic walk that have no correlation with biological fitness. Third, decreases in social complexity are not only possible but have also occurred often in history, for instance, in Central America after the collapse of the Classic Maya civilization or in Europe after the collapse of the Roman empire. This kind of statement, however, depends upon a special definition of complexity and in some respects, for instance, heterogeneity of ruling groups, structural complexity increased.

17. This argument does not necessarily mean that fewer resources for information processing and dissemination are utilized in market than in centrally planned economies. My own calculations (Pryor, 1977) have shown that these costs were roughly similar in the two types of economies, although I believe that more useful information was transmitted through the market mechanism.
18. For instance, in Malawi where the major ethnic groups number less than ten, there seems to be a much greater sense of ethnic identification than in Madagascar, where there are almost fifty. In an investigation (Pryor, 1990) of both countries I attempted to identify the ethnicity of some seventy-five cabinet ministers; in Malawi the task was easy and could be accomplished with the aid of several informed observers. In Madagascar the task proved extremely difficult and required many more interviews.

an exercise in positive economics – to identify past and future trends and to investigate the performance of particular sectors of the economy. In Chapter 6, for instance, I am more interested in how managers actually deal with increased structural complexity, rather than how they should deal with the problem, a question that I leave to well-paid business advisors to discuss. Although the policy implications of the findings in this study are important, it would take a separate book to work them out.

- Finally, I do not argue that increased structural complexity necessarily reflects progress in some general sense.<sup>19</sup> In economics the notion of progress in a general sense is not very useful. Instead, discussion focuses on the behavior of economic systems according to such concrete criteria as economic growth or the distribution of income. If economies have increased in complexity to adapt to certain circumstances, it is not clear that economic performance along many other dimensions has improved; this is a matter for empirical investigation, since theory often tells us little about the nature of the tradeoffs.

Having briefly noted what this study is not about, let me conclude by emphasizing that this study is about empirical questions of positive economics: In what ways is structural complexity increasing or decreasing in the U.S. economic system? If such changes are occurring, how do people deal with them and what impact do they have on the functioning of the economy? The concept of structural complexity provides a useful framework to examine these questions for different sectors and institutions of the economy. Each chapter constitutes a relatively self-contained essay, tied with the other chapters primarily with regard to approach and the use of the same conceptual framework.

I am not trying to provide a general theory of how the economy works, but rather to use the concept of structural complexity to ask questions about the economy that have not been previously posed and to show how diverse economic phenomena in different sectors are related. My aim is to use the concept to examine changes in institutions throughout the economy in a more systematic and fruitful fashion than up to now.

19. A biological analogy offers insight. In this discipline the notion of progress is suspect and has given rise to considerable debate (for instance, among the various authors in Nitecki, 1988). Furthermore, the linkage between progress and complexity is even more problematic. For instance, Boyajian and Lutz (1992) show that among the ammonoids, no relationship can be found between extinction rates and complexity. Moreover, if complexity of the brain and its information processing capacity is measured by mass, it is not clear that porpoises, elephants, and blue whales, all of which have larger brains than humans, are somehow smarter. In any case the notion that human intelligence is related to brain size has been long discredited (Gould, 1981).