Preface

Some ideas from established economic theories, such as perpetual growth or sustainable growth, are not consistent with basic scientific principles. Could better policies be developed to deal with today's social and economic problems if economic theories were more scientifically consistent? Economic and social policies have many dimensions. Should tax rate be higher or lower? Should interest rate be higher or lower? Should retirement age be later or earlier? Should the number of years of mandatory education be increased or decreased? Can the magnitude of business cycles and financial crises be reduced? Should government regulate business activities more or less? Does the creation of a Euro zone benefit or harm Europe? It seems that answering each question requires very specialized knowledge. In general, most people feel that social and economic problems are too complex to be understood from a simple theory.

To this, we may reflect on the evolution of our thoughts about celestial bodies. Before the development of modern astronomy, celestial bodies, which are very far away from us, were much more mysterious than the earthly matters, which are very close to us. Then, Nicholas Copernicus showed that when the sun, instead of the earth, was considered as the center of the universe, the trajectories of the planets looked simpler. Later Johannes Kepler discovered that the trajectories of planets were simple elliptic curves around the sun. The simplicity of these trajectories suggested to people that the movements of the planets may be governed by simple rules. Eventually, Newton showed that the movement of celestial bodies is indeed governed by the simple gravitational law. After that, we began to feel that celestial systems are much simpler than social systems. The level of complexity of a system often depends on how the system is described. Currently, the standard economic theory is dominated by general equilibrium theory. The idea of equilibrium has a long tradition in human society. In Bible, God created the world in six days. After that, God only intervened occasionally, such as flood in Noah's time, to restore equilibrium. However, since Darwin, scientists have abandoned this equilibrium theory about life. Today, researchers in science generally understand biological systems, which include human societies, as non-equilibrium systems. In this book, we will show that when human societies are described as non-equilibrium systems, economic activities become much simpler to understand.

Biological and social systems are indeed very complex. But beneath this complexity lies two common properties. First, all life systems need to obtain resources from the environment to compensate for the continuous dissipation to maintain life. Second, for any life form to be viable, its cost to obtain resources cannot exceed the value of the resources over its life cycle. Similarly, for a business to be viable in the long term, its average cost of operation cannot exceed its revenue. Costs include fixed cost and variable cost. The first property is a physical principle, and the second property is an economic principle. In short, all organisms and organizations need to satisfy a physical principle and an economic principle. From these two principles, we develop a mathematical theory of the relations among the main factors in economic activities, such as fixed cost, variable cost, duration of operation or life span of organisms, uncertainty, discount rate, and level of output. Due to their importance, these major factors in production naturally became the center of investigation in the early economic literature. However, because of the difficulty in forming a compact mathematical model about these factors, discussion about them became peripheral in the current economic literature. With the help of the analytical production theory, theoretical investigation in economics may refocus on important issues in economic activities. This theory greatly simplifies our descriptions of the structures and functions of human societies. It enables us to systematically analyze the return of biological and social entities with specific structures in specific environment. It enables us to perceive clearly about the long-term consequences of personal choices, economic policies, and social structures. In a recent book, *The End of Normal*, James Galbraith discussed many ideas related to this theory in great clarity.

Economic activities are based on human decisions. Any sound economic theory has to be established on a sound theory of mind. Currently, human mind is often described as "rational" or "irrational" in the economic literature. But there is no objective measure of being "rational" or "irrational." Human mind, as part of the human body, is evolved under the same economic principle that its average cost has to be less than its average value. More than one hundred years ago, Maxwell wondered, if the cost of information processing is less than the reduction of entropy from the information, the second law of thermodynamics will be violated. Because he felt that the second law is a very fundamental law, he concluded that the average cost of information processing must be higher than the average value of information, measured in terms of entropy. If this is true, how it is possible that the human mind, an information processing system, can generate a surplus? This is because the world is not entirely random. If some patterns in life are very common, they will become imprinted into human mind, becoming part of our instincts. So we do not have to reanalyze similar situations from the scratch. Instead, we respond automatically, which greatly reduces the cost of information processing.

An economic analysis suggests that the cost of information processing of our mind has to be lower than its value. How to measure the cost and value of information processing by humans and other living systems? Maxwell linked the cost and value of information to entropy. In 1948, Claude Shannon formally defined information mathematically as entropy. From the thermodynamic theory, entropy flow drives most directional movements, including movements in human societies. Hence, entropy provides a universal measure of value. However, one's subjective assessments often differ from the objective distributions and the prevailing opinions. To develop a good theory of human mind, we need to represent objective distributions, one's subjective assessments, and the prevailing opinions properly. Guided by intuition from statistical mechanics, we apply several functions generalized from the entropy function to measure the costs and values of information processing and decision making with different subjective assessments, objective distributions, and prevailing opinions. The resulting theory of mind may be called the entropy theory of mind. Since entropy provides a natural measure of value and cost for living systems, an entropy theory of mind is also an economic theory of mind. Recently, there have been many attempts to establish a behavioral theory of economics and finance. Instead of constructing a behavioral theory of economics directly, we develop an economic theory of behavior. Then, we integrate the value and cost of information processing into the overall picture in human decision making. The theory provides a quantitative link between our judgment and decision making, such as trading activities by investors. It offers simple and consistent descriptions of many patterns of asset market and investor behaviors that have puzzled the researchers. More generally, thinking and learning are guided by the consideration of value and cost of these processes. The entropy theory of mind, as an economic theory, provides a simple description about basic patterns of learning and human psychology.

The theory of mind is derived from the combination of economic and physical principles, just like the theory on the relation of major factors in economic and biological systems. Overall, the whole theory is an integration of economic and physical principles. Entropy provides a natural measure in both physics and economics. George Williams, an evolutionary biologist, once stated, "A biological explanation should invoke no factors other than the laws of physical science, natural selection, and the contingencies of history." The rate of return, an economic measure, simply provides a quantitative measure of natural selection. The contingencies of history are a consequence of fixed costs, which is a necessity from physical and economic principles. So our theory is consistent with George Williams' vision of a biological explanation.

Physical theories emphasize the relations among observable quantities.

> Today, there are not a few physicists who … regard the task of physical theory as being merely a mathematical description (as economical as possible) of the empirical connections between observable quantities … without the intervention of unobservable elements. (Schrodinger 1928, p. 58)

However, today's economic theory is mainly built on unobservable elements. Individuals are supposed to maximize "utility." Most mainstream economists believe that problems in economic activities are caused by "imperfect" competition. Yet patent laws and other legal measures are developed to promote monopoly over property rights, hence "imperfect" completion. These same economists believe that markets are the most "efficient" way to allocate resources. Nonetheless, laws and regulations are required because of "externalities" or "market failure." But government interventions often generate "government failure." Human beings are "rational" most of the time. However, stock market can turn very volatile because investors can become "emotional" or "irrational." Rarely, fundamental concepts in established economic theories are based on observable quantities.

This economic theory is built on observable quantities. We will not judge whether a person, a business, or a social system maximizes its "utility." We will not discuss whether competition is "perfect." Instead, we will only measure the return from a system with specific structures. If a system makes negative return in the long term, it will decline, whether or not it is maximizing "utility" and "perfect." We will take no position on "market failure" or "government failure." Instead, we will only measure the returns of systems with different levels of regulations in different conditions. All living systems regulate their internal environment. But the levels of regulation are system specific. We will not argue whether humans are "rational" or "irrational." Emotions often narrow the options in decision making. At the same time, they reduce cost in decision making. As long as certain emotion generates net benefits for its host, it will be preserved, whether it is "rational" or "irrational." In each case, we will assess the returns of the specific systems under specific conditions. Of course, we will make mistakes in assessments. But the ability to make falsifiable statements is the very hallmark of a scientific theory. A theory based on observable quantities can be subject to empirical testing and can improve from empirical testing. This is very different from the statement of "maximizing utility" in established economic theories. Whatever someone does, one can always argue that he is maximizing his utility by redefining his utility function in new ways.

Over time, people have developed great results on observable quantities in social sciences. But the potentials of these results are often underappreciated in an environment where utility is the main measure. For example, John Kelly developed a formula linking investor behavior and investment return more than half-century ago. His result has been applied successfully by many investors. However, his return-based theory is not compatible with the utility-based theory. Kelly's ideas were rejected by the academic establishment and have been largely ignored in academia. A detailed account of this history was presented in William Poundstone's fascinating book, *Fortune's Formula: The Untold Story of the Scientific Betting System That Beat the Casinos and Wall Street*. I struggled for many years to develop a mathematical theory to describe investors' behaviors. Only after I read Poundstone's book, I realized that my results are extensions of Kelly's theory. Had I known Kelly's theory earlier, it could have saved me from years of struggle. A major purpose of this book is to present many brilliant ideas by early pioneers in a unified framework. We hope that more people can access these ideas easily and do not have to waste tremendous amount of time struggling to redevelop the same ideas over and over again.

If it is so fruitful to study social issues from observable quantities, why the theoretical foundation of economics is still built on utility, an unobservable quantity? In his 1949 book, *Human Behavior and the Principle of Least Effort*, George Zipf advocated that social sciences should be built on observable quantities. He further pointed out that the elite will resist this idea and use the power of academic appointment to deter people from pursuing this approach. Instead of measuring the gains and losses of different parties in a particular situation, the elite like to declare that everyone maximizes their "utilities." Hence, the current situation is "optimal." We can and do make measurements on empirical data. But to be a respectable academic, one has to restrict his search of truth outside the domain dictated by political correctness. One can only study the patterns on observable quantities on minor issues. Indeed, the very purpose of political correctness is to suppress discussion on facts that will harm the interest of powerful groups. This is the most important reason why it is so difficult to make progress on fundamental issues in social studies.

Historically, the exchange of ideas between biology and economics has been very fruitful. Both Charles Darwin and Alfred Wallace were inspired by Thomas Malthus' population theory when they developed the theory of natural selection. Similarly, biology was considered "the Mecca of the economist." However, established economic theories are equilibrium theories, while biological systems are understood as non-equilibrium systems. This and many other reasons limited the knowledge flow between social and biological sciences. We will present a common platform for both social and biological systems. This will make it easier to apply insights from one area to another area. There are many advantages for an integrated approach to social and biological systems. Biological studies cover many more species over a much longer time period than social studies. Observations on other species are often more objective than observations on ourselves. Therefore, principles derived from biological studies tend to be more general and more robust than those from social studies. On the other hand, human societies are the most intensely studied biological group. Many ideas and mathematical techniques developed in economic theories can be applied to very general problems in life science. In the last several decades, our knowledge of biology has grown tremendously. This makes it very difficult for us to gain understanding on broad range of problems. A perspective from economics will weave many seemingly disparate facts into a coherent picture. This will greatly simplify our learning.

Many people have recognized that the standard economic theories are not built on a solid foundation (Hall and Klitgaard 2011). But they often have difficulty connecting basic scientific principles to specific economic policies and social structures. Our purpose is to introduce a common foundation for science and economics, so insights gained from science and economic theories can be applied to broader areas. This book is an attempt to reach a broad audience who are concerned about the current state of economic theory and the future of our society. In the first half of the book, we will present basic ideas and discuss policy issues without using mathematics. Instead, we rely heavily on intuition, which provides great understanding on most important issues. Mathematical analyses are concentrated at the later part of the book. We provide detailed background information and discussion on historical developments of related mathematical theories to make it easier for the people to see the evolution of ideas and difficulties encountered by early pioneers.

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