Preface

After the works of Schrodinger (1944), Wiener (1948) and others, there is a consensus that life processes in general and human activities in particular are thermodynamic processes. Economic activities may be characterized and studied as mechanical processes, but at a more fundamental level of nature they are thermodynamic processes. Thus one would expect that more accurate economic theories could be built on the foundation of thermodynamics instead of rational mechanics, from which neoclassical economic theory emerged. However, the theory of thermodynamics only has had a very limited impact on economic theory to date as no analytical thermodynamic theory of economics has been established. In *The Coal Question*, first published in 1865, Jevons systematically discussed many aspects of economic activities from an energy perspective. Georgeucu-Roegen (1971) and others subsequently provided a more updated economic theory based on thermodynamics. Their approaches, however, remain qualitative. The lack of an analytical paradigm prevented thermodynamic theory from offering a detailed and quantitative analysis applicable to concrete economic and business problems. In this book, we will develop an analytical thermodynamic theory of life systems, which include social system as a special case, and show how it provides much more realistic and intuitive understanding of economic and social phenomena than neoclassical economics.

The entropy law states that systems tend toward higher entropy states spontaneously. Living systems, as non-equilibrium systems, need to extract low entropy from the environment to compensate for continuous dissipation. This process is the most fundamental property of life. It can be represented mathematically by lognormal processes, which contain a growth term and a dissipation term. From the entropy law, the thermodynamic diffusion of an organic or economic system is spontaneous. The extraction of low entropy from the environment, however, depends on specific biological or institutional structures that incur fixed or maintenance costs. Higher fixed cost systems generally have lower variable costs. In Chapter 3 of this book, we derive the thermodynamic equation that variable cost of a production system should satisfy, determine the initial value and then solve the thermodynamic equation to derive an analytic formula that explicitly represents the relation among fixed costs, variable costs, uncertainty of the environment and the duration of a production system, which is the core concern in most economic decisions. This analytical representation of various factors in production processes enables us to directly compute and analyze the returns of different production systems under various kinds of environment in a simple and systematic way.

Human activities are predominantly economic activities, which are chiefly regulated by the exchange value of different economic commodities. "The problem of value must always hold the pivotal position, as the chief tool of analysis in any pure theory that works with a rational schema." (Schumpeter, 1954, p. 588) The mainstream value theory, which is systematically represented in Debreu's *Theory of Value*, does not provide a measurable quantity for value. Since all human activities represent extraction and transformation of low entropy from the environment, it is natural to relate economic value to low entropy. From the properties that the value of commodities should satisfy, we derive that the only mathematical formula to represent value, as a function of scarcity, is the entropy function. This is parallel to the case where the only mathematical formula to represent information, as a function of probability, is the entropy function (Shannon, 1948). The entropy theory of value offers a unified understanding of physical entropy, information and economic value. It provides a quantitative measure of value that is highly consistent with our intuitive understanding. Just like the entropy theory of information provided a clear understanding of the fundamental problems in communication theory, the entropy theory of value provides clear understanding of the fundamental problems in social activities. In Chapter 2 of this book, we will discuss some of the conceptual difficulties that prevent the development of the entropy theory of value in the past and how they are resolved.

Many people do not agree that theories of social sciences should be derived from physical laws. They argue that physical laws are fixed while the human mind is free. However, the human mind is shaped by natural selection and sexual selection (Pinker, 1997). Living organisms need to extract low entropy from the environment, to defend their low entropy sources and to reduce the diffusion of low entropy. The struggle to stay in low entropy non-equilibrium states is called natural selection. Sexual selection is the struggle between the individuals of one sex, generally the males, to communicate their attractiveness to the other sex in order to form a partnership for reproduction. Human beings, as well as other sexually reproducing species, are the successful descendants of the earliest sexually reproducing species about a billion years ago (Margulis, 1998). For the system of communication to be successful in different kinds of environments over such a long time, the mode of communication has to be simple, stable and universal. Since the entropy law, which states that closed systems tend towards states of higher entropy, is the most universal law of the nature, it is natural that the display of low entropy levels evolves as the universal signal of attractiveness in the process of sexual selection. As both natural and sexual selection favor low entropy state, the pursuit of low entropy becomes the main motive in human mind and animal mind. In Chapter 1, we will show that some psychological patterns reflect the constraints of thermodynamic laws. Others are evolutionary adaptations to enable efficient processing of information, which is the reduction of entropy. Still others are mental attitudes that help us survive the constant dissipation of energy endured by all non-equilibrium systems. Therefore, entropy theory offers a unified understanding of the human mind. In this way, the understanding of matter and mind is unified on the foundation of physical laws. Just like the movement of particles is governed by physical laws, thinking is governed by physical laws, albeit in more complex ways.

In the rest of the book, we will apply the theory to understand other fundamental problems in social sciences. All the problems are analyzed with the unified methodology. This is in sharp contrast to analysis based on neoclassical economic theory, where many different models are developed for different problems. Even patterns easily understood by most people, such as increasing returns, have to be described by extremely ingenious and arcane mathematical models. Very often reality cannot fit into these models very well. The discrepancy between theory and reality is often attributed to imperfection of reality, such as "imperfect market", "imperfect information", "imperfect contract", "imperfect competition", "inefficient property right", "market failure", "government failure", "externality". A brief review of the concept of imperfection in old astronomy will help us gain more understanding about it. Ancient people had long observed that stars moved in perfect harmony in the sky. Several planets, however, moved in irregular trajectories. It was thought that this was caused by the imperfectness of the planets. There were many elaborate theories why the planets were imperfect. Kepler, however, derived that all planets moved in perfect elliptic orbits around the sun. This story tells us that "imperfection of the world" often reflects imperfection of the theory that is used to understand the world instead of the world itself. In the book, we will show how this analytical thermodynamic theory offers a unified understanding of various "imperfection" or "externality".

Since a thermodynamic equation is of first order in temporal dimension, social and biological systems as thermodynamic systems are intrinsically evolutionary and dynamic, which is very different from the static view of general equilibrium theory. Given the dynamic nature of our economic activities, one may wonder why an equilibrium theory becomes the dominant paradigm in economics. Schumpeter apparently anticipated such a question when he discussed the concept of equilibrium:

> Now, an observer fresh from Mars might excusably think that the human mind, inspired by experience, would start analysis with the relatively concrete and then, as more subtle relations reveal themselves, proceed to the relatively abstract, that is to say, to start from dynamic relations and then proceed to working out the static ones. But this has not been so in any field of scientific endeavor whatsoever: always static theory has historically preceded dynamic theory and the reasons for this seem to be as obvious as they are sound --- static theory is much simpler to work out; its propositions are easier to prove; and it seems closer to (logical) essentials. The history of economic analysis is no exception. (Schumpeter, 1954, p. 964)

Neoclassical economics was founded around 1870 by Jevons, Walras and others, who believed that economics should be built on a sound physical foundation. When neoclassical economics germinated in the 1870s, work on statistical mechanics by Boltzmann happened to appear in the same decade. However it was more than thirty years later that Boltzmann's theory was generally accepted by the physicist community.

Since the dominant platform of physics in Jevons and Walras' time was Newtonian mechanics, it was natural for them to adopt this platform. However, Jevons clearly pointed out that "I believe that dynamical branches of the Science of Economy may remain to be developed, on the consideration of which I have not at all entered." (Jevons, 1957, p. vii) The analytical thermodynamic theory, as a dynamic theory of economics, is a natural continuation of their pursuits. This was very much like statistical mechanics was a natural extension to Newtonian mechanics, although it took many years for people to realize that (Isihara, 1971). Most people today agree that statistical mechanics is a sounder foundation to describe living systems than Newtonian mechanics, which is the physical foundation of general equilibrium theory in economics. As it is often the case, an analytical framework that is built on sounder foundation of physical science delivers more intuitive and simpler results. Most of the contents in the book have been taught at undergraduate classes and the students embrace the ideas enthusiastically. Since all results in this book are simple analytical formulas, they can be applied easily by researchers and students. Many examples on different applications are provided in the book. Although the book is written as a research monograph, it can be used as a textbook or reference book for many courses.

This analytical thermodynamic theory transforms the study of human societies into an integral part of physical and biological sciences. A unified framework enables us to utilize knowledge gained from biology and various branches of economics and social sciences systematically to understand particular problems. The mainstream economic theories often emphasize the uniqueness of human beings that somehow enables us to escape the physical constraints that is binding for all other living organisms. Of course, human beings are unique. All species are. But the progress of science is often marked by further recognition that human beings are not “higher” than other living organisms.

I have been contemplating an analytical thermodynamic theory of life systems since I was a college student more than twenty years ago. My neglect of other things often put me into difficult situations. I am very grateful to Nam Sang Cheng, Jin-Chuan Duan, Yonggeng Gu, Hemantha Herath, Ling Hsiao, Joel Smoller, Changyun Wang, Michael Wong, Lixin Wu, Shing-Tung Yau and many others for their kind help in my difficult times.