Open Access
*Journal of Human Thermodynamics*
**ISSN 1559-386X**
HumanThermodynamics.com/Journal.html

*Article*

# Understanding Social Systems: A Free Energy Perspective

Jing Chen

School of Business, University of Northern British Columbia, Prince George, BC, Canada V2N 4Z9; email: chen@unbc.ca

*Received: 10 December 2008; Published: 01 January 2009*

## Abstract

---

Social systems are a part of physical systems. In principle, social systems can be described by physical laws. However, there is a long running debate about how much knowledge from physics can be applied effectively to understand human societies. Compared with the vast amount of literature in both natural science and social science, attempts to understand social systems from physical laws are very sporadic. In this work, we show that the structures and evolution of social systems can be clearly understood with some simple and well established knowledge from physics.

---

## Introduction

Human societies are a part of the physical world. However, compared with the vast amount of literature in both natural science and social science, attempts to understand social systems from physical laws are very sporadic. [1] The few pioneering works about social conditions from detailed mathematical analysis of physical laws received little attention from the research community. [2] There is a long running debate about how much knowledge from physics can be effectively applied to human society. [3] In this work, we will not engage in this debate. Instead, we will follow the advice of Jaynes (1957) and see how much the properties of thermodynamics, which describe the collective behaviors of small particles, can be applied to understand the collective behaviors of large particles, such as human beings. [4] We will show that some simple reasoning from free energy, a basic concept in physics, can greatly clarify the understanding of the structures and evolution of social systems.

## Some Basic Analysis

The concept of free energy measures the quantity of energy that is available to perform work to external bodies. Free energy of a system can be defined mathematically as:

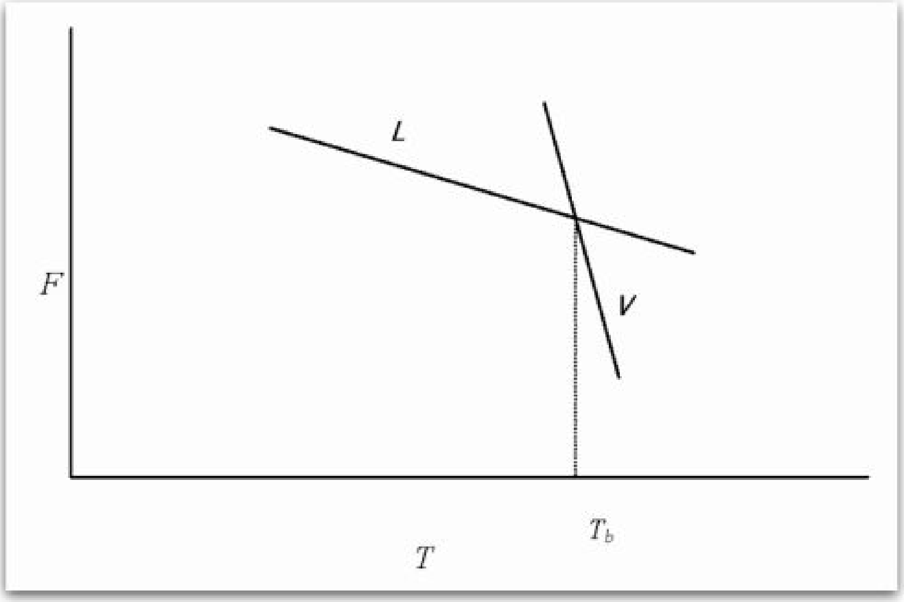
$$F = E - TS$$

where $E$ is the total amount of energy, $T$ is the temperature and $S$ is the entropy. In human society, $E$ represents the amount of energy resources available for human consumption. Changes in entropy represent a change in randomness. Where an increase in randomness represents an increase in freedom in a system. [5] For otherwise identical systems, the ones with less constraint will have higher level of entropy. [4] Entropy can be thought as the tendency to spread out. The wish to spread out is also a human desire. [6] Therefore entropy can be understood as a measure of freedom in human societies. $T$, the temperature, measures the average kinetic energy per particle in a physical system. In economics, $T$ has been used to measure the level of spending or income per person. [7]

In a physical system, $F$, the free energy will move spontaneously to its minimum. When $E$, the total amount of energy, is fixed, $T$ and $S$ will tend to increase until $TS$ reaches its maximum. In a social system, this means that people will seek the highest possible level of spending and freedom. This is consistent with our experience.

In a physical system, $T$ and $S$ both are positively correlated to $E$. Increases of $E$ often are accommodated with an increase of $T$ and $S$. In social systems, an increase in resources available to a society is often accompanied by the increase in spending and freedom. For example, conquering nations, which are newly in possession of vast amount of resources, often gain high level of income and liberty. [8] Since the relation between the abundance of natural resources and wealth is discussed in greater detail in the literature, we will concentrate our effort on the relation between $E$ and $S$, or the abundance of resource and the level of freedom.

Casual observation indicates that there are, in general, two states of human societies. One state contains much more freedom than the other. We may call one state of society a free society and the other state a restrained society. Similarly, a physical system may be in a liquid state or vapor state. A system in a vapor state has a much higher level of entropy than that of a system in a liquid state. Therefore, from the free energy equation, when the temperature increase, free energy decreases much faster in a system in a vapor state. Suppose a system is initially in a liquid state, when its temperature is increased to a high enough level, the value of free energy at a vapor state will be lower than that at a liquid state. At that point, phase transition from a liquid state to a vapor state occurs. The following figure illustrates the mechanism of this phase transition:



Levels of free energy of liquid and vapor phases at different levels of temperature. The phase with the lowest free energy, *F*, is the most stable phase at that temperature, *T*. $T_b$ is the boiling point. (Adapted from Figure 4.11 in Chang, 2005)

Similarly, when the income level of a human society becomes high enough, a free society becomes more viable than a restrained society. At that point, a transition from a restrained society to free society often occurs.

Many democratic institutions act as randomizers in a society. For example, an election randomizes the political leaders in a government. While randomizing a society does not increase income directly, it increases the level of entropy or freedom, which increases the chance of adopting new ideas to utilize more energy and other natural resources. In a resource abundant environment, a higher level of freedom will accelerate the discovery of new ways to utilize more energy, which generates continuous growth in income. With the continuous growth of freedom and income, which reinforce each other, from the free energy equation, the level of free energy will continuously decline. Eventually, it will be impossible to increase the income and freedom of the system solely from its internal resources. Historically, resource rich and democratic societies, such as the UK and US, transformed rapidly from large resource exporting countries in the world into resource importing countries.

For social systems with strong military power, they will exert control of natural resources outside their original system boundary to extract free energy to sustain their own growth. This is why there is a strong interaction between large resource consumers and large resource producers historically. From the free energy equation, the net export of free energy from a large resource producer depends not only on its resource level, but also on its level of spending and freedom. As we have analyzed, in a resource abundant environment, a higher level of freedom will keep generating new ways of utilizing more resources. A free and resource abundant society will rapidly absorb available free energy and cease to be a net exporter of free energy in a short period of time. To maintain a high level of free energy export from resource rich countries, it is essential for large resource consumers to suppress the movement towards freedom in resource producing countries. Indeed this has been the standard practice over time. [9] People often wonder why militarily strong democratic countries are often active in suppressing democratic movements in resource rich countries. But from the free energy perspective, this is necessary for the viability of strong democratic systems, which need large amount of energy input.

The influence of external factors to a social system can be further clarified by examining the relation between pressure and phase equilibrium in a physical system. When pressure is increased, the transition from liquid state to vapor state is suppressed or delayed. For example, the boiling temperature in a pressure cooker is higher than that in an ordinary cooker. Similarly, by exerting external pressure, the transition from a restrained society to a free society in a resource rich country can be suppressed or delayed, which allows large amounts of free energy to be supplied to the external world. Because of the high pressure applied to resource rich countries, phase transitions in these regions are often explosive and violent. For example, the democratically elected government in Iran was overthrown in 1953. After many years' of suppression, the Iranian Revolution erupted in 1978 and became very violent.

While a strong military presence overseas is beneficial to secure resource supply at low cost, it is also very expensive to maintain. Most countries cannot afford it. For countries without strong military power, they have to absorb the impact of low free energy internally. Entropy is an extensive variable, whose value depends on the size of a system. Reducing the population in a system will reduce the level of entropy. Since the early seventies, the average resource consumption per person in the world has been declining. As developed countries have the highest level of spending and freedom, they are the ones affected most. The fertility rates in all but one developed countries have dropped below two, the replacement rate. Countries with the highest level of income and the lowest amount of natural resources, such as Japan, also have the lowest fertility rates. This demonstrates that a high level of consumption and freedom is unsustainable when the energy supply to the system is constrained. In poor countries, which have a low level of income and freedom, the decline of fertility rates is slower. But as global resource output peaks and then declines, so will the world population. Indeed, tight food supply in many parts of the world has already become a regular news issue in a world that was used to over supply of grains.

## Concluding Remarks

Thermodynamics was originally developed to understand the efficiency of heat engines. Over time, the generality of its ideas have been more and more recognized. [10] This analysis shows that essential characteristics of social systems can be understood through the concept of free energy as can the parallels between physical systems and social systems. This leaves a question of how much basic concepts in thermodynamics can be effectively applied to understand social systems. Recent studies indicate that the income level of more than 95% of the total population can be accurately described by Boltzmann distribution, the distribution of energy levels of gas molecules. [11] For less than 5% top earner, the income level follows power laws. Power laws are often applied to understand physical phenomena that have long range connections. That the income levels of top earners follow the power law suggests that the highest income earners, as a group, are indeed well connected. [12] Many parallels between physical and social systems motivate us to do more detailed investigation in the future.

## Acknowledgements

We thank Rongshu Chen, Balbinder Deo, Hong Qian, Libb Thims and Yaoqi Zhang for helpful comments. Detailed comments and editing from Richard West greatly improved the quality of this paper.

## References

1. (a) Muller, Erich. (1998). “Human Societies: A Curious Application of Thermodynamics”, *Chemical Engineering Education*, 1 (3), 230-233.
(b) Thims, Libb. (2007). *Human Chemistry (Volume One)*. Lulu.
(c) Thims, Libb. (2007). *Human Chemistry (Volume Two)*. Lulu.
2. (a) Rossini, F. (1971). “Priestly Medal Address”, *Chem. Eng. News*, April 5, 49 (14) 50-53, American Chemical Society.
(b) Leonard, Harold. (2006). “Chemical Thermodynamics in the Real World”, Letters, *Journal of Chemical Education*, 83 (1), 39.
3. (a) Hall, Charles A.S., Cleveland, Cutler J., and Kaufmann, Robert. (1986). *Energy and Resource Quality: The Ecology of the Economic Process*, John Wiley & Sons.
(b) Ball, Philip. (2004). *Critical Mass, How One Thing Leads to Another*, Farrar, Straus and Giroux, New York.
(c) Chen, Jing. (2005). *The Physical Foundation of Economics: An Analytical Thermodynamic Theory*. Hackensack, NJ: World Scientific.
4. Jaynes, E. T. (1957). “Information Theory and Statistical Mechanics”, *The Physical Review*, 106 (4) 620-630.
5. Rossini, F. (1971). “Priestly Medal Address”, *Chem. Eng. News*, April 5, 49 (14) 50-53, American Chemical Society.

6. Cobb, Cathy. (2002). *Magik, Mayhem, and Mavericks: The Spirited History of Physical Chemistry*, Prometheus Books.

7. (a) Mimkes, J and Aruka, Y. (2005), Carnot Process of Wealth Distribution, in Econophysics of Wealth Distributions, edited by A. Chatterjee, S. Yarlagadda, B. Chakrabarti, Springer.

(b) Bryant, John. (2007). “A Thermodynamic Theory of Economics”, *International Journal of Exergy*, 4, 302-337.

8. Colinvaux, P. (1980). *The Fate of Nations*. New York: Simon and Schuster.

9. (a) McQuaig, Linda. (2004). *It's the Crude, Dude: War, Big Oil and the Fight for the Planet*, Doubleday Canada.

(b) Klein, Naomi. (2007). *The Shock Doctrine: The Rise of Disaster Capitalism*, Metropolitan Books.

(c) Lando, Barry. (2008). *Web of Deceit: The History of Western Complicity in Iraq, from Churchill to Kennedy to George W. Bush*, Anchor Canada.

10. Jaynes, E. T. (1988). “The Evolution of Carnot's Principle”, in *Maximum-Entropy and Bayesian Methods in Science and Engineering,* 1, G. J. Erickson and C. R. Smith (eds.), Kluwer, Dordrecht.

11. Chatterjee, A., S. Yarlagadda, B. Chakrabarti. (2005). *Econophysics of Wealth Distributions*, Springer**.**

12. Galbraith, James. (2008). *The Predator State: How Conservatives Abandoned the Free Market and Why Liberals Should Too*, Free Press.

Creative Commons Attribution License © 2009 by the Authors
(CreativeCommons.org/licenses/by/3.0/)