Generalized Second Law of Thermodynamics and Its Applications in Social Science

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Abstract

The arrow-of-time phenomena are everywhere in the physical world, biological systems, and human society. Despite its great importance in physics, the second law of thermodynamics can only successfully explain small percentages of these arrow-of-time phenomena in the physical world, and generally not applicable in biology and human society. For example, the powerful second law of thermodynamics can neither explain arrow-of-time phenomena like Darwin's evolution in biological systems, nor the globalization processes in human society. Most physicists regard the Darwinian evolution and human society as physical systems far away from thermodynamic equilibrium, which is a physics terminology means that the concept of entropy cannot be precisely defined and the second law of thermodynamics is not useful for studying the Darwinian evolution and human society. While the concept of equilibrium is one of the most important concepts in economics, the concept of equilibrium in economics and physics are two completely different concepts. This paper generalizes the second law of thermodynamics into a universal law of physics called law of equilibrium, which is universally applicable in any system governed by quantum mechanics including physical systems, biological systems, and human society. The concept of entropy in statistical physics is generalized using the concept of relative entropy or Kullback-Leibler divergence from the information theory. Law of equilibrium is one of five physics laws of social science, which is based on a new interpretation of quantum mechanics. In the framework of physics laws of social science, economics and other fields of social science become subfields of quantum physics. The concept of equilibrium and relative entropy are generalized to be equally applicable for all subfields of physics including biology and social science. Law of equilibrium provides a rock solid physics foundation to expand the traditional equilibrium analysis in economics and game theory into a universal mathematical framework useful to study social phenomena. This paper resolves two outstanding problems in modern physics: how to generalize the second law of thermodynamics to non-equilibrium physics, and the nature of arrow of time. This paper concludes that the irreversible processes and arrow of time phenomena in the physical world, biological systems, and human society are fundamentally the same quantum phenomena due to indeterministic nature of quantum events including human choices.

1. Introduction

The origin of the irreversible processes and the arrow-of-time phenomena has been one of the oldest unsolved puzzles in modern physics. This paper shows that the answer is to generalize the second law of thermodynamics to be applicable for all the irreversible processes and the arrow-of-time phenomena in non-equilibirum physics, biology, cosmology, and the human society.

There are striking similarities between the globalization processes in the human society and the diffusion processes in nature. Through the global transportation and telecommunication networks, massive goods, services, capitals, knowledge, and personals are exchanged between nations every day. The trend of narrowing difference between countries has been very noticeably in recent decades. For example, the new smart phones made by Apple, Inc. are available for consumers around the world almost at the same time. The McDonald stores can be found in almost every country. With the internet, the breaking news is watched by the global audiences. A research paper posted on the internet is immediately available around the world. The interesting question is where this globalization process will lead us to?

The arrow-of-time phenomena like the globalization processes are everywhere in the physical world, biological systems, and human society. Despite its great importance in physics, the second law of thermodynamics can only successfully explain small percentages of these arrow-of-time phenomena in the physical world. The second law of thermodynamics is generally not applicable in non-equilibrium physics, biology, and the human society.

For example, in natural science, the arrow-of-time phenomena like the diffusion processes are well-understood through the second laws of thermodynamics. However, the arrow-of-time phenomena like the globalization process in the human society cannot be easily analyzed through the second laws of thermodynamics.

The first road block is the definition of entropy: how to define the concept of entropy in the human society? The second road block is lack of the physics foundation of social science: Is the second laws of thermodynamics applicable in the globalization process? In this paper, we will overcome these two road blocks through recently created physics laws of social science and a new interpretation of quantum mechanics.

Since the origin of the irreversible processes and the arrow of time phenomena is one of the oldest puzzles of physics, there have been hundreds and thousands of attempts [1] to solve this puzzle. It is important to point out what is new in this paper by reviewing some previous contributions. This works is built upon several lines of previous works.

The first line of works is the relationship between the information theory [2] and the second laws of thermodynamics. Edwin T. Jaynes first pointed out [3, 4] that the equilibrium thermodynamics and statistical mechanics could be abstracted into an information theory centered on the principle of maximum entropy. If an isolated system is modeled as a Markov chain [2] with the transitions obeying the physical laws governing the system, then the relative entropy of the system will always increase.

The second line of previous works is to study the connection between decoherence wavefunction collapse [1] and the arrow of time phenomena. This line of work has run into a formable road block of the correct interpretation of quantum mechanics. The problem with this line of work is that it involves the different versions of the interpretation of quantum mechanics, which is one of most intractable problem in physics.

The third line of works is the studies of non-equilibrium steady states and the fluctuation theorem [5-7] in largely condensed matter systems. Researchers have extended several equalities and inequalities from equilibrium thermodynamics to non-equilibrium steady states.

This paper takes a new path to extend the second laws of thermodynamics into non-equilibrium physics. The first step is focusing on the key concept “choice” in the human society and the natural world. Unlike the abstract and elusive concepts of wavefunction collapse and decoherence, people are intimately familiar with the concept of choice, because people are making hundreds and thousands choices every day. Choice is the most important concept for all fields of social science. Yet physicists don’t have a physics theory for all important concept of choice. In a paper published earlier [8], to create a physics theory of choice is equivalent to create a new interpretation of quantum mechanics. The new interpretation of quantum mechanics is called the JJW interpretation of quantum mechanics.

The main ideas of the JJW interpretation of quantum mechanics are five new physics laws called physics laws of social science. The law of equilibrium is the generalized second law of thermodynamics. This paper is the detailed discussion of the scope and application of the law equilibrium.

In the section 2, we will list five physics laws of social science, which will put the social science and natural science in a common foundation. In the section 3, we will apply physics laws of social science to generalize the second law of thermodynamics into the law of equilibrium which is broadly applicable in physics, biology, and social science. In the section 4, we will apply the law of equilibrium to non-equilibrium physics to show that the law of equilibrium plays the same role in non-equilibrium physics as the central role of the second law of thermodynamics in the equilibrium physics. In the section 5, we will focus on applications of law of equilibrium in natural science like biology and Darwinian evolution. In the section 6, we will focus on the applications of law of equilibrium in social science.

2. JJW Interpretation of Quantum Mechanics and Five Physics Laws of Social Science

The interpretation of quantum mechanics is one of most elusive and intractable problems at the foundation of the modern science. The problem has been outstanding since the day the quantum mechanics was born. Many professional physicists question whether the correct interpretation of quantum mechanics is a truly relevant scientific question that could lead to new physics and new technologies. Many different interpretations of quantum mechanics have been proposed over years. Yet there is no agreement about which is the correct interpretation. Despite its all weakness, the most widely accepted version among professional physicists is still the old Copenhagen interpretation of quantum mechanics.

In an earlier paper [8], instead of focusing on the metaphysics arguments, we focus on something we are intimately familiars with in our daily life: the human choices.

People make hundreds and thousands choices every day from choosing food to eat, roads to drive, articles to read, clothes to wear, and words to say.

The human choices are so important to our humanity that most books in the world are written about human choices. History is about choices made in history; economics is about economic choices; politics is about political choices; sociology is about social choices; law is about legal choices; novels is the choices of words descripting the choices by fictional figures; medicine is about choices of medical treatments; football games is about choices of coaches and players; music is about choices made by composers and performers; and painting is about choices made by painters.

Despite its importance, we do not have a coherent physics theory about the human choices. As a matter of facts, there is no “choice” concept in the modern physics. The human behavior paradox says that the human behavior is incompatible with the existing framework of physics. The key is to show that to build the coherent physics of human choices is equivalent to build a new interpretation of quantum mechanics. The reason is simply that human free will and human choices are fundamentally quantum phenomena.

Physics Theory of Human Choices = A New Interpretation of Quantum Mechanics

Because we concentrate on something as familiar as the human choices, the previously elusive and difficult task of building a new interpretation of quantum mechanics is simple and straight forward. And the new interpretation, which we call the JJW interpretation of quantum mechanics, has profound implications on almost every corner of the human knowledge because the new interpretation essentially provides a fresh new perspective to re-examine all books ever listed in the Library of Congress.

The central ideas of JJW interpretation are is the five physics laws of social science, which have been published elsewhere in a book [9] and academic papers [10, 11]. For the benefit of readability of this paper, we list five physics laws of social science in the following.

First Law – Law of Indeterminacy

> For a closed system, the outcome of any future event in the system is indeterministic. The quantum uncertainty of the future is the fundamental property of nature and cannot be overcome by any means.

Second Law – Law of Prediction

> For a closed system, any future event in the system can be and can only be predicted precisely to the extent of a joint probability distribution among all possible outcomes. The joint probability distribution function exists and is uniquely given by quantum mechanics.

Third Law – Law of Choice

> Actions, which are constrained by fundamental laws of physics, can be taken between time 0 and time T to modify the joint probability distribution function of time T of a closed system.

Fourth Law – Law of Information

> The complete historic information of any closed system cannot be recreated based on today's complete information. At any time step, new information is created and some historic information is lost permanently.

Fifth Law – Law of Equilibrium

> For a system under certain constraints, quantum uncertainties in the system will eventually push the system toward equilibrium states.

The explanation and discussion of these five laws can be found in the book [9] and the papers [10-12]. These laws are fundamental laws of physics, which are applicable to any system including any physical and biological systems, and human societies. Fundamental equation of economics is one application of these physics laws in economics.

3. Generalization of the Second Law of Thermodynamics

In this section, we first define the necessary and sufficient condition for the existence of the equilibrium state by applying physics laws of social science. Then we define the relative entropy and generalize the second law of thermodynamics.

3.1 Definition of Equilibrium State

The equilibrium concept is widely used in many fields of natural and social science. The law of prediction gives one universally applicable definition of the equilibrium state.

According to the law of prediction, for a closed system, any future event in the system can be and can only be predicted precisely to the extent of a joint probability distribution among all possible outcomes. The joint probability distribution function exists and is uniquely given by quantum mechanics.

The equilibrium state is simply defined as the following: if the long-term joint probability distribution function is time independent, the closed system has a long-term equilibrium state.

Because the law of prediction is applicable to any closed system governed by quantum mechanics, the definition of the equilibrium state is universally applicable in all fields in natural and social science. It is interesting to note that the physics definition of equilibrium in this paper is very similar to the mathematical definition of Nash equilibrium in the game theory in social science.

This definition of equilibrium covers all thermodynamics equilibrium in physics, many steady states in non-equilibrium physics, steady states in biology, and many equilibrium states in economics, politics, and other social science.

This definition of equilibrium also includes many non-steady states with the time independent joint probability distribution function. For example, the Brownian motion of one or a few particles within a confined space will have a well-defined long-term equilibrium state with a time independent joint probability distribution function. However, at any moment, the particles are always moving. Many proteins in natural environment will have well-defined long-term equilibrium configurations.

This definition of equilibrium does not require the system to be isolated. As long as the system is closed with well-defined energy, mass, information, and other exchanges with the surrounding environment, the definition will be valid. Since virtually all systems in social and natural science are governed by quantum mechanics, the concept of the equilibrium state can be applied from equilibrium to non-equilibrium physics.

3.2 Relative Entropy

We can apply the standard information theory [2] to expand the definition of entropy for any closed system with an equilibrium state.

Let *Q* be the time independent long-term joint probability distribution function, which characterizes the equilibrium state, and *P* be the time dependent joint probability distribution function at time t. The relative entropy is defined as the Kullback-Leibler divergence [2] of *P* and *Q*:

$$\mathrm{S} = \sum P \ln \frac{P}{Q}$$

Form the information theory [2], we have the generalized Gibbs' inequality

$$\mathrm{S}(t) \geq 0$$

S(t) = 0 when and only when *P* is the same as *Q*.

Because the law of equilibrium is so broadly applicable, we cannot prove that *S(t)* will be always monotonicity decrease towards the equilibrium state. The overall trend of *S(t)* will be certainly decreasing. However, it has been proved that if an isolated system is modeled as a Markov chain [2] with the transitions obeying the physical laws governing the system, then the relative entropy of the system will always monotonically decrease.

In the real world application of the law of equilibrium, the monotonicity of is not always important. The very existence of the equilibrium state is very important because it captures the essence of the dynamics of the closed system and the general arrow of time which points towards the equilibrium state.

3.3 Equilibrium Equalities and Inequalities and Fluctuations

From the time independent long-term joint probability distribution function of the equilibrium state, we could define a set of statistical averages, equilibrium equalities and inequalities, equations governing fluctuations near the equilibrium states.

For example, for a single particle Brownian motion in a confined space, there is a well-defined average position to find the particle. The system can be viewed as if the particle fluctuates around the equilibrium positions.

4. Non-equilibrium Physics

One of the outstanding unsolved problems in modern physics is how to extend the success of the second law thermodynamics into non-equilibrium systems. The short answer is the law of equilibrium. For any closed system, the dynamics is described precisely by the law of prediction. If the system has a well-defined equilibrium state, we have the law of equilibrium as the generalized second law of thermodynamics. In this section, we will take a fresh look at the thermodynamic equilibrium, Rayleigh-Benard convection, the cosmological arrow of time, and Darwinian evolution in biology.

4.1 Indeterministic View of Irreversible Processes and Thermodynamic Equilibria

The origin of the irreversible processes has been an outstanding since the creation of the second laws of thermodynamics. Historically thermodynamics and statistical physics were developed many decades before the establishment of the quantum mechanics. Many physicists notice that the irreversible processes are fundamentally incompatible with the classical Newtonian physics. This fundamental difficulty is known as the "ergodic hypothesis" and Loschmidt's paradox in classical statistical physics.

With the creation of JJW interpretation and law of equilibrium, we will take a decisive indeterministic view of irreversible processes and thermodynamic equilibria. Because the choices made by quantum particles are time irreversible, there is no Loschmidt's paradox according to JJW interpretation of quantum mechanics.

Take a cup of water as an example. According to JJW interpretation, the collisions among water molecules are indeterministic processes governed by quantum mechanics. When making forecasts of the future molecular water configurations, we could only forecast the probability distributions. And the precise configuration of water molecules is unknowable and forbidden by quantum mechanics. Therefore, according to JJW interpretation of quantum mechanics, the cup of water is an entangled quantum soup of dynamic water molecules. In reality, the static equilibrium state does not exist. Only the dynamic equilibrium exists in reality and the future probability objectively exists.

In essence, JJW interpretation rejects the deterministic ergodic hypothesis. Deterministic systems do not have irreversible processes or thermodynamic equilibria. The irreversible processes and the thermodynamic equilibria in nature are distinctly macroscopic quantum phenomena. The indeterministic view of irreversible processes or thermodynamic equilibria can be extended into non-equilibrium physics.

4.2 Rayleigh-Benard Convection

The Rayleigh-Bernard convection [13] is a classical non-equilibrium physics phenomenon. Since the first quantitative experiments [14] performed by Henri Bernard in 1900, the Rayleigh-Bernard convection has been extensively studied as a model system of the self-organization for systems far away from the thermodynamic equilibria.

The law of equilibrium brings a brand new perspective to this well-known phenomenon. The Rayleigh-Bernard convection should be viewed as an equilibrium phenomenon depending on the external constant boundary conditions. When the temperature gradient changes from zero to a very large number, the system equilibrium states shift from the traditional thermodynamic equilibrium, the stable convection, to the turbulent flow.

Turbulence flow is one of the oldest unsolved problems in physics. To treat the turbulent flow as a macroscopic indeterministic quantum phenomenon could open the new path for further investigation.

4.3 Cosmological Arrow of Time

The cosmological arrow of time points to the direction of the expansion of the universe not the opposite. There are many discussions [1] about the possible connection between the cosmological arrow of time and the thermodynamic arrow of time. Many physicists regarded [15] the early universe is a low entropy state, and the entropy increases as the universe expands.

The law of equilibrium clarifies the nature of the cosmological arrow of time. Both the cosmological arrow of time and the thermodynamic arrow of time are quantum phenomena. The universe can be viewed a quantum system with a long-term equilibrium state. The cosmological arrow of time points to the equilibrium state just like any other quantum systems. Although the exact nature of the long-term equilibrium state, whether it is a big chill with the exhaustion of all usable free energy or a big crunch with the reversion of the eventually expanding universe, remains an open question.

To summarize, the law of equilibrium vastly expands the scope of the second law of thermodynamics from the Rayleigh-Bernard convection to the cosmology, and the law of equilibrium becomes the cornerstone of the non-equilibrium physics.

5. Quantum Evolution Theory

One of major short-comings of modern physics is its failure to provide a sound physics foundation for the Darwinian evolution theory. While the second law of thermodynamics does not rule out the possibility of the Darwinian evolution theory, it is obvious that the second law of thermodynamics does not support the Darwinian evolution theory either. The obvious weakness of lacking the physics foundation for the Darwinian evolution theory has caused many attacks on the evolutional theory.

For example, on August 9, 2005, President George W. Bush shocked the nation by announcing that he was in favor of teaching an evolution theory known as “intelligent design” in the schools, in addition to Darwin’s Natural Selection Theory. He said, “I think that part of education is to expose people to different schools of thought.” Intelligent design is an alternative evolution theory, which claims that living creatures on the earth are designed by an intelligent creator outside the Earth.

The scientific community was furious at President Bush’s comments. Alan Leshner, the CEO of the American Association for the Advancement of Science, said, “There is no science to intelligent design, it’s not even a scientifically answerable question.”

The debates around “intelligent design” will have real impacts, such as what will be taught to our children in biology classes.

Controversies about "intelligent design" obscured true scientific weaknesses about Darwin's Natural Selection Theory: Does the natural selection process violate the Second Law of Thermodynamics? Why is there no direct support to Darwin's theory from fundamental laws of physics? What is the physics force driving the evolutional process? Is the evolutional process deterministic or indeterministic? Why is the natural selection process able to break the time symmetry, and point the direction time opposite to that of the Second Law of Thermodynamics? Is human intelligence purely accident or inevitable results of the evolution process? Biologists gave various answers to these fundamental questions. However, assurances from biologists often sound hollow because these questions are ultimately physics questions, which are unanswerable in the existing framework of biology.

While it is one of the most successful theories in science supported by millions of empirical evidences, the Natural Selection Theory remains an empirical theory, and the connection between Darwin's evolution theory and fundamental laws of physics is completely missing. Without a firm physics foundation, the Natural Select Theory becomes a scientific mystery, and becomes an easy target of peudo-scientists and other forces in societies. For example, it is easy to explain why a dead person will decay and become dust using the Second Laws of Thermodynamics. However, it remains a deep mystery why humans are able to evolve from dust in billions of years, ignoring the Second Laws of Thermodynamics.

The JJW interpretation of quantum mechanics is the missing connection between Darwin's Natural Selection Theory and physics.

The JJW interpretation says that quantum uncertainties dominate the evolution process. The evolution process is fundamentally indeterministic in nature. Collisions between molecules and thermal fluctuations in solutions are indeterministic. Most genetic mutations are indeterministic. Animals have free wills. The evolution processes are also influenced by many indeterministic natural factors, such as the weather and earthquakes.

Quantum uncertainties are most creative forces in nature. Quantum uncertainties can create new things that have never existed before by searching through every possible combination. Under constraints, the law of equilibrium says that quantum uncertainties will inevitably push any system toward the equilibrium state. Many these equilibrium states correspond to most magnificent creations of the nature, such as motors used by E. Coli bacteria, flowers of plants, and even human intelligence. Therefore, quantum uncertainties and the law of equilibrium are the mystery forces driving the evolution processes.

Natural selection can be viewed as choices made by nature. Choices are made by indeterministic quantum uncertainties to favor those living creatures closest to equilibrium states under whatever constraints.

The law of equilibrium breaks the time symmetry. The natural selection process and the Second Law of Thermodynamics are special cases of the law of equilibrium. The natural selection process does not violate the Second Laws of Thermodynamics. However, it can be explained by the law of equilibrium, and cannot be explained by the Second Laws of Thermodynamics. If a dead person is buried under ground, the Law of Equilibrium says the person will reach the equilibrium state of dusts. Under certain unknown constraints, dust was able to aggregate and evolve to be living creatures.

By combining Darwin's Natural Selection Theory and the JJW interpretation, it is possible to build computer models to recreate the complete evolution process. Computer models should deepen our understanding of causality relationships in evolution processes.

With a physics foundation, the evolution theory becomes more receptive to different ideas. It may be surprising to some people that the JJW interpretation actually accepts the intelligence design as a valid scientific hypothesis as long as no supernatural beings, who do not obey quantum mechanics, are involved. Because the evolution processes are fundamentally indeterministic, the intelligent design is one of many possible ways to reach equilibrium states. However, the intelligent design has zero supporting evidence so far, while Darwin's Natural Selection Theory has millions of empirical evidences. With zero empirical evidence, the intelligence design does not have a seat among scientific ideas.

In conclusion, the JJW interpretation is the missing connection between Darwin's evolution theory and physics, and the JJW interpretation answers questions and removes the mysteries about the Natural Selection Theory.

6. Applications in Social Science

Some of the most interesting applications of the law of equilibrium can be found in social science [16-21]. The concept of equilibrium has been one of the most important concepts in social science. However, there is no universally applicable definition of equilibrium in social science. With establishing physics laws of social science, social science becomes a branch of quantum physics. There is only one universally applicable concept of the equilibrium state given by quantum mechanics for all fields of physics including all fields of social science.

6.1 Generalized Equilibrium Analysis in Social Science

Social science can be broadly divided into positive social science, which studies "how" the social reality works, and normative social science, which studies "what ought to be done" regarding the social problems. In natural science, positive physics is simply known as physics while normative physics is commonly known as engineering. The positive social science is value free while the normative social science depends on the value system, which is beyond the border of science.

The most importance application [19] of the law of equilibrium in social science is that it opens a value-free approach to problems of the normative social science.

For an example, consider to divide a cake between two identical-twin brothers. There are many ways to divide a cake. How to divide a cake is a normative social science question which depends on the value system. There is no scientifically "right way" to divide a cake. However, if the surrounding environment is well-defined, the law of equilibrium and the law of prediction say that there will be a time-independent probability distribution of all possible cake divisions, and the distribution will peak sharply and be symmetrically centered on the equal division of the cake. The result could be verified through repeated experiments. To summarize, the question how to divide a cake is not an answerable question by science alone. However, the question what is the most likely outcome when two identical-twin brothers divide a cake in a well-defined environment is 100% answerable by science using the law of equilibrium and the law of prediction.

6.2 One Equilibrium Definition for All Subfields of Physics

While equilibrium is one of most important concepts in economic, there are many definitions of equilibrium depending on different branches of economics: market equilibrium for the perfect competition, Walras equilibrium in general equilibrium theory, general equilibrium in macroeconomics, Nash equilibrium in game theory, and market equilibrium in financial market theory. There are many controversies [16-18] surrounding how to apply the equilibrium concept in the real economic analysis. For example, during the 2003 and 2013, the WTI crude oil spot price changed significantly from $20's in 2003 to peak $140's in 2008, then back to $30's in early 2009 during the great recessions, and to $100's in late 2013. What is the market equilibrium of WTI oil price during that ten-year period? Are all daily closing prices market equilibrium prices because they were results of balancing the daily supply and demand? In macroeconomics, was the overall market in general equilibrium before, during, or after the great recession of 2008? In financial markets, is the financial market always in equilibrium all the time?

The law of equilibrium [11,12] rejects the concept of market equilibrium in the general market analysis, rejects the Walras equilibrium in the general equilibrium theory and macroeconomics, and modifies the Nash equilibrium in the game theory.

In the general market analysis, the market equilibrium is built on the observation that the amount sold equals the amount bought. However, by using the chemical reaction as a parallel system, it is easy to show that the amount sold equals the amount bought does not define the equilibrium condition. Take a reversible chemical reaction as example,

$$H_2O \leftrightarrows H^+ \quad + OH^-$$

No matter how far away from the equilibrium, the total mass of H_2O consumed always equals the total mass of H^+ and OH^- being produced because the conservation law of mass. But that is not the equilibrium condition at all. The true equilibrium condition is defined very differently: at any moment, on average, when the amount H_2O consumed equals to the amount H_2O produced in the reverse reaction, the system reaches chemical equilibrium. In the market places, the observation that the amount sold equals the amount bought is always true simply by definition. Therefore, it has been a sad and simple mistake for many generations of economists to apply incorrectly the concept of equilibrium in the market place over last hundred years. And what even worse is that entire economic framework like general equilibrium theory and DSGE models are built upon this simple misconception.

In the framework of the law of equilibrium, market equilibrium is defined as the future joint probability density distribution function of supply, demand, and price is independent of time. This definition is an application of law of equilibrium in the general market analysis.

In the framework of the law of equilibrium, the markets in general are dynamic and not in equilibrium. Markets in equilibrium are special cases where the supply, inventory, demand, and price are range-bound and stable. Under very special conditions, the flow of products from producers, wholesale and retail inventory, to the end consumers is stable. We can claim that the market is in equilibrium and the nature of this market equilibrium is a flowing equilibrium, which is similar to many flow equilibria in hydrodynamics. Thus, the necessary and sufficient condition of the market achieving the flowing equilibrium is that the production, inventory, demand, flow, and prices are all range-bound and stable with only small idiosyncratic fluctuations. This type of the market equilibrium is boring and rare. Sometimes the equilibrium analysis is a useful tool for the long-term market forecasts.

In contrast, the traditional Marshallian framework, every economist knows that the necessary and sufficient condition for the market equilibrium is that supply equals demand. However, in reality, the Marshallian equilibrium condition is simply wrong and makes no sense. One issue is the existence of the inventory. The other issue is that even the production and demand are equal and stable, any big disruption or even potential of a big disruption in the supply chains could cause the market huge swings. For example, the potential disruption of oil tanker traffic in the Suez Canal or the Strait of Hormuz would send the world oil price skyrocketing while the world oil production and demand are stable.

Take the US automobile market as another example. Except very few red-hot models which need the waiting lists to manage the demand, most auto models carry inventories by dealers. When one walks into any auto dealer in the neighborhood, one would find out immediately that the supply of new and used cars for sell is often far more than the demand of potential customers on any day, because auto dealers typically carry inventories of 45 to 60 day's sell volume. Therefore, with the existing of inventories, the supply of autos is always much greater than the demand on any given day, the supply curve is well above the demand curve, and there is no Marshallian cross possible. The condition that the daily production equals the daily demand would only imply the stable inventory not the market equilibrium.

To summarize, in microeconomics, the equilibrium analysis should be only used when the real market is in the true measurable physical equilibrium in the first place. Generally speaking, the markets are dynamic and not in equilibrium, and must be analyzed as disequilibrium in economic models.

The law of equilibrium framework rejects the Walras equilibrium in the general equilibrium theory because the Walras equilibrium and the general equilibrium theory are built upon the market equilibrium misconception.

In macroeconomics, because the existence of business inventory and the spare capacity, the aggregated supply is always greater than aggregated demand, there is no macroeconomic market equilibrium. DSGE models are built upon the wrong framework of the general equilibrium characterized as the aggregated supply equals aggregated demand.

The law of equilibrium is almost consistent with the concept of Nash equilibrium in the game theory. The difference is that the equilibrium state of the law of equilibrium is a physics concept while the Nash equilibrium is a mathematical concept. Therefore, in real life, human and society behavior could be far away from Nash equilibrium solutions proposed by traditional game theory. Only When the Nash equilibrium and game theory are used as a mathematics tool in the framework of the law of equilibrium, these two versions of equilibrium concepts become identical.

6.3 Equilibrium Solution to Humanity Governing Problem

Solving the humanity governing problem [19-21] is probably the most important problem solved using the law of equilibrium. In essence, the law of equilibrium and the law of prediction says that there is an equilibrium political structure of the humanity.

One problem is standing out above all others in social science: how should humanity govern itself? The problem is so important that all wars of humanity in the past, present, and future, are directly related to this problem. Despite the fact that this problem has attracted interests of some greatest thinkers for thousands of years: Confucius, Plato, Aristotle, Machiavelli, Locke, Washington, Jefferson, Madison, Kant, Marx, Einstein, Hayek, and many others, yet the problem remains unsolved. The latest thinking on this governing problem by mainstream social scientists is represented by views of Friedrich Hayek. In his writings [22-24], Hayek repeatedly warned that we must shed the illusion that we can deliberately create the future of mankind.

With physics laws of social science, we disagree with Hayek and prove that this problem is a many-body problem in physics solvable scientifically after all applying recently-created physics laws of social science, if the problem is formulated in a correct way: what kind of governing political structure of humanity is most stable? Most-stable structure problems appear routinely in the theoretical and experimental condensed matter physics. We show that the humanity governing problem is equivalent to find an equilibrium political structure of a human society, which is a many-body physics problem 100% solvable using the maximum entropy approach widely-used in the condensed matter physics.

Physics laws of social science establishes the framework and methodology of quantum politics and replaces traditional political philosophy with quantum physics as the solid foundation of political science, and analyzes the equilibrium political structure of a human society. Quantum politics says that we can create free, fair, just, peaceful, and prosperous human societies. We prove that there is certainly no better alternative than the equilibrium political structure, which is defined by a set of 16 democratic principles. Quantum physics clearly says that there is a global political equilibrium state, which corresponds to the permanent world peace. The equilibrium political structure provides a theoretically-sound and practical solution to eliminate the nuclear, biological, chemical, robotic, and other forms of weapons of massive destruction. In the long run, humanity can finally grow up and will put an end to deaths, miseries, and economic destruction caused by wars, which have been plagued us since the dawn of humanity.

6.4 Hydrodynamic Mode Approach in Social Science

The hydrodynamic mode approach is a proven powerful tool in the condensed matter physics. With the unified framework of physics laws of social science, the hydrodynamic approach can be applied effectively in social science [21].

Since the most stable political structure in any nation is an equilibrium state of the political structure, which is characterized by 16 democratic principles. These democratic principles are the Goldstone bosons or hydrodynamic modes of human societies. Despite the complexity of human society with billions and billions of changes every day, the only important driving forces of the long-term political, economic, and social changes are these 16 hydrodynamic modes. These democratic principles or Goldstone bosons have dominated the word history since the dawn of the humanity, and these same 16 global mega-trends of the Goldstone bosons will continue to dominate the world political and economic dynamics in the future, and eventually push the human society towards the equilibrium state of the permanent world peace. The hydrodynamic mode approach not only answers the question what drives social changes, but also becomes a powerful new tool to study world history, social science, and futurology (or scientific astrology).

Therefore, the arrow-of-time phenomena in the human society and the natural world share the same identical fundamental causes of quantum indeterminacy and human choices.

6.5 Equilibrium Solution to Government Deficit Problem

The equilibrium political structure analysis provides an equilibrium solution to the government budget deficit problem in a value-free way [25].

The government budget deficit problem is one of most intractable and contentious problem in modern political economics. The debates about how to deal with government budget deficits are raging all over the world. In US, the federal government forced to shut down for 16 days in October 2013 because of the failure to pass a budget through congresses, and barely averted a default of federal government obligations due to failure to raise the federal debt ceiling limit. The city of Detroit filed the largest municipal bankruptcy in the US history on July 18, 2013, despite Michigan State constitution's balanced budget requirement. In Europe, the sovereign debt crisis has dragged down the entire EU economy since late 2009 with no end in sight. In Japan, the government debt to GDP ratio is well over 200%, which is one of the highest in the world. In the world of academics, the debates of government deficits have become the key battlegrounds of different schools of thoughts of economics. Economists and political scientists could not even agree to a framework to solve these issues, let alone settle these debates.

The law of equilibrium provides a permanent solution to government budget deficits. The political equilibrium structure has the time translational symmetry in treating different generations equally. One result of applying physics laws of social science to study the most stable political structure is that the most stable political structure is not only to require the majority voters must deal with minority voters fairly to avoid the tyranny of the majority, but also to require the voting generation must exercise their fiduciary duty to their children and future generations. In terms of government budget deficits, the fiduciary duty means that the current voting generation must take the full responsible of the current government budget deficits or surplus. The permanent solution of government budget deficits is legally and personally held the voting generation accountable for the current fiscal surplus and deficit at all level of governments. In contrast to the balanced budget approaches, the permanent solution in this paper allows deficit spending and government debt as long as the government debt must be paid off by the responsible borrowers and voters. The method to solve the government budget deficit problem is an excellent example of applications of law of equilibrium, which can be used to solve economic, political, and other social problems in a value-free way. The permanent solution to government budget deficits presented in this paper is consistent with a different line of reasoning in economics, which is known as the tragedy of the commons. In cases of government budget deficits, the tragedy of fiscal abuse happens because the exact ownership of government budget deficits by which generation is unclear in the US constitution, and current voting generation financially takes unfair advantage of their children and the future generations, who virtually have no political power.

To summarize, while the equilibrium analysis is not new to social science, the law of equilibrium brings the precise physics definition of the equilibrium state and provides new tools like the many-body physics approaches to social problems.

7. Conclusion

While the second law of thermodynamics could explains only small percentages of the arrow of time phenomena, the generalized the second law of thermodynamics is applicable to applicable for all arrow of time phenomena in the non-equilibrium physics, cosmology, biology, and the human society.

One importance application of the law of equilibrium in social science is that it opens a value-free approach to important problems like the humanity governing problem and the government budget deficit problem.

6 Reference and Notes

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