Physics Laws of Social Science

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Abstract

Economics, and other fields of social science are often criticized as unscientific for their apparent failures to formulate universal laws governing human societies. Whether economics is truly a science is one of the oldest questions. This paper attempts to create such universal laws, and asserts that economics is a branch of quantum physics just like chemistry. Choice is a central concept in economics and other fields of social science, yet there is no corresponding concept of choice in modern physics. This article suggests that by introducing the concept of choice to the existing framework of physics, one can formulate five new physics laws, which establishes a common physics foundation for all fields of social and natural science. Applications in economics, biology, history, and finance prove that these new laws remove the invisible wall, which has been artificially separating social science from natural science. One implication of this article is that to establish a sound scientific foundation for social science requires not only advances in psychology and neurobiology but also a new interpretation of quantum mechanics.

Introduction

Choice is a fundamental concept in economics. In a popular economics textbook by Frank and Bernanke *(1),* economics is simply defined as a subject of studying choices in a world of scarcity. However, despite its fundamental importance to economics, there is no corresponding concept of choice in physics. Actually if a choice by a person is an action that could modify the future physical world, modern physics does not even allow people to have any choice in a macroscopic world. Most physicists believe that the macroscopic world is governed by the deterministic Newtonian physics and only the microscopic world is governed by indeterministic quantum mechanics. Because Newtonian physics is deterministic, French physicist Pierre-Simon Laplace declared long time ago that if he could have the complete information about the universe at a moment, using Newtonian physics, he would have the complete knowledge of the past, present, and future universe down to every detail.

However, the idea that people do not have any choice in life is absurd to people's everyday experience. People are facing hundreds of choices everyday, from clothes, foods, books, medicines, speeches, investments, to political elections. The entire pharmaceutical industry is built around the notion that medicines would cure diseases if people choose to take them. The idea that people do not have any choice in life is also against everything taught in an economics textbook. The inability of modern physics to explain choices made by people in the real world was highlighted by several recent papers *(2, 3)*.

This article attempts to introduce the concept of choice to the existing framework of physics. The result is five new physics laws of social science, which establish a common foundation for both social science and natural science.

Five New Physics Laws of Social Science

In this section, we will present five new physics laws. The explanation and discussion will be presented in next sections. These laws are applicable to any system that is made of elementary particles, including any physical and biological system, human being, and human society.

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 Predicting the Future

> 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 constrains, quantum uncertainties in the system will eventually push the system toward equilibrium states.

Interpretation of Five Physics Laws of Social Science

These five physics laws of social science are closely related with each other. The Law of Indeterminacy is the starting point. The Law of Predict the Future addresses how to predict the future and the cause and effect relationships of an indeterministic system. The Law of Choice addresses how to make a choice and how a choice will modify an indeterministic system. The Law of Information addresses how information is created and destroyed. The Law of Equilibrium addresses the time symmetry, the direction of time arrow, and equilibrium states. Figure 1 shows the relationship among five laws.

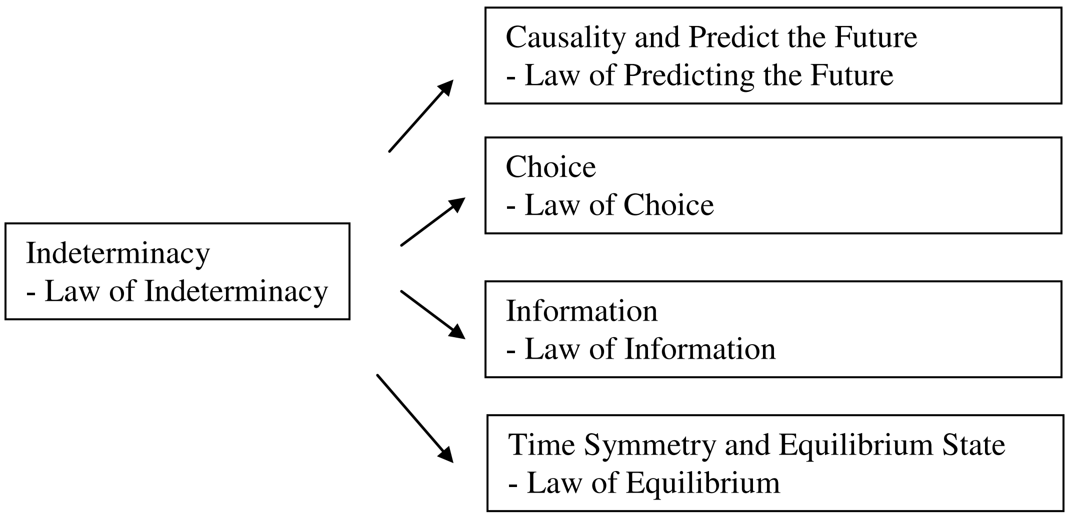

Figure 1 illustrates the relationship among five physics laws of social science.

The First Law, Law of Indeterminacy, is nature for any system that is made of elementary particles. One of most significant achievements of the twentieth-century science was the creation of quantum mechanics as the physics foundation of all fields of natural science. Since quantum mechanics unambiguously states that the behavior of elementary particles are indeterministic, it is nature to expect that the behavior of any system, which is made of elementary particles, is also indeterministic.

The Law of Indeterminacy rejects the mainstream idea in the scientific community that indeterministic behavior is limited to the microscopic world of atoms and elementary particles, and the macroscopic world can be completely described by deterministic Newtonian physics. Common senses tell us that the indeterministic radioactive decay could cause indeterministic events such as cancers due to the radiation damage. Radiation from a single atom is sufficient to break DNA molecules to cause cancers later in people. Indeed a report from National Research Council *(4)* says that even low doses of radiation like X-rays are likely to pose some risk of adverse health effects. No threshold of exposure below which low levels of ionizing radiation can be demonstrated to be harmless or beneficial. Put it simply, the true safety threshold is zero. The famous Schrödinger cat paradox *(5)* again demonstrates that the indeterministic radioactive decay can be easily magnified by using a Geiger counter into an indeterministic event of killing a cat in the macroscopic world.

Besides the radiation, there are many other indeterministic macroscopic events caused by magnified indeterministic behavior of microscopic elementary particles. The most important magnifying mechanism is atomic collisions and thermal fluctuations. The collision and scattering of elementary particles are the best understood physical processes in modern science, because the entire particle physics is directly built upon experiments of collisions of elementary particles. The collision process can be completely described by quantum mechanics, and the outcome of a collision process is indeterministic *(6)*. In fact, in his Nobel Prize acceptance speech *(7)* in 1954, physicist Max Born used indeterministic outcomes of collisions of elementary particles as experimental evidences that supported the famous Born's statistical interpretation of the wave function. Because thermal fluctuations in any system are directly results of collisions of elementary particles, indeterministic outcomes of collisions of elementary particles imply that thermal fluctuations in any system must be indeterministic. Since thermal fluctuations are universal for any system with a temperature, the behavior of any system must be fundamentally indeterministic and the deterministic behavior of any system is just an approximation or illusion. Recognizing that outcomes of collisions of elementary particles and thermal fluctuations are indeterministic has profound implications *(8, 9)* for physics, chemistry, biology, and social science. The Law of Indeterminacy is created to recognize a simple fact that both microscopic and macroscopic world are fundamentally indeterministic.

The Second Law, Law of Predicting the Future, comes from the generalization of the Born's statistical interpretation of the wave function. Indeterministic behavior of any system could only be described by quantum mechanics. However, quantum mechanics equations governing the dynamics of multi-particle systems are often too complicated to be solved directly. The Law of Predicting the Future is created to bridge the gap between quantum mechanics equations and the observed dynamics of systems.

The Law of Predicting the Future illustrates the dynamics and causality relationships in an indeterministic system. Because the joint probability distribution function exists and is uniquely given by quantum mechanics, it is not always necessary to solve quantum mechanic equations in order to describe causality relationships of an indeterministic system. Approximation methods, such as logistic regressions, or even simple guesses could be sufficient in applications.

The Third Law, Law of Choice, describes the modifiable nature of an indeterministic system. Since the future of a deterministic system is precisely described the system dynamic equations and initial conditions, there is no concept of choice for a deterministic system. However, the Law of Indeterminacy says that the world is not deterministic, and Law of Predicting the Future reflects the probabilistic worldview of quantum mechanics. Choice can be introduced as a fundamental concept in quantum mechanics. In physics, as well as in social science, a choice can be defined as an indeterministic action taken by elementary particles or collection of elementary particles like people. For example, the radioactive decay of a radon atom is a choice made by the radon atom. The future of an indeterministic system is depending on collective choices made by all elementary particles in the system. The Law of Choice is created to reflect the impact of a choice on the future probability distribution of possible outcomes of an indeterministic system.

The Fourth Law, Law of Information, clarifies the quantum mechanic nature of information. Since the outcome of choice can not be predicted deterministically by any means, any choice becomes new information. For example, the radioactive decay of a radon atom produces brand new information that the radon atom has finally decayed. The choice of a war against Iraq made President Bush was new information. For a closed system, because the behavior of elementary particles is indeterministic, some existing information must be destroyed at any time step. The Law of Information is created to reflect the non-conservative nature of information.

The Fifth Law, Law of Equilibrium, describes the quantum mechanic origin of the direction of time arrow observed in the nature world and human societies. The Law of Predicting the Future breaks the time symmetry between the future and the history. If one looks back to the history, the indeterministic world takes only one path. If one looks forward to the future, the world could take many possible paths. If we reverse the direction of time, our present universe will not follow the historic path exactly because of the indeterministic choices of all elementary particles in our universe. The movement of any indeterministic elementary particle is not time reversible and is not symmetric in time. For example, the random walk of Brownian motion is not reversible. Therefore, there is a definitive direction of time arrow pointing to the direction of equilibrium states, as defined by the Law of Equilibrium.

The Second Law of Thermodynamics states that for a closed and isolated system, the system entropy always increases with time. For example, add salts to a cup of water, and soon the whole cup of water becomes salty. The process is irreversible simultaneously and it defines a definitive direction of time. The Law of Equilibrium is a generalization of the Second Law of Thermodynamics. The scope of the Second Law of Thermodynamics is limited to indeterministic atoms and molecules, and the Law of Equilibrium is applicable to any indeterministic system including systems in economics and finance. The equilibrium states are most likely states of an indeterministic system, and movements of indeterministic elementary particles create fluctuations among equilibrium states. The universality of the Law of Equilibrium unifies the concept of equilibrium from thermodynamics to economics.

These five new physics laws of social science are built upon quantum mechanics. Since quantum mechanics is universal applicable to any system, these five new physics laws should be applicable to any system including human beings and human societies. The Second Law of Thermodynamics is certainly qualified as one of most important laws of physics. Since the Law of Equilibrium is more general than the Second Law of Thermodynamics, these new laws should be qualified to be called physics laws, because they are profound statements of properties of the nature world and human societies.

Applications of Five New Physics Laws of Social Science

In this section, we will demonstrate applications of physics laws of social science using four examples in economics, biology, history, and finance respectively.

The first example is to replace the Rational Choice Theory *(10)* in economics, which describes how people make rational decisions, with the Law of Predicting the Future and Law of Choice. The Rational Choice Theory has achieved phenomenal successes well beyond the scope of modern economy. The Modern Portfolio Theory in finance, welfare economics, microeconomics, and the Public Choice Theory in political economics are examples of the application of the Rational Choice Theory. However, the Rational Choice Theory has to assume that (a) people are rational and selfish; (b) people are always utility maximizer. Utility is a measurement of the happiness or satisfaction gained from receiving goods or services. Based on the perceived utility, people make decisions based on the optimal choice by weighting the utility against the cost. However, common senses tell us that people are not always rational, selfish, or utility maximizer. Therefore, despite its huge success, to many critics, the Rational Choice Theory is only a half-truth but useful empirical theory. They are many attempts to generalize the Rational Choice Theory to include people's behavior such as irrationality and bounded rationality *(10 - 12).*

In a contrast with the Rational Choice Theory, the Law of Predicting the Future and Law of Choice are universal physics laws applicable to any system including human beings and human societies. In the context of people's decision-making process, the Law of Predicting the Future captures the dynamics and causality relationships of a system, and the Law of Choice tells us the impact of different choices on possible outcomes of a system. The precise choice made by people is indeterministic and ultimately it is up to people's free will. There are rational people who prefer the optimal choice based on causality relationships and the optimal tradeoff between benefits and costs, irrational people who make poor choices, and somewhat rational people who make suboptimal choices. Therefore, the Law of Predicting the Future and Law of Choice provides much cleaner framework to describe people's decision-making process. Since the Rational Choice Theory is the heart and soul of modern economics and many other fields of social science, the replacement of the Rational Choice Theory signals a brand new era of economics and social science.

The central assumption of the Rational Choice Theory is that people's rational behavior can be explained using logical and mathematical reasoning, while the central idea of physics laws of social science is that people's all behavior is governed by fundamental quantum mechanics equations. Therefore, as long as logical and mathematical reasoning reflects the dynamics permitted by quantum mechanics equations, the Rational Choice Theory can be viewed as a special case of the application of physics laws of social science.

Because the Law of Predicting the Future and Law of Choice are universally applicable to animals, bacteria, and even aliens outside the earth, these laws provide theoretical guidance to study the decision making process of animals, bacteria, and even aliens if their exist. In contrast, it is difficult to apply the Rational Choice Theory to explain the behavior of living creatures other than humans.

The second example is to provide a theoretical framework to understand and quantify errors in biochemical reactions, such as genetic mutations and noises in gene expression in biology. Needless to say that genetic mutation is fundamental to biology and Charles Darwin's Natural Selection Theory. Yet origins and physics of genetic mutation are not well understood *(8).*

Physics laws of social science clarify the roles of quantum fluctuations in generating errors in biochemical reactions. Since outcomes of collisions of elementary particles and thermal fluctuations are indeterministic, outcomes of biochemical reactions must be indeterministic according to the Law of Indeterminacy. Under a normal circumstance, errors in biochemical reactions are limited to the microscopic molecular level and invisible to the macroscopic world. However, under a special circumstance like errors in replications and transcriptions, the information of errors in biochemical reactions can be magnified millions times to be easily visible in the macroscopic world.

In a recent review article *(8)*, Raser and O'Shea highlighted the stochastic nature of biochemical reactions in a cell by pointing out that when a few molecules of a specific type exist in a cell, stochastic effects can become prominent, while when large numbers of molecules are present, chemical reactions may proceed in a predictable manner.

While the Law of Indeterminacy provides a theoretical explanation of genetic mutations using quantum fluctuations, the Law of Predicting the Future further predicts that probability of indeterministic outcomes of the same biochemical reaction under the same environment is precisely given by quantum mechanics. Therefore, the Law of Predicting the Future provides a powerful tool to quantify the probability of genetic mutations under controlled laboratory environments.

The third example is to provide a firm connection between quantum physics and the subject of history of humanity. History is an ancient subject about discovering objective historic truths, or things exactly happened in the past. One fundamental question in history is whether precise historic facts could be reconstructed based on today's information. For example, there have been controversial for years about the unusual circumstances surrounding the assassination of President J. F. Kennedy in 1963. The Law of Information unambiguously states that the complete historic facts cannot be reconstructed using today's information for any closed system. Therefore, there are fundamental uncertainties about historic facts, and some historic information has lost permanently because of indeterministic movements of elementary particles. The existence of complete, objective, and unambiguous historic facts is just an approximations or illusions. The Law of Information shows the importance to preserve historic evidences in order to minimize historic uncertainties about significant events that happened in the past.

The forth example is to provide a theoretical foundation for the derivative pricing theory in finance. Since the seminar work of Black and Scholes *(13)* in 1973, the derivative industry has witnessed of an explosive growth from virtually nothing into a notional amounts outstanding of $270 trillion as of June 2005, according to the latest statistics from the Bank for International Settlement *(14)*. In terms of its ability to explain the empirical data, Black-Scholes Option Pricing Theory is the most successful theory not only in finance, but in all of economics *(15)*. However, it is a mystery why Black-Scholes Model has worked so well for so many years.

After applying physics laws of social science to derivative pricing, it becomes clear that the success of the Black-Scholes Model is because it is a very good approximation to the Law of Indeterminacy and the Law of Predicting the Future. The essence of Black-Scholes Model *(16)* is to assume that stock prices follow an indeterministic geometric Brownian motion process and the probability of the future prices of a stock follows a lognormal distribution. The Law of Indeterminacy states that the future stock prices are indeterministic and the Law of Predicting the Future states the future stock prices follow a probability distribution, which may or may not be the lognormal distribution. Therefore, the Black-Scholes Model is a special case of the application of the Law of Indeterminacy and the Law of Predicting the Future, two fundamental laws of physics.

Once one understands the secret behind the phenomenal success of Black-Scholes Model, one could improve the Black-Scholes Model by using other probability distributions to capture more realistic price movements. Indeed it has been the general trend *(16)* in recent years in the field of the derivative pricing to explore more sophisticated dynamic models, such as jump diffusion and stochastic volatility models, to go beyond lognormal distributions. Therefore, physics laws of social science provide a firm physics foundation for the general derivative pricing theory.

Above four examples have demonstrated that these laws can be seemly applied to different fields in both natural and social science. Although there are very little in common among the Rational Choice Theory in economics, genetic mutations in biology, uncertainty in historic facts, and derivative pricing theory in finance, these physics laws of social science can provide coherent answers to fundamental questions in different fields and powerful guidance to improve existing theories. These new laws have removed the invisible wall, which is artificially separating social science from natural science. Therefore, for the first time, we have established a shared physics foundation for all fields in social and natural science.

Since physics laws of social science are applicable to any system that is made of elementary particles, these laws are experimentally testable. There are many other useful applications in fields in social and natural science. Further applications will be presented in future books *(17)* and other publications.

A New Interpretation of Quantum Mechanics

In this section, we will discuss how these new physics laws of social science will fit in the existing framework of physics.

After the 300 plus year rapid development since Isaac Newton, physics is a mature and complete field in a sense that it is extremely difficult to add new physics laws to the existing framework of physics without solving some very fundamental problems such as the reconciliation between quantum theory and general relativity. These new physics laws of social science fit in the existing framework of physics by solving the famous measurement problem in quantum mechanics. These physics laws of social science represent a new interpretation of quantum mechanics, which is substantially different from the Copenhagen Interpretation.

While quantum mechanics is a precise and one of most successful theories of explaining and predicting experimental observations, what exactly quantum mechanics is saying about the nature is still very controversial in physics and philosophy. The traditional Copenhagen Interpretation suffers a measurement problem from the difficulty to separate the measurement process and the physics reality. According to the Copenhagen Interpretation, the measurement process is indeterministic, while the physics reality described by quantum mechanics equations are deterministic. The indeterministic collapse of the wave function by measurement and the deterministic mathematic formulation of quantum mechanics are directly contradictive with each other. Dozens of new interpretations of quantum mechanics *(18)* have been proposed to solve the measurement problem in the Copenhagen Interpretation. However, none of new interpretations has been widely accepted or confirmed by experiments.

The Law of Indeterminacy solves the measurement problem by rejecting the assertion that the physics reality described by quantum mechanics equations are deterministic. The Law of Predicting the Future implies that the deterministic mathematical equations, such as Schrödinger equations, describe the evolution of the probability distribution, not the deterministic reality. It is widely used in statistics to use deterministic differential equations to describe indeterministic processes. For example, in Black Scholes Option Pricing Model *(16)*, the deterministic diffusion equation is used to describe the indeterministic stock price movements. The new indeterministic view of quantum mechanics implied by physics laws of social science, is consistent with existing experimental evidences and the original Born's statistical interpretation of the wave function. Details of a new experimentally testable interpretation of quantum mechanics will be presented in future publications.

These new physics laws of social science can fit in the existing framework of physics without too much interruption. The new physics laws of social science largely left the formulation of quantum mechanics intact. The Newtonian physics and general relativity can be viewed as approximations to the indeterministic physics reality.

Concluding Remarks

Since Issac Newton discovered the laws of motion in 1687, for the next 300 plus years, scientist have been searching for physics laws of social science. We have shown that it is possible to create a coherent common foundation for social and natural science by introducing the concept of choice in physics and creating a new interpretation of quantum mechanics. There are many questions remaining to be answered. For example, we know very little about the biochemical mechanism about how human and animal brains are able to control and take advantage indeterministic thermal fluctuations.

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