Fundamental Equation of Economics

Wayne, James J.

Lawrence Cedar House LLC

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James J. Wayne
jjwinterpretation@gmail.com

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Abstract

Recent experience of the great recession of 2008 has renewed one of the oldest debates in economics: whether economics could ever become a scientific discipline like physics. This paper proves that economics is truly a branch of physics by establishing for the first time a **fundamental equation of economics (FEOE)**, which is similar to many fundamental equations governing other subfields of physics, for example, Maxwell's Equations for electromagnetism. From recently established **physics laws of social science (PLSS)**, this paper derives a fundamental equation of economics, which is the one mathematic equation that governs all observed economic phenomena. FEOE establishes a common entry point to solve all economic problems without any exception. We show that establishing FEOE clarifies many open questions regarding the foundation of economics. For example, the number one question for all economists ought to be what can be forecasted and what cannot be forecasted in economics. Without FEOE and PLSS, this number one question cannot be answered scientifically within the existing framework of economics. While FEOE re-affirms many existing economic theories, we also have found that many other popular economic theories are not compatible with FEOE, and we conclude that FEOE comes with its own version of microeconomics and macroeconomics. In microeconomics, the framework of laws of supply and demand and market equilibrium, which is traditionally assumed by most economists as the foundation of economics, is replaced by a new model called indeterministic supply demand pricing (ISDP) model. ISDP model is far more precise and universal mathematical abstraction of market reality than the framework of Marshall's market equilibrium and laws of supply and demand. In macroeconomics, a new macroeconomic model called indeterministic balance sheet plus (IBS+) model can be derived from FEOE. Unlike the popular DSGE and Agent-based Computational Economic (ACE) models, the IBS+ model is universally applicable in any kind of economy, empirically falsifiable, making forecasts with reasonable accuracy, truthful abstraction of reality, capturing macroeconomic dynamics accurately, and most importantly based on a sound theoretical foundation. In conclusion, this paper shows that FEOE provides a solid physics foundation for both theoretical and practical economics. Therefore, after establishing the fundamental equation of economics in this paper, there should be no doubt that economics is simply a branch of quantum physics in parallel with chemistry and optics. Over last four hundred years, there are many schools of thoughts emerged in economics while there is only one school of thought by Newton-Einstein-Bohr survived the experimental and theoretical scrutiny in physics over the same period. The logic conclusion is that there must be only one school of thought allowed in economics as a subfield of physics.

1. Introduction

Recent great recession of 2008 has pushed many economists *(1, 2, 3)* to re-exam one of the oldest questions in the field: whether economics could ever become a scientific discipline like physics. In most branches of physics, there is a fundamental equation that describes most if not all observed phenomena. In classical mechanics, it's Newton's laws of motion; in electromagnetism, it's Maxwell's Equations. If a fundamental equation of economics could be established for all observed phenomena in economics, it would solve many fundamental and practical issues in the field, and let no doubt that economics is a science or more specifically a subfield of quantum physics.

In this paper, we first introduce the five physics laws of social science as the starting point. Then a **fundamental equation of economics (FEOE)** is derived from physics laws of social science. FEOE is used to clarify many issues regarding the foundation of economics. After pointing out many flaws in the framework of laws of supply and demand and market equilibrium, we use FEOE to establish a more solid and universal mathematical model called the indeterministic supply demand pricing model. We show that laws of supply and demand and market equilibrium could be valid only as special cases and invalid as generalized market behavior. We pointed out macroeconomic models, which are built on the flawed conceptual framework of general equilibrium and laws of supply and demand, are not going to work well against the real economics. In the end of this paper, since there is only one school of thought existing in physics, if economics is a subfield of physics, we suggest that many current schools of thoughts in economics must be unified into one coherent truly scientific theory.

2. Five Physics Laws of Social Science

The starting point of establishing a fundamental equation of economics is the five physics laws of social science, which have been published elsewhere in a book *(4)* and an academic paper *(5).* 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 constrains, 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 *(4)* and the paper *(5)*. 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. Derivation of the fundamental equation of economics

In this section, we will derive the fundamental equation of economics from physics laws of social science. The central hypothesis of this paper is that human free will is a quantum phenomenon. Then the human behavior and human society are ultimately governed by the famous Schrodinger Equation *(6)* in quantum mechanics.

If ψ is the wave function for a closed social system, then the future evolution of the wave function ψ is given by the Schrodinger Equation

$$i\hbar\frac{\partial \psi}{\partial t} = \mathrm{H}\,\psi$$

where i is the imaginary constant complex number, ħ is the Plank constant, H is the Hamiltonian operator.

To apply the regular Schrodinger Equation to describe the human behavior and human society is difficult for a few good reasons:

(1) Each term in is Schrodinger Equation is defined by quantum mechanics precisely. The wave function ψ describes the collective behavior of all elementary particles, and it is not clear at all how to describe the Hamiltonian for such a large system.

(2) Even we know how to write down the Schrodinger Equation for human society, how to solve such monster equation is totally out of question based on the existing technology. Physicists and chemists have difficulties to solve the Schrodinger Equation for small molecules involving only a handful of atoms.

(3) In theory at least, one could find ways to simplifying the Schrodinger Equation through approximation. It is not clear how to do so for human behavior and human society.

In short, even though we know the regular Schrodinger Equation is the fundamental equation of human society, because each item in Schrodinger Equation has precise definition in physics, we don't know how to apply it to describe the human behavior and human society in practice. In order to create the more useful equation for human behavior and human society, we have to apply one of physics laws of social science, law of prediction, which is the generalized Born's statistical interpretation in quantum mechanics.

Law of prediction states that 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.

Let φ be the joint probability distribution function, the law of prediction translates into the **Fundamental Equation of Economics (FEOE).**

$$\frac{\partial \varphi}{\partial t} = \mathrm{H}\,\varphi$$

Here H is an operator. In principal, for a closed system of human behavior and human society, H operator is precisely defined by quantum mechanics. At this stage, we do not know to define H exactly starting the atomic level interactions. We do know that, however, H operator does exist and is uniquely defined because of law of prediction. For all practical purpose, as long as H exists and is uniquely defined, we could always construct an approximate H operator from empirical data and physics laws, and then compare the forecast against the future outcome. The difference between the realized outcome and model expectation provides the needed feedback to further improve the forecasting models. The initial condition φ(t=0) reflects the existing economic reality. As an example, Feymann-Kac equation *(7)* for option pricing theory in finance can be viewed as a special case of FEOE.

For most applications of FEOE in economics, we can further specify the joint probability distribution function φ. In economics, we mainly concern about monetary matters. Since money always belongs to somebody, in most applications, the joint probability distribution function φ is simply the joint probability of possible values of assets in balance sheets. Therefore, FEOE describes the time evolution of the joint probability distribution of future valuation of assets and liabilities. The initial condition φ(t=0) reflects the economic reality of the existing assets and liabilities.

FEOE is broadly applicable in wide range areas. Besides economics, FEOE is applicable for all human behavior, nature, and social phenomena. Even though we call the equation as the fundamental equation of economics, it is equally applicable in

politics, business and military strategy, sociology, and other field of social and natural science.

Even in physics, FEOE is a very unusual mathematical equation because the future joint probability $\varphi(t)$ is not the future reality itself, rather it is the probability distribution of all possible future realities. In all other subfields of physics with exception of quantum mechanics, most fundamental equations like Maxwell's Equation, deal with the measurable reality itself. FEOE captures the indeterministic quantum nature of human society. The strangeness of FEOE explains why economic and social phenomena are so different from other phenomena observed in the physical world in everyday life.

We must emphasize that FEOE and quantum economics is far more than just applying probability theory for the economic analysis. In physics, quantum mechanics is far more than just applying probability theory for the physics analysis. In the FEOE framework, the future joint probability distribution function is unique and objective, and can be forecasted precisely only at one moment. FEOE is the generalized Born's statistical interpretation in the human society.

4. Questions about Foundation of Economics

4.1 Causality in Economics

In all fields of science including economics, the scientific analysis is about analyzing and discovering the causality relationships. FEOE essentially says that all causality relationships in economics are indeterministic and fundamentally quantum mechanics in nature, that is because human beings have free wills, human free wills are quantum phenomena, and human behavior including economic behavior is indeterministic.

Just like in quantum mechanics, indeterministic causality relationship means that the same cause could produce different effects, and no cause is needed to have effects. For identical decaying radioactive atoms, while the laboratory environment and initial conditions are the same, the decay time of individual atoms are very different. Radioactive decay is spontaneous and no external causes are needed to have the atom decay. Similar things happen in our everyday life. Under the same condition, a person could get out of the bed at very different times. Also no external cause is required to have the person get out of bed. Thus human behavior in a fundamental way is the same as the behavior of radioactive decaying atoms.

To summarize, the quantum nature of human behavior demands the description of economic phenomena using the mathematics of probability. FEOE is simply the bridge connecting the current economic reality and all future possibilities.

4.2 One and Only Equation Governs All Observed Economic Phenomena

FEOE reflects most critical and most fundamental features about human economic behavior: human free will is a quantum phenomenon; the causality in social science is indeterministic and probabilistic in nature; human individual and society obey the same set of physics laws of quantum mechanics; the importance of property ownership; the owner of balance sheets generally tend to manage the assets and liabilities

to maximize the owner's total wealth and minimize the risks of bankruptcy; the existing economic reality; and the various constrains imposed on the free wills to limit their choices.

FEOE is the mathematical bridge connecting the current economic reality and all future possibilities. One side of the bridge is the current economic reality, which is mathematically organized in terms of balance sheets. FEOE emphasizes the central role of balance sheets in economics. In many fields of science, the complexities of observed phenomena are often reduced to the interactions of basic units. For example, in biology, those basic units are individual cells; in chemistry, the basic units are individual atoms and molecules. In economics, FEOE asserts that those basic units are individual balance sheets. Because all economic phenomena can be viewed as the interactions of balance sheets, FEOE becomes the one and only one equation needed to describe all observed economic phenomena.

FEOE is equally applicable in both microeconomics and macroeconomics. In microeconomics, the focus is how the individual balance sheet evolves from the current existing state into all future possibilities. Balance sheets analysis is already widely used to study the consumer finance. The central role of balance sheet analysis in corporate finance is unquestionable. In the public sector, the government balance analysis is widely used but often less emphasized. Thus all economic analysis in microeconomics can be easily repackaged in terms of the language of FEOE.

Because both current and future balance sheets have nice properties that can be mathematically combined and divided, the macroeconomics can be viewed as applying FEOE to study the time-evolution of the aggregate balance sheets of key sectors. The usual macroeconomic measures like GDP, unemployment rates, inflation and interest rates can be viewed as key secondary parameters. The FEOE's approach to macroeconomics puts equal emphasis on the stock and flow while traditional macro-analysis puts more emphasis on flow.

It's important to note that FEOE can be different from traditional balance sheet analysis because FEOE emphasis the existing economic reality, indeterministic nature of causality relationships, the central roles of free wills in the decision making, future uncertainties, and the use of joint probability distribution function to describe the future possibilities. For example, tradition balance sheet accounting analysis uses largely arithmetic while FEOE employs the probability distribution function as its main mathematical language.

4.3 Fundamental Question of Economics

Traditional economics is not sure whether economics should focus on forecasting the future like physics or interpreting the past events like history. Among a small group of brave economists who are devoted to forecasting the future, few of them have ever asked the most fundamental question of economics: what is predictable and what is not predictable in economics. Therefore, it leaves no doubt that traditional economics is not a science. That is the most important reason why we need FEOE to clarify these fundamental questions.

In the framework of FEOE, economics is a forecasting science as a subfield of physics. To build any forecasting model based on the economic reality, the first question

and also the most fundamental question of economics must be what is predictable and what is not predictable in economics. Strangely, such a fundamental question in economics has been rarely discussed in standard textbooks or economic literatures.

In practice, ignoring the fundamental question of economics is fatal to an economic forecasting model. For example, people who built the popular DSGE models in obviously have not carefully analyzed what is predictable in macroeconomics and decided to treat the economic crises as exogenous shocks. That decision makes DSGE models far less useful and also blind to dangerous endogenous economic imbalances like stock, credits, housing, and other bubbles. Therefore, to use DSGE models to guide the monetary policies is like asking a blind person to drive a school bus.

One major contribution of FEOE and physics laws of social science is to clarify the most fundamental question in economics what can be forecasted precisely and what cannot be forecasted in economics. The precise which event will happen cannot be forecasted while the unique objective probability of the future events can be precisely forecasted at any moment. That is exactly what happens in quantum mechanics. In quantum physics, the precise timing when a radioactive atom will decay cannot be forecasted while the probability of the decay time can be precisely forecasted and checked with experiments.

Many economists devoted their lifetime forecasting precisely the next unemployment rates or the upcoming year end stock price. Their work is no longer scientific and no better than astrology because they are forecasting things cannot be forecasted scientifically. Law of prediction says that only the objective probability distribution of the next unemployment rate or the year end stock price can be precisely forecasted.

4.3 Economic Forecasting

Historically, economic forecasting has been a major source of embarrassment for professional economists. The famous quote “the only function of economic forecasting is to make astrology look respectable.” is very accurate description of the state of arts of the profession.

One contribution of FEOE is that FEOE provides the universal starting point and the framework for all forecasting in social science. In traditional economic forecasting, various forecasting methods are used by practitioners. Different methods often produce different answers. For example, to forecast the year end stock price, one could use linearly extrapolate, different moving averages, fundamental valuation, technical analysis, supply and demand analysis, surveying experts, or even trying astrology. FEOE sets a much higher standard for choosing the forecasting methods. The acceptable model in social science must to be a physics model based on the mathematic abstraction of reality and laws of physics. In astrophysics, to forecast the future motions of planets in the solar system, the acceptable physics models must apply the Newtonian laws of motion and law of gravity or other closely related theories like general relativity. Even though astrology might make the correct forecasting of the star movement, it still does not make astrology as an acceptable scientific model.

Just like models in physics, FEOE requires the a scientific forecasting model in economics to be logically self-consistent, making forecast with reasonable accuracy,

truthful abstraction of initial reality, capturing key dynamics accurately, and based on a sound theoretical foundation. The quick way to achieve the requirement is to apply FEOE to model economic processes.

4.4 Role of Empirical Data in Economics

Economics is often advertised as an empirical science, and what economists really mean is that only economic models built upon historic empirical data are acceptable. FEOE rejects the fundamental role of empirical data. At the top level, only the initial condition and FEOE are needed for forecasting. Therefore, at the top level, the empirical data are actually irrelevant.

In most sub-fields of physics, the historic data are usually irrelevant. To forecast the future motions of planets around the sun, only the initial condition of planets and laws of physics are needed. The historic data are not required. Although historic empirical data could be useful to back-test the forecasting model, that importance is secondary. At the top level, the historic data has no use and not required in all fields of physics, which must include economics.

The emphasis on the initial condition and laws of physics instead of empirical data is very important because it brings economics up to the same playing level as other fields of physics, and force economists to focus on the future instead of interpreting what happened in the past. There is a widely shared believe among economists that their main job is to interpret the history instead of forecasting the future. In contrast, the main tasks of scientists in most other subfields of physics are to forecast the future instead of interpreting the past.

In practice, empirical data are critical for calibrating and back-testing the forecasting models. When empirical data are used, we are assuming the history will repeat itself in some fashions. In social science, because people have free wills, there is no guarantee that history will repeat itself. Figuring out what will repeat in the future is the heart and soul of the FEOE-based economic analysis.

4.5 Money as Socialized Free Energy

Money plays the central role in FEOE. It brings up the most important question in economics: what is the money? Traditional economics textbook *(8)* often simply defines money as the exchange medium. From the physics and FEOE point of view, money is more properly viewed as the "socialized" form of free energy. There are several reasons why money plays the role of "socialized free energy" in the human society.

(1) The second law of thermodynamics dictates that the continuous inflow of free energy is essential for sustaining all human activities. There are many different forms of free energy are used in human societies: manual labor, food, oil, electricity, heat, natural gas, solar energy, nuclear, and other forms of energy. While money itself is not a form of free energy, money can be used to buy real free energy in order to sustain human activities. Because there are many forms of free energy in the human society, money is created to play the

role of universal and "socialized" free energy. Without money to buy free energy, almost no social activity can be sustained.

(2) Looking beyond human societies, free energy flow is usually the defining factor of many biological, ecological, and physical systems. More interestingly, many systems employ their own unique universal free energy units. For example, ATP molecules are the official providers of free energy for biochemical reactions in cells insider our human body. Edible food is the official carrier of free energy for the ecosystems like Everglades National Park in Florida. Animals could flourish with ample amount of food and also could perish for lack of foods. In human societies, money is created to play the same role of universal and "socialized" free energy. Each balance sheet grows or shrinks because of the flow of money. Cities, factories, and families could flourish with available large amount of money and also could perish for lack of money.

(3) In traditional economics, natural resource, labor, and capital are key factors of production. Free energy is the ultimate limiting factor of economic activity because the law of energy conservation dictates that the available free energy cannot be created or destroyed arbitrarily. In the FEOE framework, real free energy and capital plays more fundamental roles in human economic activities than land and labor.

(4) In traditional economics, the factors of production include land, people, and capital. And some economists also include entrepreneurship. In quantum economics, the economic system is viewed through the thermodynamic lens just like analyzing any thermodynamic systems. In quantum economics, the factors of production include real free energy and capital, waste energy disposal, materials, waste material disposal, land and spacetime, and people. Put it differently, a relatively independent economic unit in certain spacetime is to take in the free energy and raw material, provide products or services for the benefits of people, and produce the waste thermo energy and the waste material. That is the way our human body or any thermodynamic systems work. We get free energy and material from foods and water, produce research papers and other things, and generate waste heat energy and other human wastes.

(5) In both quantum mechanics and Newtonian physics, Hamiltonian is defined as some forms of free energy. If money is "socialized" free energy, FEOE brings the economics analysis in line with other branches physics. FEOE is an equation governing how "socialized" free energy evolves with time.

(6) In physics, minimizing or maximizing the free energy is often the key organizing feature of an equilibrium state. In economics, the maximizing the wealth of balance sheet is the key to optimize the economic structure.

4.7 Wealth Maximizing Principle and Invisible Hand

The nature of the "invisible hand", which efficiently organizes the worldwide economic system, has been in great interests to economists since Adam Smith. In physics, there are similar invisible hands in many physical systems. For example, snowflakes are spontaneously self-organized into beautiful symmetric patterns. If money is viewed as the socialized free energy, then two invisible hand phenomena in economics and physics are the same phenomena with similar dynamics. In physics, the "invisible hand" is characterized by the maximization of entropy or minimization of the free energy depending on the boundary conditions. In economics, the "invisible hand" is driven by the maximization of wealth, which is money or socialized free energy.

In a free society, it is important to emphasize that decisions of the maximization of wealth must come from consumers, private corporations, and nonprofit organizations instead of imposing those economic decisions by central governments upon the entire society. Therefore, there are rooms for the existence of freedom of choices and animal spirits of consumers and producers, which will cause the short-term indeterministic fluctuations of the economic outputs for whatever reasons.

In the framework of FEOE, popular general equilibrium theory is replaced by the principle of wealth maximization.

In economics, at the consumer and corporate level, the primary responsibility of the person who is in charge of a balance sheet is to maximize the net worth of the balance sheet while keeping potential risks of bankruptcy in check. In the process of pursuing the maximization of wealth, the economy becomes more efficient because the people earning potential is maximized and the costs and wastes are minimized. If the net wealth is maximized for all individual balance sheets in an economy, then the net wealth of the aggregate balance sheet of entire economy is also maximized. Therefore, the aggregate net wealth of the aggregate balance sheet of an economy becomes a fundamental measure of the efficiency of the economy as whole.

4.8 Replacing General Equilibrium Theory with Wealth Maximizing Principle

In the framework of FEOE, the popular general equilibrium theory is abandoned and replaced by the wealth maximizing principle.

While the general equilibrium theory is widely recognized as a landmark achievement by the traditional economic textbooks, the general equilibrium theory requires many strict and unrealistic assumptions like perfectly competitive markets. The main problem with general equilibrium theory is the following:

(1) It is fact that most economies in the world at the national level are either growing or shrinking. A growing or shrinking economy simply cannot be modeled as a static equilibrium.

(2) Inventory, spare capacity, and unemployed labor forces are fundamental features of any market economy. The existence of inventory means supply is

always greater than demand. Therefore, in reality, there is no such thing as a general equilibrium characterized as aggregate supply equals aggregate demand.

(3) The general equilibrium theory is characterized by Pareto optimal efficiency. However, the real economy efficiency is achieved by both Pareto efficient actions like free trade and non-Pareto efficient actions like downsizing work forces, Schumpeter's creative destruction processes, law suits, standardization, legislation and regulations by political leaders. Most firms achieve the economic efficiency by ruthlessly cutting back of the labor forces. Although the work force reduction is not a Pareto efficient process by definition, it is one of key methods to achieve the economic efficiency.

(4) The general equilibrium theory is inconsistent with the FEOE framework which requires the strict, scientific, and precise definition of equilibrium.

The wealth maximizing principle reflects the basic human nature which is characterized by Warren Buffett as people choose to work hard every day to make their life better today than yesterday. The desire of improvement is the fundamental force driving the economic growth through innovation, efficient use of scare resources, and building capitals by saving and investments. The wealth maximizing principle is a profoundly powerful force which pushes human society towards the limits of science and technology, making maximum use of the available resources, minimizing wastes, and achieving the maximum efficiency through self-organization of the entire society.

The wealth maximizing principle reflects a growing not static economy because the wealth maximizing processes is on-going and would never end until it hitting some fundamental limits that cannot be overcame by human free wills. Most importantly, the wealth maximizing principle reflects the profit seeking behavior of individuals and firms in a competitive market economy.

The wealth maximizing principle is closely related to the central problem of economics "how does the economy satisfy unlimited desires with limited resources"? Detail discussions will be published elsewhere.

The wealth maximizing principle includes but not limited to many logical consequence of general equilibrium model, which makes general equilibrium model popular:

(1) The wealth maximizing principle includes but not limited to Pareto efficiency improvements.

(2) The free market is fundamental to achieve the wealth maximizing. However, the importance of the free market does not imply the diminishing roles of government. In the FEOE framework, the effects of government policies could be evaluated with forecasting. Therefore, the roles of government in economy can be evaluated on the logics and empirical merits.

(3) The inter-connection of various markets is an important consequence of the wealth maximizing principle. For example, one logic consequence of the wealth maximizing principle is the no arbitrage principle in the financial markets. If there are arbitrage opportunities exist in the financial markets, profit hungry traders would take advantage of those opportunities. The no arbitrage principle could be generalized to the entire economy. If there are profitable opportunities exist, the free market will find ways to take advantage of those opportunities.

(4) Just like the minimizing free energy principle explains many spontaneous order phenomena in physics, chemistry, and biology, the wealth maximizing principle naturally implies spontaneous economic orders. It is less obvious why the market-clear static general equilibrium would lead to spontaneous orders.

4.9 Importance of Voluntary Exchanges in Economics

The main reason that the market equilibrium and general equilibrium theory have gained such wide acceptance among economists is that it helps explain the importance of the free market. However, as we will discuss in more details, in reality, the market equilibrium is very poor abstraction of the economic reality. In reality of most markets, the market equilibrium characterized by supply equaling to demand does not exist, because most markets carry inventories and inventories by definition means that the markets do not clear completely and supplies always exceed demands. Sometimes, the supply, demand, inventory, and price are very stable. The stability can be characterized by the flow equilibrium just like the fluid flows in the hydrodynamics. The difference between the flow equilibrium and the market equilibrium is that the flow equilibrium does not have any important theoretical implications such as the free market is socially optimal.

In quantum economics, the voluntary exchange and the free market are fundamentally important because the voluntary exchange and the free market allow the society to maximize the wealth.

Consider two societies. Both societies produce the same among goods and services. One society allows the voluntary exchange and the free market, and the other society allows the central planning officials to distribute the goods and services. It is obvious that the society with the free market is wealthier than the society with the central planning. However, that extra wealth is coming from the voluntary exchanges and not from the market equilibrium. The voluntary exchanges will maximize the total wealth of the society.

One major flaw of traditional economics is to derive the Pareto optimal efficiency of the free market through the market equilibrium mechanism. However, in reality, most markets are not in equilibria.

In the new framework of quantum economics, we derive the Pareto optimal efficiency of the free market through the voluntary exchanges. The separation of Pareto

optimal efficiency and the market dynamics provides the critical flexibility to model the market reality using universal disequilibrium models in both microeconomics and macroeconomics.

4.10 Diminishing Role of Axiomatization Approach in Economics

One widely-used approach in theoretical economics is the axiomatization method. The establishment of PLSS and FEOE diminish the usefulness of the axiomatization approach.

In physics, the axiomatization method is rarely used because the fundamental laws of physics are universally recognized axioms. Physicists cannot create additional arbitrary axioms as they wish. The basic requirement of the axiomatization approach is that the axioms must be always true. Over last 300 plus years, they are only dozens of fundamental laws of physics ever discovered. The requirement of adding new axioms to the existing laws of physics is so high that most professional physicists would not think axiomatization is a valid approach to most physics problems except solving truly fundamental problems in physics like unifying the quantum mechanics and general relativity.

Because economics becomes a branch of physics after the establishment of PLSS and FEOE, the role of the axiomatization approach must be minimized. In order to reach the correct conclusions using the axiomatization method, axioms must be always correct and useful. With exceptions of PLSS and FEOE, it is impossible to have any statement in economics to be both useful and correct. Dozens of widely-recognized basic economic principles like people reacts with incentives and laws of supply and demand are downgraded into statistical relationships of general human behavior, which are sometimes true and sometimes false.

In essence, physics laws of social science are only valid axioms in the all fields of social science including economics. There are no need additional axioms in economics.

4.11 Value-Free Economic Analysis

Historically one of the dreams of economic professionals has been to have value-free economic analysis. In practice, however, opinions from economists often divergent widely even with the same set of identical publically available data. The reason is that different people uses different methods of analysis.

It is not controversial to separate the normative economics from the value-free analysis of positive economics. How to conduct the value-free analysis is an open question. For the same public data set, the opinions vary because economists are using different starting points, methodologies, and assumptions. For example, at this point of writing this paper, what the future of Chinese economy will be in the next few years is very controversial even though the public data available about Chinese economy is more or less the same.

FEOE provides a reliable and universal approach to economic forecasting. FEOE forecasting is inherently value-free because it starts with economic reality and applies laws of physics and causality relationships for economic forecasting. Economic reality

and laws of physics are independent from passive observers. Causality relationships are based on logics and empirical data. The variation of economic forecasting depends on the approximations and assumptions. Law of prediction demands the forecasted joint probability distribution to be unique. Therefore, there must be some correct ways to make the assumptions and approximations. FEOE puts tight constrains on approximations and assumptions.

4.12 Reality-Based Economics

Central criticism of existing economic theories are that many existing fundamental theories requires unrealistic assumptions: people with perfect rationality, perfectly competitive market, general market equilibrium, perfect information, maximizing of profits, efficient financial market, no transaction costs, and many others. FEOE uses none of these assumptions. FEOE only works when dealing with reality because physics laws only applicable to physical reality. In imaginative worlds like video games or fairy tales economic theories, physics laws cease to work. In practice, reality is often complicated. Simplification and approximation are essential and often made through insights gained through research. For example, the super-conducting phenomena in physics are too complicated to be understood by applying first principles of quantum mechanics. Through a brilliant insight, BCS theory was proposed for traditional superconductors. BCS theory is an example of good theory that balances between fundamental laws of physics and simplification of reality. In the end, whether simplification and assumption are good or not is judged by the accuracy of forecasts, accuracy of estimating uncertainty, and the correct capture of dynamics.

5. Flaws in Framework of Laws of Supply and Demand and Market Equilibrium

Creating marketplaces for voluntary exchanges is one of most important inventions of humanity. Yet it has been very challenging to create scientific descriptions of the market phenomena. If the economics is a branch of physics, FEOE should provide truly scientific descriptions of these simple and fundamentally important economic phenomena. In this section, we will derive a new model called indeterministic supply demand pricing model (ISDP) to replace the framework of laws of supply and demand and market equilibrium.

In tradition standard economic textbooks, the market phenomena are described in the framework of laws of supply and demand and market equilibrium. Historically this framework has been widely criticized over centuries by different schools of economic thoughts *(9)*. However, other economic schools have not come up a different and convincing framework.

Because laws of supply and demand and the concept of market equilibrium have worked poorly in the real economy, most economists have been so discouraged that they have come to a wrong conclusion that economists should interpret what happened in the past instead of forecasting what will happen in the future. Of course, the whole point of science is to make scientific predictions.

5.1 Flaws in Laws of Supply and Demand

Although it is has been widely recognized as the foundation of economics, the framework of laws of supply and demand and market equilibrium is deeply flawed. Laws of supply and demand are not fundamental laws of physics for several reasons:

(1) Because physics is a precise science, all variables referred in laws of physics must be precisely defined. The quantity of supply and quantity of demand are hard to define precisely. Potential demands are not directly observable by definition in the market places because potential demand implies the psychological states of minds of potential buyers, which could change at any moment at consumers' free will. There could be many measures to gauge the potential buyers' interests. However, law of supply and demand does not state precisely how to quantify the amount of demand. Take the US housing market as an example, the amount demand can mean many things: the number of households showing interests in purchasing houses in consumer survey, the number of households showing interests and financially prepared to purchase a house, the amount foot traffic to open houses and local sell offices, the legally-binding bids received for houses listed for sell, the mortgage applications for purchasing houses, and the number of houses sold in a given period. While all these measures are good indicators of the amount of demand in the US housing market, none of them can measure precisely the amount of potential demands at various price levels.

(2) Laws of physics must be always true. Even when the potential supply and demand could be approximately measured, the laws of supply and demand are not always true. During the housing booming years of 2004 and 2005, when the housing prices were soaring, the demand interests measured by various indicators are also soaring. Yet when the housing prices plunged in 2008 and 2009, the demand indicators also plunged. In other words, the observed housing prices were positively correlated with the consumer demand. This empirical observation contradicted the laws of demand. In everyday life, most prices of goods for sell in supermarkets, retail stores, and restaurants are often fixed regardless the amount of short-term supply and demand. For example, the prices of hamburgers in McDonald Restaurant do not automatically change, simply because there are more peoples are standing in the line and waiting. Therefore, unlike universal applicable laws of physics, laws of supply and demand are not always true.

(3) Laws of supply and demand incorrectly specify causality among supply, demand, and price three variables. In reality, these three variables inter-depend on each other without any simple, clear, and universal-applicable dependence. Future supply is a function of production feasibility constrained by reality, and past, present, and future expectations of demand and price; future demand depends on recent demand history, and past, present, and future expectations of supply and price; future prices are determined by the

pricing mechanism, pricing history, and past, present, and future expectations of supply and demand. Because buying and selling houses are one of the biggest financial decisions for US consumers, potential sellers and buyers of courses will use all information available to them in order to make sound decisions.

(4) Laws of supply and demand deny that people have free wills. Law of demand states that with everything else fixed, when price rises, the demand falls. However, if buyers have free wills, they don't always have to react passively, rationally or mechanically according to any price change. Therefore, laws of supply and demand directly contradict with physics laws of social science and are fundamentally wrong.

To summarize, the laws of supply and demand are not laws of physics. In order to make economics a real science, the laws of supply and demand must be abandoned as the foundation of economics and downgraded into statistical relationships, which work sometimes and do not work in other times.

5.2 Inconsistency in the Concept of Market Equilibrium

While equilibrium is one of most important concepts in economic, there are many definitions of equilibrium depending on different branches of economics: perfect competition, general equilibrium theory, macroeconomics, game theory, and financial market theory. There are many controversies surrounding how to apply the equilibrium concept in the real market 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 concept of 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,

$$H_2O + CO_2 \leftrightarrows H_2CO_3$$

No matter how far away from the equilibrium, the total mass of H_2O and CO_2 consumed always equals to H_2CO_3 produced because the conservation 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_2CO_3 produced equals to the amount H_2CO_3 consumed 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 misconception.

Statistical physics has its own rigorous definition of equilibrium, which has been applied so successful that the concept of equilibrium has become a corner stone of modern physics, chemistry, and biology. However, to many physicists, since market places and human society in general are phenomena of far from equilibrium, they believe that it is a mistake to apply the concept of equilibrium to study the market dynamics and human societies *(10).*

In short, from statistical physics to different branches of economics, there is no consistency about the concept of equilibrium. This paper asserts that economics is a subfield of physics. There must be a single universal definition of equilibrium applicable to all branches of economics and all fields of physics. Details will be published elsewhere.

5.3 Indeterministic Supply Demand Pricing Model (ISDP)

In this section, we apply FEOE to construct a new universal framework of supply, demand and market price without laws of supply and demand and market equilibrium. The new model is called indeterministic supply demand pricing model. We use the US housing market as an example. The framework presented here is applicable to all other markets.

In the FEOE framework, since the future supply (S), demand (D), and prices (P) are indeterministic, only the joint probability density function J(S, D, P, t) at time t is predictable.

The future supply S(t) has its own supply dynamics. The exact future supply is not predictable and only the probability distribution of supply is predictable. It depends on all factors related to future production including past, present, and future expectations of demand and price. In the US housing market, the housing supply comes from the new and existing home sells as well through the banks' and mortgage servicers' foreclosure, short-sells, and REO process. The housing supply dynamics changed dramatically before and after the 2008 great recession. It confirms the notion that it is impossible to forecast the future housing supply exactly.

The future demand D(t) has its own market demand dynamics. The exact future demand is not predictable and only the probability distribution of potential demand is predictable. It depends on all factors influencing consumer demand. In the US housing market, the housing demand depends the strength of overall economy, consumer confidence, mortgage financing, and recent housing price history whether it's bull or bear market. Consumer demand is very sensitive to consumer psychology.

The future price P(t) also has its own pricing dynamics. The exact future price at time t is not predictable and only the probability distribution of price is predictable. It depends on the pricing all factors related to future pricing including past, present, and future expectations of supply and demand. In the recent US housing, the housing prices went through a bull market between 1999 and 2006, a bear market from 2006 to 2012, and a recovery in 2012 and 2013. The experience by most housing market analysts during

the great recession is that the housing prices are largely unpredictable exactly. Despite it great importance of the US housing market, there were virtually no analyst in 2006 would foresee the US housing prices would drop 30% or more in the next three years.

With the three margin probability distribution functions for the future supply, demand, and prices, the joint probability density distribution function of J(S, D, P, t) at time t can be constructed as the final forecast by considering all relevant information available.

5.4 Concept of Market Equilibrium in FEOE

In the FEOE framework, market equilibrium is defined as the future joint probability density distribution function is independent of time, i.e., J(S, D, P) valid for all time t instead of time-dependent J(S, D, P, t). This definition of equilibrium is an application of law of equilibrium of physics laws of social science. It is one universal definition applicable to all fields of physics including all fields of economics.

In the FEOE framework, 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. I

Thus, in the FEOE framework, 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.

In essence, 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.

5.5 Derivation of Laws of Supply and Demand from FEOE

The tradition framework of laws of supply and demand and market equilibrium is a special case of a more general ISDP model.

There is a relationship between the average supply <S> and price P. For given price P and time t,

$$< S > = \iint S\, J(S, D, P, t) dSdD \;/\; \iint J(S, D, P, t) dSdD$$

The average supply and price relation is similar to law of supply except that here supply curve could take any shape depending on the market condition. For example, in the US housing market, at the December of 2006, if the housing market was forecasted for the end of 2008, if the housing price continued to rise relative to 2006, the supply curve would be positively sloped; however, if the housing price dropped, the supply curve would be negatively sloped because the rise of housing supply due to the foreclosure and short sells.

Similarly, there is a relationship between the average demand <D> and price P. For given price P and time t,

$$< D >= \iint D\, J(S,D,P,t) dSdD \;/\; \iint J(S,D,P,t) dSdD$$

The average demand and price relation is similar to law of demand except that here demand curve could take any shape depending on the market condition. For example, in the US housing market, at the December of 2006, if the housing market was forecasted for the end of 2008, if the housing price continued to rise mildly relative to 2006, the demand curve would be negatively sloped; however, if the housing price dropped, the demand curve would be also positively sloped because the unusual severe recession and the bearish housing market could easily scare buyers away.

Many tradition economic models start with the construction of supply and demand curves. We have shown how to use an ISDP model to build supply and demand curves scientifically. Without the assistant of an ISDP model, it is certain that it is impossible to quantify the supply and demand curve scientifically. Therefore, one important conclusion of this paper is that most economic models based on the marshallian cross are no more than handwaving arguments and cannot be considered as quantitative models without the assistant of ISDP models despite their quantitative appearance.

To summarize, FEOE offers a straight forward and realistic description of the market price, supply and demand dynamics. The FEOE approach is universally applicable for all markets while the framework of laws of supply and demand and market equilibrium is reserved for some special markets. Laws of supply and demand are valid only in special cases as statistical relationships.

5.6 Importance of Analyzing Inventory in Microeconomics

In a market-based economy, most markets carry inventories. For markets like housing, auto, labor, daily supplies in supermarkets, diamond, gold, silver, oil, gas, other commodities, stocks, and bonds, analyzing inventory is often the key to study the market dynamics in microeconomics.

Strangely, most standard economy textbooks [8] rarely talk about inventories. Why? It is simply because the existence of inventory almost invalidates the entire framework of laws of supply and demand and market equilibrium.

Existing inventory in a market simply means that supply always greater than demand, and therefore in reality, there is no such thing as the market equilibrium defined as supply equals demand. One might attempt to fix the problem by re-defining the market equilibrium as production equals demand. However, the fact that production equals to demand would only mean the stable inventory not the market equilibrium defined as supply equals demand. With the existence of inventory, the pricing changes in a far more

complicated fashion than laws of supply and demand would conclude. For example, when the potential supply is greater than the potential demand, the market price could rise, stable, or fall. When inventories run low, suppliers may or may not choose to raise prices even though supply is always greater than demand. Inventory would damp the pricing impacts due to small changes in production and consumer demand. The central tenet of Marshall's cross diagrams is the intersection of supply and demand curves. Because inventory means supply is always greater than demand, the existing of inventory means that the supply and demand curves will never cross.

Take the US automobile market as an 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 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.

With the existence of the inventories, the market dynamics is usually dominated by the inventory dynamics. When both the inventories and the spare production capacity are very high, such market condition is often called the buyer's market. The producers could choose to low the prices to attract more buyers. On the other hand, when both the inventories and the spare production capacity are very tight, it is often called the seller's market. The producers could choose to raise prices to damp the demand. Between the buyer's market and seller's market, there is an inflection point and a relatively stable state where small fluctuations in inventory, production, demand, and price would not result substantial changes in the market dynamics. Essentially, the inventory mechanism is serving as the market buffer and stabilizer. Since all these observations are empirically verified endless times as our parts of daily experience, we can understand the market dynamics perfectly well without using the flawed concept of market equilibrium. Therefore, because supply is always greater than demand with the existing of inventories, the framework of laws of supply and demand and market equilibrium are pure theoretical constructions like fairy tales. While in the real life, most markets carry inventories.

In an ISDP model, inventory or a waiting list is a natural behavior of the market. An ISDP model would simply treat the inventory as a state variable of supply. As a special case, the market could reach a steady state with stable inventory, production, demand, and price. In the US existing housing market, the inventory and its turnover are certainly the most important variables every real estate profession is watching very closely for any clue of the future market direction.

In short, because inventory is such an inconvenient truth to traditional economic theories, most standard economy textbooks have chosen to ignore one of the most important features of a real market economy.

5.7 A Side-by-side Comparison between ISDP and Traditional Models

In this section, we will do a side-by-side comparison between an ISDP model and a tradition standard model based on the framework of laws of supply and demand and market equilibrium.

(1) An ISDP model is a scientific forecasting model dealing with the supply, demand and pricing at any time of the future while a tradition model is a point analysis in the past if used for the purpose of the history interpretation, or a forecast of one point of the time in the future or the static future.

(2) An ISDP model emphasizes modeling of the dynamics of real markets. A tradition model is static.

(3) An ISDP model is universally applicable for any market in the real world. Strictly speaking, a traditional model could only work for the perfectly competitive market which is a fairy tale and does not exist in the real world. In order to handle the real market reality, a large set of new concepts must be invented to patch the logical inconsistencies and contradictions with observed facts, such as imperfectly competitive markets, sticky price, supply shocks, demand shocks, exogenous shocks, serial equilibria, Keynesian new equilibrium, disequilibrium, luxury goods exception, investment products exception, Giffen goods, Veblen goods, etc.

(4) An ISDP emphasizes the uncertainties in the future supply, demand, and pricing with a keen interest of tail risks. A traditional standard model works mechanically and does not handle uncertainty.

(5) An ISDP model is quantitative while a tradition model is quantitative only superficially because of the difficulties in constructing the supply and demand curves accurately.

The starting point of an ISDP model is the construction of the future probability distribution functions of supply, demand, and pricing. These are basic and most important aspects of any market analysis. Then a full ISDP model can deal with the joint probability distribution function, which is much more complicated mathematically. A tradition model starts with the construction of supply and demand curves, which does not exist in the real world unfortunately because fixing demand and price does not deterministically produce a fixed supply in contrast of the supply curve, and fixing supply and price does not automatically produce a fixed demand in the real markets because consumers has free wills after all. Therefore, without the assistance of an ISDP model, it is very hard to quantify the supply and demand curves in reality with any accuracy. For example, for a simple market like the gold market, who could quantify the tomorrow's supply and demand curves for some degree of confidence? The different starting points make a big difference in practice.

(6) An ISDP model is a falsifiable forecasting model. A traditional model can be formulated as a falsifiable forecasting model. However, because a traditional model is a deterministic model, it makes forecasts with 100% certainty about indeterministic human behavior, and its forecasts are almost always wrong.

For example, for tomorrow's closing gold price and the trading volume, it is very difficult to produce a quantitative Marshallian cross diagram model. Even when the model is constructed, whatever produced by a deterministic traditional Marshallian cross model about tomorrow's closing gold price and the trading volume are almost always wrong. That is one reason why economic forecasters have gained such poor reputations over years, and virtually no gold trading desk would ever use a quantitative Marshallian cross diagram model for the market analysis, trading, or risk management.

On the contrary, in the gold market, the tail risk distribution from an ISDP model is widely used by investment banks and trading desks for the risk management purpose. The probability distribution of gold price from an ISDP model is widely used for the valuation of gold derivatives like options by investment banks and trading desks.

(7) A traditional standard model cannot handle the inventory. However, in reality, inventory universally exists for most markets, and the inventory dynamics is often the most important part of a market analysis.

(8) A traditional standard model incorrectly characterizes the market equilibrium condition as supply equals to demand. In the FEOE framework, 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.

(9) With a universal model like ISDP model, it is easy to see where a traditional standard market equilibrium model goes wrong. First the traditional model ignores the indeterministic nature of buyers and sellers. If the supply, demand, and prices are indeterministic, there are no simple supply and demand curves. Second, the traditional model ignores the existing of inventory. If there is inventory, supply is always greater than demand. There will no market equilibrium characterized as supply equals demand, and there is no Marshallian cross. Third, the traditional economic model assumes incorrect deterministic causalities in terms of laws of supply and demand to describe the complicated relationships among supply, demand and prices.

For people live in a market economy, the markets are the most basic and familiar phenomena in our everyday life. It is a sad fact that the traditional economics could not model such simple phenomena correctly for hundreds of years. That is one more reason why we need FEOE.

6. Flaws in Macroeconomic Models Based on General Equilibrium Theory

From FEOE analysis of the market price, supply and demand dynamics, we have concluded that markets in general are not in equilibrium, and laws of supply and demand are poor description of the general market behavior.

Although general equilibrium theory *(8)* has been widely regarded as one of landmark achievements of modern economics, general equilibrium theory is not compatible with FEOE. There are many fundamental problems with general equilibrium theory. Unfortunately many macroeconomic models are built on the central idea of general equilibrium, aggregate supply and aggregate demand, and laws of supply and demand. These models are deeply flawed for several reasons:

(1) The main objective of macroeconomic modeling is to forecast the short-term economic growth fluctuations and long-term growth potentials. The world "growth" is key to describe the economic reality. If the main tool is based on the concept equilibrium where everything variables is static or close to static, it's not a coherent picture of economic reality. It should be obvious to any observers that a growing economy is not in equilibrium in the long run, and economics suffering boom or bust cycles is not in equilibrium in the short run. If the real economic are not in equilibrium, the equilibrium based models are not likely to work well.

(2) The general equilibrium theory generally ignores the economic reality by assuming perfectly competitive markets. In reality, few markets can be described as perfectly competitive or in equilibrium. For example, US housing market, a key consumer market, does not remotely fit with the idealized competitive market or in equilibrium.

(3) A good macroeconomic model should be built on economic reality and how economic reality evolves in the future. In FEOE framework, the economic reality is the balance sheets of the existing economics. General equilibrium macroeconomic models generally ignore the balance sheets of the existing economics. For example, how many DSGE macroeconomic models built in toxic CDOs and the high leverage of Wall Street banks before the great recession of 2008? Without examining the balance sheets of high tech firms and telecom industries at 1999, how could macro models built in the over investments during the dotcom boom. Without looking at the subprime mortgage quality at 2006, macro models are unlikely to forecast the massive defaults in the following years.

(4) A good macroeconomic model should describe correctly the key economic dynamics. General equilibrium macroeconomic models built upon the flawed idea of laws of supply and demand. It is important to realize that laws of supply and demand sometimes work and sometimes do not work. For example, many economists have warned the runaway inflation after the great recession of 2008 because the excessive money supply by the Federal

Reserve. It did not happen that way. The excessive money supply produced below average inflation. In this case, the law of supply did not work. A reliable macroeconomic model cannot start with sometimes so shaky.

(5) General equilibrium theory is characterized by Pareto optimal efficiency. However, the real economy efficiency is achieved by both Pareto efficient actions like free trade and non-Pareto efficient actions like downsizing work forces.

(6) In a real economy, the general goals of households, firms, and other organizations are not to achieve Pareto efficiency. Instead, the general economic goals of most economic players are to maximize their wealth through voluntary exchanges and cutting costs to improve economic efficiency including the reduction of the workforce. As discussed in earlier section, FEOE offers its own version of explanation of the economic invisible hands. Since money as be viewed as socialized free energy, the maximizing the overall wealth of an economy is equivalent to maximize the free energy. Therefore, economic invisible hands share the same dynamics of other invisible hands in other branches of science such as condensed matter physics.

(7) As forecasting models, static general equilibrium models have been performing poorly as pointed out by Hicks *(11)*. While they are better than static ones, dynamic general equilibrium models like DSGE also performed very poorly during the great recession while simpler accounting models performed remarkable well *(12,13,14)*. In the end of day, in any field of science, it is accuracy of forecasting that separates a good economic model from bad models.

In conclusion, a good macroeconomic model should be built on rock solid foundation of FEOE, and it deals with the economic reality instead of the unreliable framework of law of supply and demand and general equilibrium. Law of supply and demand and general equilibrium are not necessary to macro models, and do not add anything new insights to understand how macroeconomic works.

We can derive a new macroeconomic model called indeterministic balance sheet plus (IBS+) model from FEOE. The details will be published elsewhere. The applications of the new macroeconomic models to analyze the Chinese economy and US economy will be published in other papers.

7. Importance of Analyzing Inventories in Macroeconomics

After rejecting the general equilibrium theory in previous section, various inventories in economy emerge as key variables determining the growth and fluctuations of macroeconomics. As we discussed earlier, the existence of inventories almost invalidates the framework of laws of supply and demand and market equilibrium. In this section, we will show that analyzing the inventories is also critically important in macroeconomics.

There are many kinds of inventories in a market-based economy. In goods producing part of economy, inventories include both the physical inventories and the spare capacities of production. With the existence of inventories, the aggregate supply is always greater than the aggregate demand. The unemployment rate is a direct measure of inventory of the labor supply. There is a strong causality relationship between inventories and the inflation rate. In the money market, because the existence of cash can be viewed as a form of inventory of money for future consumptions and investments, the existing of money inventory means that saving is always greater than investment.

Once of most important empirical observations in macroeconomics is the Philips Curve, which represents the relationship between the inflation rate and the unemployment rate. The Philips Curve is the direct result of the inventory dynamics in the economy.

The central tenet of traditional macroeconomic models is the general equilibrium defined as aggregate supply equals to aggregate demand and saving equals investment. However, in reality, because the existence of inventories, the aggregate supply is always greater than aggregate demand, labor supply is always greater than labor demand, and saving is often greater than investment, many macroeconomic models based on the concept of the market general equilibrium become irrelevant.

In conclusion, when applying FEOE to macroeconomics, inventory emerges as one of the most important concepts of macroeconomics. A good macroeconomic model must be built upon the analyzing inventory dynamics of labor, money, physical inventories of finished products, and spare capacity under the framework of indeterministic future aggregate balance sheets. Details will be published elsewhere.

8. Some Applications of FEOE

In this section, we apply FEOE to examine some existing economic theories. As it turns out, FEOE comes with its own version of microeconomics and macroeconomics theories, which are different from existing theories in many cases, and the same in other cases.

In microeconomics, the framework of laws of supply and demand and market equilibrium is replaced by the indeterministic supply demand pricing (ISDP) model as described in previous sections.

The rational choice theory is not compatible with FEOE. The rational choice theory is replaced by a new universal choice theory to be published elsewhere. The rational choice theory works when assuming people are rational. However, the precise scientific definition of rationality does not exist. Take the chess game as an example. The chess players have ranking levels from the beginner to the world champion. What choices could be considered as rational or irrational in a chess game? Take travel salesman problem with large number of cities as another example, the extremely rational people could choose the unique optimal solution; average persons could be happy with sub-optimal solutions using approximation methods; less rational people could simply choose a solution randomly. The new universal choice theory based on physics laws of social science is equally applicable to well-educated and extremely rational scholars, average

persons, world champions, mad people, monkeys, or rocks. After all, studying the behavior of people with mental illness is a well-established medical science.

As discussed in previous sections, despite its historic importance, general equilibrium theory is not compatible with FEOE. The concept of market equilibrium is generally a poor abstract of the economic reality of the market dynamics. With the existence of inventory, unemployed labor, and spare capacities, the overall economy is not in an equilibrium characterized by the balance of aggregate supply and demand. In the FEOE framework, the general equilibrium model is replaced by the maximizing wealth principle.

In personal finance, FEOE implies a realistic and scientific sound way to manage financial wealth. Take playing lottery as an example. While many intelligent people refuse to play the lottery, yet nearly all of them are dreaming to be millionaires one day. With FEOE, it is very easy to see why one should play lottery with a limited amount of money because it increases your probability to become a millionaire in your lifetime. However, it does not mean you should spend a lot of money on lottery. As long as the amount is not a significant sum over your lifetime, the financial impact on ones' other activities will be minimum. More importantly, the same logic applies to ones' other economic activities like pursuing a career as a physician, lawyer, trader, investment banker, or CEO, saving, investing, or starting a new business. What FEOE teaches is that the probabilities can be estimated scientifically and that future probabilities can be manipulated by ones' actions. Therefore, with FEOE, you actually can have a realistic and scientific sound way to become a millionaire or billionaire. It is all in probabilities. Even better this is all physics!

In consumer finance, one of central questions facing banks and other financing institutions is how to predict which customers will voluntarily prepay their debts like mortgages, voluntarily or involuntarily stop paying debt obligations. Analyzing problems with empirical data and FEOE, we reach a surprising conclusion that there is a fundamental limit how well a model can forecast consumers' voluntary and involuntary behavior. This fundamental limit can be traced back all the way to Heisenberg uncertainty principle in quantum mechanics. Therefore, this fundamental limit is important in both physics and economics. The existing this fundamental limit greatly constrains the choice of the forecasting models because any deterministic models like multiple variable linear regression models must be avoided. Details of this research will be published elsewhere.

In game theory, FEOE agrees with many game theory analyses *(15, 16)* with probability theory. The equilibrium concept in game theory is largely consistent with law of equilibrium. However, FEOE is fundamentally different from traditional game theory. One key assumption of the game theory is the rational choice theory, which is not compatible with FEOE. In the framework of FEOE, the future probability of a game in the real world is precisely defined while it is somewhat arbitrary given in game theories. Therefore, in real life, human and society behavior could be far away from Nash

equilibrium solutions proposed by traditional game theory *(17).* Take rock paper scissors game. FEOE gives you scientific guidance: 1) People have free wills. Don't be so sure you can guess how others will move. That is laws of physics; 2) On average, you cannot lose if you could use or mimic a quantum random number generator; 3) FEOE assures you that the probability how others moves is precisely predictable. Therefore, the key is to think in terms of probabilities. The same logic applies to other games. Essentially FEOE uses the special version of probability theory to study game theory and equilibrium. Although many economists regards game theory as the theoretical foundation of economics, the difference between FEOE and game theory regarding the future probability shows that FEOE is the true foundation of economics and game theory is an useful analytical tool only when the assumptions are consistent with FEOE.

In financial economics, FEOE is compatible with option pricing theory. However, FEOE is a more general approach than the Black-Sholes formulation. FEOE invalidates the popular Modern Portfolio Theory and Capital Asset Pricing Model. Details will be published elsewhere.

In financial markets, one most difficult problem in recent years is how to price a CDO with mortgage, corporate, or muni bonds. The Gaussian copula pricing models of CDOs were widely blamed as one of the major causes of the great recession. Despite the poor reputation of copula models, FEOE confirms that the copula functions are the correct approaches to the CDO pricing because copula functions are closely related with general JPDFs. However, FEOE advises not to use Gaussian copula in general. There are hundreds other copula and there are many ways to build your own copula functions. This more general approach works well before, during, and after the great recession of 2008. FEOE are useful for other financial market theories like risk management. Details will be published elsewhere.

In corporate finance, FEOE works naturally with balance sheets analysis. The only difference between FEOE and traditional balance sheet analysis is that FEOE emphasizes more on the indeterministic nature of future evolutions of corporate balance sheets.

In government financing, FEOE sees no difference between public financing and private corporate financing. Strict accounting standards required for most corporations should be required more all government institutions. In terms of fiscal policies, the government budget deficits have been key controversial issues among economists. FEOE and PLSS offer a surprising value-free physics permanent solution to government budget deficit problem. The new solution greatly limits the usefulness of Keynesian active fiscal policies. Details will be published elsewhere.

In political economics, the public choice theory *(18)* is generalized into a broad framework of quantum politics, which will be published elsewhere. While quantum politics shares many concerns of conflicting interests of elected public officials with the public choice theory, quantum politics has a more broad scope of replacing the entire traditional political science. In other words, politics is also a branch of quantum physics

like economics and chemistry. Quantum politics largely rejects the constitutional economics *(19-22)* as a valid approach. Detailed analysis shows that many key constitutional principles are deeply rooted in laws of physics. The traditional economic approach of the rational choice, incentive, and utility are generally too narrowly focused to be useful for studying the constitutions. For example, the principle of separation of church and state is a reflection of the important relationships between science and religion, which is well beyond the scope of the traditional economics but well within the scope of PLSS.

In macroeconomics, FEOE translates into the Indeterministic Balance-Sheet Plus (IBS+) model and rejects popular DSGE models and Agent-based Computational Economic (ACE) models. FEOE is fully compatible with national account system. IBS+ models can be viewed as a natural extension of current and historic data captured in national account system. The new model emphasizes the inventory dynamics of goods, spare capacity, labor, and money in the framework of indeterministic balance sheets. Details will be published elsewhere.

To summarize, FEOE is compatible with many existing economic theories like option pricing theory and national accounting system. FEOE elevates these compatible theories to be permanent features of quantum economics. In other words, these compatible theories will be parts of economic theories forever in the same way the Maxwell equations will be permanent parts of physics. Those questions addressed by these compatible theories should be regarded as settled once for all. One of most important applications of FEOE is to decide whether an economic problem is settled or remains open.

After reviewing existing economic theories, FEOE is not compatible with many existing theories like rational choice theory, DSGE models, modern portfolio theory, and general equilibrium theory. These theories incompatible with FEOE will be thrown into historic dustbins. One great strength of FEOE is that not only FEOE attacks the existing economic theories but also one can derive relevant theories from FEOE to replace these abandoned theories. Although many economic theories incompatible with FEOE are very popular among mainstream economists and standard economic textbooks, we must abandon these theories because these are theories that prevent economics from becoming a true science. As discussed in earlier sections, if economics is a true science, laws of supply and demand must be downgraded into statistical relationships. Many economists regard the law of demand as an axiom. However, law of demand means that people does not have free wills, and of course people have free wills.

One outstanding feature of shared by FEOE compatible theories is that they are universally applicable in analyzing the economic reality. National accounting system is applicable to all economic entities. General option pricing theory is applicable for pricing any optionality in economics and other social sciences. An ISDP model is applicable to analyze any market. The universal choice theory is applicable for any choice made by rational and irrational human, animals, and even radioactive atoms. An IBS+ model is

applicable for all economic entities. In other subfield of physics, a fundamental model like the Newton's laws of motion and Maxwell equations are universally applicable within its well-defined boundary. Therefore, if economics is truly a subfield of physics, it is perfect reasonable to require the same universal applicability from basic economic theories and models. The reason why FEOE is useful is exactly because FEOE offers such universality for all economic phenomena.

On the other hand, those economic theories that are rejected by FEOE are not universally applicable. The framework of rational choice theory requires people to act always rationally. It is widely known that the general equilibrium theory requires a set of very strict and unrealistic conditions. A DSGE model requires exogenous shocks, unrealistic rational choices, micro-foundation, and general equilibrium theory. It is very difficult to extend DSGE models to developing or undeveloped markets like China and North Korea.

To summarize, FEOE offers its own version of microeconomics and macroeconomics. Although FEOE is a strange equation because the human behavior is very different from other physical objects, it should be no doubt this FEOE is real and useful in all branches of economics.

9. Unifying Different Schools of Economic Thoughts

In last 400 years, different approaches to economic problems have created many different schools of economic thoughts. In comparison, over the same time period, there is only one school of thought survived the endless experimental tests and theoretical scrutiny in physics, which is the Newton-Einstein-Bohr physics.

One key assertion in this paper is that economics is a branch of quantum physics like chemistry and optics. The logic conclusion is that different schools of economic thoughts must be unified into one single framework of Newton-Einstein-Bohr economics. Nobody is entitled to their own physics or economics.

Many economic problems are about "what ought to be done". Normative economics is often involves the value-based arguments. It is important to realize that the value-based arguments will be never totally replaced by science. In physics, engineering problems cannot be solved completely by value-free science. In that sense, the different schools of economics could still exist as different philosophical schools of values in the future.

FEOE is the universal starting point of solving all economic problems. By recognizing economics as a branch of physics, it transforms the traditional economics consisting of many schools of thoughts into a single coherent framework based on FEOE.

10. Concluding Remarks

Since Issac Newton discovered the laws of motion in 1687, for the next 300 plus years, physics has achieved great successes in describing the microscopic world of elementary particles to the large scale structures of the universe. It has become dreams of many generations of social scientists to replicate the success of physics in describing

human society. Establishing physics laws of social science and fundamental equations of economics are firm steps towards realizing those dreams. These papers are just the very beginning. There are many questions remaining to be answered. For example, the mathematics of joint probability distribution functions is exceedingly complicated and challenging when many assets are involved. The science and art of making approximations and simplifications remains largely unexplored.

11. Reference and Notes

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