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Extensive Quantum Economics: Wave-Cycle, Wave Function, Uncertainty and Quantum Statistics

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ABSTRACT: First, we research basic equations of the extensive quantum theory. Second, based on the extensive quantum economics, we propose wave-cycle and wave function. Third, we discuss the uncertainty of extensive quantum economics. Fourth, according to the extensive quantum statistics, the extensive quantum economics should be divided three types: BE economics, FD economics, mixed economics. Fifth, the input-output model corresponds to Heisenberg equation and S theory. Sixth, we search knowledge economics and its four theorems, and e-market. Seventh, we discuss some other mathematical methods in economics. Human society and economics are very complex, and the extensive quantum economics only provides a new research method and a possible development direction.

Key Words*: economics, quantum, wave function, uncertainty, statistics, input-output model, knowledge, mathematics.*

I. INTRODUCTION

Economics is the social science that studies the choices that individuals, businesses, governments and entire societies make as they copy with scarcity and the incentives that influence and reconcile those choices [1].

Mankiw defines that economics is the study of how society manages its scarce resources [2]. Keynes described the economic problem as the "struggle for subsistence", in other words the problem of meeting everyone's basic needs. Mankiw proposed ten principles of economics [2].

Bernard Schmitt and A. Qadir earliest proposed quantum economics [3]. Then Schaden and Baaquie researched quantum finance [4,5], in which the market has its own uncertainty principle. Orrell proposed the quantum economics, whose research shows that money exhibits quantum properties such as duality and entanglement, etc [6].

Based on the extensive quantum theory and combining Orrell's quantum economics [6], we proposed the extensive quantum economics and its three fundamental principles: duality, uncertainty principle and extensive statistics. Such we may apply quantum principles, theory and mathematical equations to economics. The corresponding Schrödinger equation and its potentials are studies, in which different potentials correspond to different economic policies and development models in quantum economics, and form different results and varying energy levels. Further, we discussed some economic models, such as the nonlinear theory of economic growth, the multiply connected topological economics and so on, and proposed a specific prediction method. Since quantum theory has rich mathematical and physical contents, so the extensive quantum economics not only may be applied to many economic regions, and theory may be corrected and developed [7]. In this paper, we propose basic equations of extensive quantum economics, and research wave function, uncertainty, quantum statistics, and input-output model.

II. BASIC EQUATIONS OF EXTENSIVE QUANTUM THEORY

Based on the extensive quantum theory, we proposed that energy and momentum are:

$$E = H\nu, P = H/\lambda . \quad (1)$$

Assume that the wave function is:

$$\psi = A\exp(ip_\mu x_\mu / H) = A\exp[i(pr - Et)/H] . \quad (2)$$

Such we obtain that the momentum-energy operators are:

$$p_\alpha = -iH\frac{\partial}{\partial x_\alpha}, E = iH\frac{\partial}{\partial t}. \quad (3)$$

From $E = (p^2/2m) + V$ we derived the extensive Schrödinger equation [8,9]:

$$iH\frac{\partial \psi}{\partial t} = -\frac{1}{2m}H^2\nabla^2\psi + V\psi. \quad (4)$$

Its time-independent Schrödinger equation (H=1) is:

$$\frac{d^2\psi}{dr^2} + 2m(E-V)\psi = 0. \quad (5)$$

We have calculated the different man, cell and macromolecule quantum systems between Bohr atom model and Solar system [8,9]. By using similar method we can calculate various quantum systems between the solar system and man.

The average distance of sun-earth is $1.495985\times10^{11}m$, the height *2.8136m* of a mankind house. Both middle value is $6.488\times10^5 m$. It is a scale on small country or big city.

The corresponding quantum constant $H = (aGM_O)^{1/2} = 9.1317\times10^{14} m^2/\sec$. For man the quantum constant is $H_1 = 7.5876\times10^3 m^2/\sec$. The middle value of both quantum constants is $H_2 = 2.6328\times10^9 m^2/\sec$.

The earth mass is $5.977\times10^{24} kg$, human weight is *57.678kg*. Both middle value is $1.857\times10^{13} kg$.

In the extensive quantum economics [7] individual behavior, etc., as particles correspond to microeconomics, while some fields as waves, holism and entanglement correspond to macroeconomics.

III. WAVE-CYCLE AND WAVE FUNCTION OF EXTENSIVE QUANTUM ECONOMICS

Based on the social structure we proposed the social individual-wave duality, which describes the social changes with a tendency after a tendency [10].

Economic development and prices in market economy have all wave property. The spectral density function can analyze and characterize economic fluctuations and economic cycles.

The Schrödinger equation with the linear potential V=Fr shows the wave form [7].

Economics and sociology can define functions and function spaces. A function space is often a normed space X, whose elements are some functions with definition fields and value fields. The vast majority is still the Banach spaces. The norm ||f|| of function f in X measures size. This can be compared, such as the happiness index, etc.

Further, we combine the wave-cycle in economics, and may introduce the wave function of economics. The social and economic wave function determines the state and probability of the systems including people, and the wave function collapse is the decision.

Based on the wave function in economics, we can logically introduce various corresponding quantum theories and equations in quantum economics.

According to the correspondence principle and Ehrenfest theorem $d\hat{p}/dt = -\nabla V = \hat{F}$ corresponds to Newton mechanics and $p = mv = Ft$. It is similar completely to MV=PY in the quantity theory of money. Here M is money, V denotes velocity of circulation, P represents price, and Y stands for real income. PY is the nominal income [11].

In quantum mechanics, wave packets will diffuse with time, which may correspond to inflation. Both phenomena are inevitable. But, if the diffusion is too rapid, the system will become unstable.

IV. UNCERTAINTY IN EXTENSIVE QUANTUM ECONOMICS

The uncertainty principle [12,13] governs both macro and micro scales, with equilibrium being transient. Money is a classic measure of uncertainty [6].

Both behavioral economics and psychology have sequential effects, which are the non-commutation in quantum theory:

$$p_\alpha x_\beta - x_\beta p_\alpha = iH\delta_{\alpha\beta}. \quad (6)$$

This leads to the uncertainty principle.

Wave derives uncertainty, which is originating from the quantum fluctuations. Maybe for different countries, different fields can have different waves, wavelengths, frequencies, and H. For the macroeconomics and the microeconomics are also different. Thus they introduce different wave functions, operator representations and equations (1)-(5).

In electromagnetic field the extensive Schrödinger equation is:

$$iH\frac{\partial\psi}{\partial t}=[\frac{1}{2m}(-iH\nabla-\frac{q}{c}A)^2+q\varphi]\psi. \quad (7)$$

Energy levels are still:

$$E_n=H\nu(n+\frac{1}{2}), \text{ n=0,1,2,…} \quad (8)$$

Bundling and cooperation may correspond to multiple fields. In magnetic field Zeeman effect divides into 3 sections: positive-inverse-general. Usually, the stronger the outfield, the easier it is to follow.

V. QUANTUM STATISTICS AND CLASSIFICATION OF EXTENSIVE QUANTUM ECONOMICS

It is well-known that quantum statistics includes Bose-Einstein (BE) and Fermi-Dirac (FD) statistics, both numbers of particle are [14]:

$$dN=\frac{gd\tau}{e^{(\varepsilon-\mu)/T}\pm1}. \quad (9)$$

In the statistical system, the general elements have no interaction g=0. It corresponds to the ideal gases, and the absence of interaction between molecules [14]. Based on in FD statistics the quantum exchange effects lead to the occurrence of an additional effective repulsion between the particles, and in BE statistics there is an effective attraction between the particles. Further, we discussed the extensive quantum statistics (EQS) and general relations with various interactions [15]. For attraction g>0, for repulsion g<0, the entropy increase should be extended. EQS is probably ±1→±n.

Statistics is applied when interactions exist. So statistical mechanics corresponds and is extended to interactions. Such quantum statistics may be applied to chemistry, biology, astronomy, geoscience, social sciences and so on.

If some interactions cannot apply statistics, they will be a correspondence:

The extensive BE statistics because BEC correspond to the attraction, and similar to opposite charges and the interaction of various attractions, such as strong interactions and Van der Waals (VdW) forces.

The extensive FD statistics because Pauli Exclusion Principle (PEP) correspond to the repulsion, and similar to same charges and various incompatible things, such as weak interactions and decay.

Statistical unity corresponds to strong-weak micro unity [16,17], and distance scale unity.

Further, the extensive statistics are extended to general systems, in which opposite attracts, and same repels; and high or low emotional intelligence.

There are three types of statistics: 1. Similar BE statistics, mutual attraction. 2. Similar FD statistics, mutual repulsion. 3. It is variable between the two types, or is independent each other, or is Maxwell-Boltzmann (MB) statistics.

Many economic systems have randomness, for which the most similar physical theory is general quantum theory. Moreover, quantum entanglement may occasionally manifest.

According to the extensive quantum statistics, the extensive quantum economics and market should be divided three types: BE economics, FD economics, mixed economics.

Table 1. Statistics of Extensive Quantum Economics

BE statistics	BEC	Attraction each other (g>0)	BE economics and market
FD statistics	PEP	Repulsion each other (g<0)	FD economics and market
MB statistics	Not interaction	Independent each other (g=0)	Mixed economics

FD economics includes scarce resource, opportunity cost, monopoly market, and oligopoly, etc. BE economics includes early reciprocal economy, modern complementary economy and reciprocal strategic alliance, etc.

Statistics is usually used in econometrics. Different quantum statistics are used for different social systems, social compositions and interactions. We may research quantum statistics in social economics. Kings and certain positions are unique and necessarily incompatible, which need to use FD statistics. The free market agrees with MB statistics.

In quantum economics and quantum sociology statistics are divided into two categories: extensive bosons

are ordinary people, corresponding to democracy and equality. Extensive fermions are some special persons, such as the king, the dictator, etc.

Quantum economics and market can be divided into three types: BE economy and FD economy, and between the two may be MB economy corresponding to mixed economy and mixed market. The statistical distribution of the market determines the economy and society.

Quantum money is divided into gold finite corresponding to FD, paper money infinite corresponding to BE.

The assignment corresponds to the quantum, and the opportunity cost is mutually exclusive.

VI. INPUT-OUTPUT MODEL, HEISENBERG EQUATION AND S THEORY

In quantum matrix mechanics Heisenberg equation is:

$$\frac{dF(t)}{dt} = \frac{1}{i\eta}[F(t), H] = \frac{1}{i\eta}[F(t)H - HF(t)]. \quad (10)$$

Input-output model proposed by Leontief is a form of macroeconomic analysis based on the interdependencies between different economic industries for inputs (materials and intermediate goods) and outputs (final products). It may also represent the flow of money in an economy between industries.

The Leontief Input-Output Model as a pseudo-equation:

Total Amount Produced = Internal Demand + External Demand. (11)

This is given by:

$$P = MP + D. \quad (12)$$

Here the matrix *M* is the consumption matrix. The vector *P* is the production vector. The vector *D* is the external demand vector. The vector *MP* is the internal demand vector. An economy is closed if *D* = 0 and open if $D \neq 0$. From this we derive

$$P = (I - M)^{-1} D. \quad (13)$$

The input-output model and Heisenberg equation apply the linear algebra, which may have different eigen values.

In fact, the input-output model corresponds completely to the S-matrix theory as a formal device for describing the connections between all possible reactions, consistent with known conservation laws, which can be associated with a given group of particles. Its form is primarily determined by two physical requirements: Conservation of flux, and time-reversal invariance [18]. Here particles correspond to different elements in the extensive quantum economics.

Matrix mechanics corresponds to Hilbert space. This may have n-dimensions, which correspond to many elements in economic systems.

The Black-Scholes-Merton option pricing model is actually the financial version of Schrödinger wave equation, which is a special example on “market is extremely unstable and effective” [19].

Quantum fluid mechanics [20] corresponds to the flow of money, capital, talent, etc.

VII. KNOWLEDGE ECONOMICS AND ITS FOUR THEOREMS, AND E-MARKET

A production function in the classical economy is $Y = F(K, L, X_i)$. New epoch of knowledge economy shows a new paradigm of economic growth. Based on the main characteristics of knowledge economy and its similarity with the information theory, we proposed the four theorems of the knowledge economic theory [21,22]:

1).The innovation theorem by talented persons. The knowledge economy is innovative economy, in which talented persons are the most important. Labor and capital will fall to second roles.

2).From zero to things theorem. This is a process of information translated into substance and wealth. Its mathematical representation is $\int 0dT = C$.

3).The increment theorem by cooperation. A main character is networking in knowledge economy, which must emphasize cooperation in a system. For the economic development it includes an exponential change law $F = Ce^{at}$, here the innovative index *a*>0. This may mathematically apply the Haken’s synergetics.

4).The continuous cycle theorem. The output of knowledge economy possesses very high scientific and technological content, so it is light and corresponding waste is also little. This theorem includes two aspects: (1) Since the capital is smaller, so that the required natural resource and corresponding waste are also very little, therefore, it is a model of sustainable development. (2) Much riches may be created due to talented persons, and capital can attract more talented persons, such it will enter a fine cycle. This can use Eigen’s hypercycle.

These theorems are also a developed process, in which theorem 1 is basic, which corresponds the human capital investment in neoclassical growth model, and other theorems are some results of innovation and development.

For the epoch of knowledge economy, knowledge is first in various bases, talented person is first in various resources, innovation is first in various developments, and cooperation is first in various managements. Its precondition is a right decision-making, which requires confirming a developed mode and a choice function. The talented person is only an order parameter for the new epoch. The production function will be simplified to an approximate single variable function Y=F(T). It is the most important mathematical character on knowledge economic theory. The talented person is a mostly stanchion, and knowledge and information are the most important and the essential production factors. The worth of knowledge is a scale of developed level on the microscopic knowledge economics. The innovation is a core and spirit, and is not a simple clone and expanded reproduction.

The basic mathematical model for the knowledge economy is nonlinear theory. In this case, the Cobb-Douglas production function [23,24] $Y = AK^{\alpha}L^{\beta}$ will become to $Y = BT^{\alpha}$, in which α is an index on the talented person, and it includes the amount and quality of talented person, and α =0 is a point of phase transformation.

Assume that the quantum equation (4) of time component for *V=ia(t)* is simplified:

$$iH\frac{d\psi}{dt} = ia(t)\psi . \qquad (14)$$

Its solution is:

$$\psi = C\exp[\frac{1}{H}\int a(t)dt]. \qquad (15)$$

When *a*>0, the economy will show an exponential growth [21]. We think that topology and its tools in this economy will exhibit larger function due to networking of the epoch.

Further, the knowledge economic theory should develop a model of the simultaneous algebraic or differential equations, which are probably applied to describe the macroeconomic configuration of the large system. The epoch of knowledge economy will really realize Francis Bacon's well-known maxim: Knowledge is power!

In economic topology, the economic equilibrium states are some stationary equilibrium regions in the static economics. The economic theory of knowledge economy combined new economics of sustainable development and the nonlinear theory of economic growth will be able to form the nonlinear whole economics [22].

The e-market and AI are classical knowledge economy. For this the fixed cost of production information is more expensive, but the marginal cost is lower, and the cost of information replication and transmission is very low [11]. Eq. (8) represents the jump on the increase in profits. It is easy to produce a monopoly economy. The prediction will lead that the functional income distributions have more difference, more polarization and unemployment. The solving methods are more taxes and more training.

VIII. Some Mathematical Methods in Economics

Economics and ecology is often a cycle, and includes 2-dimensional circular flow between home and business and 3-dimensional circular flow among home-business-government [24]. This may correspond to the torus, which has n holes, i.e., genus n. It corresponds to the multiply connected topological economics [25-28].

Mathematics of quantum and corresponding economics may include various groups, such as permutation groups and rotation groups, SU(N), SU(2,3), SO(n), U(1) corresponds to the electromagnetic field.

Three major characteristics of the quantum theory are superposition, measurement and entanglement.

In superposition the quantum bit (qubit) has infinite states, and a variety of corresponding particles. Not the bit is either black or white. Complex numbers are introduced in the extensive quantum, and have two basic set, i.e., 1 and i, correspond to x-y, etc. $|a|^2 + |b|^2 = 1$ invariance seems correspond to energy conservation. It can develop to x-y-z…n dimensions in Hilbert space.

The measurement lies in the true randomness.

Entanglement and its generalization is the network. Quantum economics may use quantum computation, and should be quantum random sampling, only can predict probabilities. It may realize quantum advantage.

Different energy bands correspond to the isolation between economic levels, cultural educations, and social status. Equal or similar status can correspond to conductor; too far apart each other, corresponding to insulator. Various extensive quantum theories (economic, social, biological systems) correspond to different energy-momentum (1), and determine the wavelength and H.

In microeconomics the behavioral economics is based on rational economic man, which corresponds to ideal particles in classical physics. There are many similarities between our behavior and the principles that the particles follow. Personal behavior is similar to the quantum fluctuations of particles, and should be based on conformity convergence in electromagnetic fields. It should be based on quantum logic, namely the environment,

education, etc.

From the perspective of economics, Hong introduced the economic interpretations and applications of some basic concepts, ideas, methods and tools in probability and statistics. Examples include subjective probability, cumulative distribution function, stochastic dominance, mean and variance, law of large numbers, statistical significance, spectral analysis of time series, etc. Economic applications consist of rational expectations, depicting income inequality, efficient market hypothesis, capital asset pricing model, financial derivatives pricing, risk management, model risk, measuring economic causal relationships, identifying economic cycles, and macroeconomic interval management. These examples and applications are helpful in understanding the importance and usage of probability and statistics in economic research and analysis [29].

Modern economics mainly studies the efficient and fair allocation of limited scarce resources under uncertain market conditions. The best mathematical tool to describe uncertainty, the risks caused by uncertainty, and the decision-making behavior of economic subjects in an uncertain market environment is probability theory. Econometrics is the most important methodology of empirical research in modern economics, and its mathematical basis is probability theory and mathematical statistics.

The market is unpredictable, and corresponds to the efficient markers. Vines and Wills think that the dynamic stochastic general equilibrium model has two key assumptions: efficient markers hypothesis and rational expectation [30].

There are several constraints in economics, ecology and sociology, and related to optimization and Lagrange multipliers, such as the environment in ecology, morality in sociology, etc. Wealth has an upper boundary, and can be added. Ecology and life have upper boundaries and limits.

Freeman developed proposed stakeholder theory to systemic strategic management, which not only shall be responsible to the shareholders and to any group or individual that affects the enterprise or is affected by the enterprise in the process of achieving its objectives, and should develop a corporate culture. This is related to nonlinear economics, the multi-connected topological economics [31].

Enterprises are a place where individuals and groups are committed to mutual care, and their purpose is to promote each other and achieve unique human achievements [32]. Moreover, Ferber, French, Engster, et al., discussed economics closely related to sociology and moral behavior [33-35]. The typical examples of the care economy are enlightened landlords and the state economy. Geuss discussed public goods and private goods [36].

IX. SUMMARY

Based on the sociology of general relativity [37], we may research the general relativity economics, in which the bending of space and time determines economic behavior.

Based on the basic equations of the extensive quantum theory and the extensive quantum economics, we research wave-cycle and wave function, the uncertainty, the extensive quantum statistics and classify. The input-output model corresponds to Heisenberg equation and S theory. We search knowledge economics and its four theorems, and e-market.

In a word, both human society and economics are very complex, and the extensive quantum economics only provides a new research method and a possible development direction.

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