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Some Types of Economics: From Mathematics, Nonlinearity, Topology to Synergetics and Knowledge Economics

Yi-Fang Chang

Department of Physics, Yunnan University, Kunming, 650091, China.

***Corresponding Author**: Yi-Fang Chang

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Abstract

First, economics should be different types. Next, the mathematical economics is discussed. Third, we investigate the nonlinear economics, which includes the chaos economics. Fourth, we researched the topologic economics, which is related to corruption economics. Fifth, the economic theory of the knowledge economy era is searched. Sixth, the synergetic economics and the fractal economics are proposed. Seventh, methods of multinational enterprises are different economic systems. Many types of economics should be studied, such as the crisis economics.

Keywords: *economics, mathematics, nonlinearity, chaos, knowledge economics, synergetics, fractal.*

1. 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, and proposed ten principles of economics [2].

General economics study market, supply-demand relations and efficiency, etc. New types of economics include Environmental Economics, Psychological Economics, Crime Economics, Aging Economics, Multinational Enterprise Economics, and so on. While we don't fully agree with perspective of Hill and Myatt [3], there's no doubt that economics encompasses various distinct branches, and some of which are even entirely different from one another.

At present based on the extensive quantum theory and combining Orrell's quantum economics [4], 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. We 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 [5]. Further, we proposed wave-cycle and wave function, and discussed the uncertainty of extensive quantum economics. According to the extensive quantum statistics, the extensive quantum economics should be divided three types: BE economics, FD economics, mixed economics. The input-output model corresponds to Heisenberg equation and S theory. Human society and economics are very complex, and the extensive quantum economics provides a new research method and a possible development direction [6]. In this paper, we investigate some types of economics, such as the mathematical economics, the nonlinear economics, the topologic economics and so on.

2. Mathematical Economics

Currently, there are mathematical economics, econometrics, and economic dynamics, etc. The extension from local differential approaches to global integral methods corresponds to the transition from microeconomics to macroeconomics. The input-output model is exemplified as latter approach.

Klein proposed the computer models designed to predict economic fluctuations. Tobin introduced the mathematical models for investment decision-making. Mathematical economics and econometrics should be employed to study optimal control theory in economics, thereby establishing optimal planning models for national and global economic development. To some extent, this approach corresponds to wartime economics, and allows for modifications to general economic theories. In economic models, selection and control parameters are critical.

The economic system, as a topological structure [7], corresponds to economic crisis when its topology breaking. The delayed feedback model of economic growth is:

$$\frac{dx(t)}{dt} = ax(t) + xG(x)\,. \tag{1}$$

The feedback function G(x)= $-b\exp(-x^2/\sigma^2)$ is a key generated chaos. xG(x)=F(x) is the control function, which represents a generalization of the logistic equation.

The marginal problem is solution on market saturation. Cyclical economic crises can be modeled using equations with variable parameters, such as population difference equations:

$$N_{t+1} = \lambda N_t e^{-aN_t}\,. \tag{2}$$

Its periodic solution may provide an approximate description. To a certain extent, economic crises may correspond to chaos. The approach to overcoming economic crises involves eliminating the conditions that give rise to chaos. This relates to chaos control; thus, general methods of chaos control can be applied to manage chaos and related crises in the economy. Repeated application of carefully selected small perturbations to a system can maintain originally unstable trajectories as stabilized periodic motions. General chaos control encompasses four aspects [8-12]: harnessing chaos, generating chaos, chaos control, and chaos synchronization.

More generally, it is essential to investigate the discriminants of social and economic instability derived from nonlinear social and economic equations, in order to minimize the occurrence of economic crises.

The general theory of economics must consider: 1) Fixed tangible assets, such as non-renewable resources, which are finite. 2) Costs, including tangible pollution and the reinvestment required to restore the original state, as well as intangible damages such as ecological and cultural losses. 3) Operating funds and typical economic factors. When both factors (1) and (2) are considered inputs, a new cost theory emerges; when factor (2) is treated as an output, it constitutes negative output. This is a new input-output model where positive output represents value, negative output represents cost, which requires further input. The initial investment yields short-term benefits, while subsequent investments yield medium to long term effects.

This leads to three key economic indicators: (1) Gross National Product (GDP); (2) Output-to-Cost Ratio; and (3) Efficiency Indicators. The latter two are closely linked to resource economics, ecological economics, environmental economics, and the generalized input-output model. While (3) is associated with the net welfare index. This generalization of economic efficiency connects to welfare economics. By integrating economic theories under sustainable development frameworks, the limits of development can be determined.

An ideal economic development model should: 1) be based on and resemble the optimal business development paradigm; 2) exhibit a certain cyclical pattern; 3) be interconnected with concepts such as synergetics and the Lotka-Volterra equation system. Consequently, the theory of comprehensive economic development can be structured into three distinct stages.

The most fundamental economic quantities vary across different fields. Microeconomics focuses on market regulation with price as its central focus, while firms pursue maximum profit. In contrast, bureaucratic systems prioritize attaining the highest official rank, which fundamentally contradicts economic principles.

Marginal analysis involves differences or differentiation. Normative economics incorporates specific initial conditions, boundary conditions, and transitional constraints. By Fourier series and wavelet analysis, various developmental and evolutionary cycles in economics can be studied, for example, by introducing economic functions:

$$f(x) = a_0/2 + \sum_{n=1}^{\infty}(a_n \cos nx + b_n \sin nx)\,, \tag{3}$$

which is superposition of various cycles.

The foundation of the equilibrium theory corresponds to the law of conservation of matter, while change corresponds to energy transformation. Furthermore, the principle evolves from conservation to the extremum of the minimum action principle, which is similar to how economics develops from quantitative changes to extremum analysis; it corresponds to minimum consumption, t represents the minimum time required to restore the original ecological state. More generally, this corresponds to the variation principles in economics, sociology, and related fields, such as Buddhist economics and resource economics.

When essential goods A are available, individuals like X can be approximated under first-order conditions [13] its growth rate is:

$$dX/dt = kAX, \quad (4)$$

death rate: $dX/dt = -bX$. (5)

Assuming A is unrestricted, when kA>b, the X exhibits exponential growth, leading to population explosion (Malthusian growth); when kA<b, the exponential growth decays to zero, resulting in species extinction. However, A is generally limited, and its consumption rate plays a critical role:

$$dA/dt = -hAX. \quad (6)$$

A is generated in some way, or exhibits conservation such as

A+X=N=constant, (7)

such obtain the logistic-Verhulst equation:

$$dX/dt = kX(N-X) - bX. \quad (8)$$

This nonlinear equation admits both general solutions and chaotic solutions. Eq. (8) has an ordinary solution X_0=0 (unstable) with extinction, and a saturation solution $X_0 = N-(b/k)$.

This can be applied to urban planning, commodity production, supply and demand dynamics, etc. For instance, in commodity production: let X represent output, and let A denote the market when raw materials are secured. Eq. (5) represents commodity sales; therefore, production can only be expanded when kA>b, first by expanding the market and second by encouraging consumption. Eq. (6) indicates competition and market contraction.

Both equations (4) and (5) apply to cities. Furthermore, this frame helps clarify the relations between daily necessities (such as water): a portion of water is recycled, while another portion is consumed. If equation (6) also holds true, then

$$A = A_0 e^{-hXt}. \quad (9)$$

Its linear approximation is $A = A_0(1-hXt)$. (4)+(5) is:

$$dX/dt = kAX - bX \approx kA_0(1-hXt)X - bX. \quad (10)$$

This is similar to (8), but the variable t has already appeared; the consumption component must be omitted for the cycle to be complete. It can be applied to factory production, corporate investment, and expansion, subject to certain conditions.

Consumption Equation (6) can also be modified. For example $dA/dt = -hAX$, then $A = -hXt + A_0$. Eq. (10) is:

$$dX/dt = (A_0k - b)X - A_0khtX^2 = aX - cX^2. \quad (11)$$

It is Bernoulli equation. Let y=1/X, so

$$dy/dt = -ay + ct. \quad (12)$$

Solution is:

$$y = \frac{c}{a}(t - \frac{1}{a}) + C_0 e^{-at}. \quad (13)$$

X=0 is also a solution. As long as consumption occurs, X→0 when t→∞. This represents humanity's tragic future. Only when resources are recyclable with zero consumption, h=0 (its meaning is no nonlinear terms) can sustainability be achieved

$$dX/dt = (kA_0 - b)X, \quad X = X_0 e^{(kA_0-b)t}. \quad (14)$$

In reality, however, this is impossible—at least according to Eq. (7). The only viable approach is to continuously adjust parameters and develop resources. A more general equation would be:

$$dX/dt = A_0kXe^{-htX} - bX. \quad (15)$$

In economics, the pursuit of extremum values gives rise to singularities, mutations, bifurcations, and chaos, etc. The dynamics of prices and markets are described using fluid mechanics equations.

Marginal utility follows a decreasing linear function MU =a–kQ, where Q≥1, extending to a general descending function. Consumer utility functions incorporate personal factors, psychological elements, and stochastic amplification.

In economic systems we research elements, sets and structures, which with symmetry form the basis of mathematical groups (additive or multiplicative groups), and include the symmetry between goods and money. The equivalence principle states the mutual equivalence of commodities and currency. Free competition embodies symmetry, whereas multi-connected topologies represent symmetry breakdown. In government-business functions, asymmetry reflects official-civilian inequality. Equality corresponds to symmetry (permutation). Under such systems, all aspects—including value orientations—spontaneously tend toward symmetry breakdown. The literary giant Victor Hugo observed: All social problems can be summarized as wealth production and wealth distribution. The most basic equality is fair and reasonable. Perfectly equal distribution maintains symmetry but eliminates competition and stifles production; conversely, wealth creation and production involve symmetry breakdown. The ideal of human society lies in balancing symmetry with its breakdown. It is a perspective applicable to sociology and worldviews.

3. Nonlinear Economics

The early economic dynamic process is represented by a simple linear function [1]:

dx/dt=F[x(t)]. (16)

However, any economy is inherently nonlinear [14].

It is well known that the economy is complex [15,16], one of whose key characteristics is nonlinearity [17,18].

The nonlinear economics includes chaotic economics [19-21], fractal economics, nonlinear economic growth theory and so on [21,22].

We proposed new nonlinear theory of economic growth and its three laws: Economic takeoff-growth-stagnancy law, social conservation and economic decay law, and economic growth mode transition and new developed period law [22,6]. The social open-reform is a necessary and sufficient condition for further economic development.

4. Topological Economics and Corruption Economics

Topological economics represents a crucial branch of mathematical economics, exhibiting certain correspondences between economic principles and topological concepts. Using the similar formulas of the preference relation and the utility function, we proposed the confidence relations and the corresponding influence functions that represent various interacting strengths of different families, cliques and systems of organization. Since they can affect products, profit, prices, and so on in an economic system, and are usually independent of economic results, therefore, the system can produce a multiply connected topological economics [7,22-24]. If the political economy is an economy chaperoned polity, it will produce consequentially a binary economy. When the changes of the product and the influence are independent one another, they may be a node or saddle point. When the influence function large enough achieves a certain threshold value, it will form a wormhole with loss of capital. Various powers produce usually the economic wormhole and various corruptions. One source of corruption economics is asymmetric information. This is a mathematical application to economics, and has the fractal structure.

If the political economy is an economy chaperoned polity, it will produce consequentially a binary economy. The political economy is usually imperfect economic question, even completely is not an economic question for some particular cases. It is not a strict economic rule, because in this case economy is only an appendage of polity. The economy will change along with polity.

The political economy as a multiply connected topological economics can be described by the complex function and the elliptic functions, which have two periods of economy and policy. The complex function corresponds to a complex system of economy and polity. In the multiply connected topological economy, economy corresponds to a real part, and policy and relation, etc., correspond to an imaginary part. A complex plane corresponds to the surface of the Riemann sphere, which is called a stereographic projection [25].

When output and influence remain mutually independent, they may form nodes or saddle points. When influence functions exceed a certain threshold, they create wormhole with capital outflows. These wormhole and black holes subsequently foster corruption and eventual system collapse. Further, we may explore economic topology and evolutionary economics, and apply qualitative analysis theories to examine dynamic relations and evolving patterns in dynamic economics and microeconomics.

In topology, the planned economy and its planners represent a singularity; the market economy, on the other hand, is a freely deformable and adaptable manifold. The planned economy corresponds to rigid social dynamics; the oligopolistic economy is a non-elastic system, such as a monopolistic funeral economy. The market economy corresponds to a malleable society in topology.

The isomorph, homologies, and homotopies of the two economic systems should be studied. The market economy should ideally be simply connected, whereas the oligopolistic economy is multiply connected with various divisions and gaps prone to tearing during deformation. In algebraic topology, their fundamental groups are different.

In topology n manufacturers (entities) constitute an n-dimensional manifold. The supply and demand sides (XY) form a two-dimensional manifold, where there always exists an equilibrium point (corresponding to a fixed point) within a specified initial and final region. In non-market economies, the intervention of a third or additional entity transforms the system into the multiply connected structure, either of higher dimensionality (human-governed dimensionality) or involving external forces and potential V in the equations. The outcome varies with different values of V, making spontaneous equilibrium difficult to achieve. If V is artificially and inequally determined, the system exhibits greater randomness.

Generally, changes in supply-demand functions are:

$$\frac{dQ_d(Q_s)}{dt} = f(Q_d, Q_s, p) + \text{V} + \text{S}. \qquad (17)$$

Here V is government potential, and S is random time. Further, the general relativity is combined with topology. Power acts as an attractor, proportional to m; corruption (m) creates economic wormholes; absolute power constitutes an economic black hole. The socio-economic objective is a confidence function (in families, groups, and government-business relations). If it is expressed as V=$2aX^2Y$, where a is the weight coefficient, X represents confidence level, Y denotes economic benefits. V can be estimated using the difference between theoretical and actual values.

In topology, the Euler number is defined as

$$\alpha_0 - \alpha_1 + \alpha_2 = 2 - 2p. \quad (18)$$

The larger the deficiency p, the smaller the Euler number. The presence of multi-layer confidence functions renders topological economic manifolds riddled with vulnerabilities. Moreover, the multiply connected topological economies can extend to encompass economics and politics, family, religion, and other domains. Specifically political economy integrated, or conversely political and economic separation. These effects further permeate all fields unrelated to economics directly, including welfare, environment and employment, exhibiting both positive and negative impacts.

Economic quantities can be categorized into two types: production functions and utility functions. Furthermore: 1) These two types can be combined. 2) They can be used to form simultaneous equations for qualitative analysis. 3) The latter can serve as constraints, such as those related to development and the environment, etc. Similar utility functions can be introduced to account for varying environmental preferences.

Political economics constitutes a coupled system of political and economic equations, encompassing various forms of authoritarian regimes. When politics dominates, the economic equations can be omitted. Periods of alternating political and economic dominance exhibit cyclical patterns: under normal circumstances, this is not purely economic; during exceptional times, it becomes entirely unrelated to economics. When the two conflict, economic considerations take precedence, demanding reform; when economic factors yield to political ones, societal regression occurs. Political economics lacks rigorous economic laws, as economics serves merely as a derivative of politics, evolving alongside political shifts. A complete economic system thus becomes riddled with fractures and scars. The multiply connected topology can be extended to analyze political-laws systems, political-education frameworks, and host-people dynamics. M. Buchanan's public choice theory posits that human society comprises both economic and political markets. This is a quintessential example of multiply connected topological economics.

5. New Research of Knowledge Economics

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 [26,22]:

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

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.

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 [23].

The innovativeness of the knowledge economy corresponds to catastrophe theory. The knowledge economy and talent costs are tied to values. Integration, interconnection, globalization, and sustainability within the knowledge economy correspond to nonlinearity, holism, and synergetics. The knowledge economy exhibits amplification (snowball) effects and dam effects. Consequently, education, investment models, management practices, and decision-making must differ accordingly from mere imitation to complementarity and innovation. The four characteristics of the digital age are: 1) Decentralization; 2) Globalization; 3) Harmony; 4) Empowerment. These are grounded in resource (information) sharing, information accessibility, and social transparency. Attitude toward these principles serves as a primary indicator of societal civilization and democracy. In economics, if there are two control variables, catastrophe theory predicts seven distinct catastrophes.

The knowledge economy is closely intertwined with scientific research, teaching, quality education, learning, and management, all of which should advocate innovation, independent thinking, and a relaxed, free environment. Furthermore, management practices must align with the key characteristics of the knowledge economy era: 1) Replace, supplement, and develop Gross National Product (GNP) using value-cost ratios; 2) Establish five or n primary structural frameworks; 3) Investigate input-output models for the knowledge economy era and their evolution, incorporating nonlinear methodologies; 4) Prioritize talent strategies; 5) Study corresponding investment theories and risks, along with their nonlinear equilibrium relations. Specific areas of focus include investment strategies, cost management, and comprehensive planning, etc.

6. Synergetic Economics and Fractal Economics

The economic system is an extremely complex system comprising numerous interacting subsystems. In synergetics, a few order parameters are used to describe and simplify such complex systems, and by altering these parameters, the economic state of the system can be modified, thereby yielding an economic model. For example, shifting investments aimed at increasing output to those focused on production rationalization leads to full employment. Oscillations between these two states have been observed and can be explained through synergetics. Another example of macrostructural development is the evolution from an agricultural society to an industrial society.

Synergetics has developed an investor model that closely agrees with real-world [27]:

$$\frac{dX}{dt} = I + RX - CX^3 . \qquad (19)$$

In synergetic economics, the first step is to determine the order parameters, such as price, profit, talent, or the interplay between markets and macroeconomic regulation. Linear relations correspond to revenue-expenditure equilibrium and input-output models, which may employ linear algebra. Nonlinear relations indicate revenue-expenditure imbalance, necessitating further development of the aforementioned models and methods.

From an overall economic perspective, the command economy involves rigid controls where enterprises operate passively as mechanical components within society, and corresponding to the "instrumental man." In contrast, a market economy is self-organizing and collaborative, corresponding decision-makers and social man.

The dissipative structure theory, referred to by Toffler as the scientific revolution of the new era, can also be applied to the economic domain. The corresponding economic theory of complexity science is characterized by instability, imbalance, nonlinearity, and diversity. Specifically, the urban evolution model of the dissipative structure theory [28] can be utilized to establish a framework for planning the distribution of commercial establishments (e.g., restaurants, hotels) and tourism sites. This approach can further be integrated with graph theory. Additionally, a tourism equation can be formulated, incorporating: 1) the distinctive features of tourism; 2) the potential and actual tourist capacity; and 3) considerations regarding competitors.

There are systems economics, information economics, and economic cybernetics, etc. The market economy forms approximately self-organization. Mathematical economics may apply concepts like chaos and non-equilibrium statistics, etc. Economic development and crises (often stemming from product saturation) follow two distinct cycles. Economic collapse corresponds to entropy maximization and chaotic phenomena. General chaos, attractors, and source-sink dynamics correspond to focal points and hotspots. Under competitive conditions, instability is ubiquitous. Chaos in economics can be analogized to earthquakes, from which patterns and approximate periodicity can be derived.

For the fractal economy, the fractal dimension measured for economic activity indices is quite low (<2). Economic phenomena such as supply-demand relations and population dynamics exhibit periodicity (e.g., the Lotka-Volterra equation) and chaos. State-owned enterprises are prone to chaos and can only be controlled through legal means. This approach can be applied to enterprises by utilizing a series of data points, including profits and taxes, workforce size, comparisons with industry averages, past performance records, market conditions, wage levels, and their impacts on national and social welfare. It first eliminates underperforming officials; if remediation proves impossible, the enterprise itself should be shut down.

Various levels of power (multiply connected) embedded within the economic system give rise to a series of self-similar corrupt structures. The concept of "separation of politics and economy" indicates that the original structure was topologically connected.

The current input-output model in economics is based on matrices and linear relations. Therefore, it is necessary to employ a combination of various methods to develop new approaches. For instance, extending the model to nonlinear relations in the context of nonlinear economics requires corresponding adaptations of matrices and models. This includes the nonlinear dynamic equilibrium theory and nonlinear input-output models, and incorporates social issues such as unemployment into these models, and investigates input-output models for environmental pollution. For addressing various forms of inflation, it is essential to integrate established theories with input-output models, systems theory, and mathematical methods, utilizing computer simulations to implement appropriate control measures.

7. Multinational Enterprise Economics

Multinational enterprise economics is an important branch of world economics. It initially focused primarily on minerals and economic resources. Today, its emphasis has shifted toward international investment, trade, transportation, and high-tech applications. Its fundamental goal typically is the pursuit of high profits.

However, approaches vary widely among individuals. As of January 1, 2024, the combined net worth of the world's ten wealthiest individuals approached $1.47 trillion: 1. Elon Musk; 4. Larry Ellison (Oracle Corporation); 6. Bill Gates and 10. Steve Ballmer (Microsoft); 8. Larry Page and 9. Sergey Brin (both from Google), and artificial intelligence (AI) are primarily in the high-tech sector. Other are 2. Bernard Arnault (in luxury goods); 3. Jeff Bezos (founder of e-commerce giant Amazon); 5. Mark Zuckerberg (owner of Facebook/Meta Platforms, the world's largest social network); 7. Warren Buffett has the most renowned investment firm and most generous billionaire.

8. Summary

Economics can be classified in various ways, from the biggest world economics to the smallest household economics. Many of its branches merit in-depth further study.

The foundation of behavioral economics is determined by value economics and psychological economics, which include everything from hedonic economics to its complete counterpart—Buddhist economics. Social economics examines production and distribution, focusing on social justice. Happiness economics, or general psychological economics, corresponds to irrational economics. Furthermore, confronted with various crises from global human challenges to individual survival dilemmas, we must thoroughly study ecological economics and general crisis economics.

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