Evol. Inst. Econ. Rev. 5(1): 81–127 (2008)

ARTICLE

Equilibrium Illusion, Economic Complexity and Evolutionary Foundation in Economic Analysis[1),2)]

Ping CHEN

Professor of Economics, China Center for Economic Research, Peking University, Beijing 100871, China; and Center for New Political Economy, Fudan University, Shanghai 200433, China. E-mail: pchen@ccer.edu.cn

Abstract

It is widely believed that an equilibrium framework based on simple models, such as the representative agent and bilateral bargaining, in a frictionless economy provides a consistent framework in micro, macro, finance, and institutional economics. However, equilibrium believes in self-stabilizing market and institutional convergence broken down when inherent instability and non-predictable uncertainty emerge under nonlinear and social interactions. Equilibrium illusions in economics and econometrics are pretty in math modeling but dangerous in policy decision. Known examples are the Frisch model of noise-driven cycles, the Lucas model of microfoundations, and the Coasian world of zero transactions. These models not only violate basic laws in science but also lack evidence in economic history. Their common problem is associated with linear Hamiltonian economics with symmetric information without history. Economies are dissipative systems in nature, characterized by symmetry breaking, information flow, a time arrow, and history. The many-body problem is fundamentally different from the one-body and two-body problem in mathematics. Both computational and natural experiments, such as a stock market crash and a transitional depression, reveal the severe limitations of equilibrium thinking and structural changes from evolutionary dynamics. The new science of complexity offers new tools of nonlinear dynamics and non-stationary time series analysis. Existing puzzles in equilibrium economics, such as persistent cycles, interruptive crises, market resilience, social movements, and organizational diversity, can be better understood by nonlinear dynamic models. Like the paradigm shift after Einstein in physics, the evolutionary perspective provides a general framework, while equilibrium models serve as its special cases, since the equilibrium picture is an approximation of economic complexity in a short-time window taken from a long-term historical current.

Keywords: equilibrium illusion, evolutionary foundation, market instability, social asymmetry, economic complexity.

JEL: B41, B52, C00, K00.

[1)] This paper is based on the paper "Equilibrium Illusion and Evolutionary Foundation in Economic Theory" presented at the JAFEE (Japanese Association for Evolutionary Economics) annual meeting in Kagoshima on Sept. 23, 2007. The author is grateful for the inspirational discussions in the past with Paul Samuelson, Richard Day, James Galbraith, Finn Kydland, Edward Prescott, Steven Cheung, Gregory Chow, Ulrich Witt, Joseph Stiglitz, Kurt Dopfer, Yagi Kiichiro, Yuji Aruka, and the recent participants of the Kagoshima meeting.

[2)] This work was supported by Grant No. 07BJL004 from the National Social Science Foundation of China.

The flying arrow is at rest.
The all is one.
— Zeno of Elea (about 490 BC–425 BC)

The way gave birth to unity, Unity gave birth to duality, Duality gave birth to trinity, Trinity gave birth to the myriad creatures.
— Lao Tzu (about 600 BC–500 BC)
Tao Te Ching, the Classic Book of Integrity and the Way, translated by Victor H. Mair, Bantam Books, New York (1990).

1. Introduction

It is widely believed that the idealized world without friction is a unifying foundation for equilibrium economics. This belief faces fundamental challenges from new findings in complexity science, which will lead to a paradigm shift in economic thinking and quantitative analysis.

Two basic models in equilibrium economics are the optimization model and the representative agent, which are based on a Hamiltonian framework in economic theory. The Hamiltonian approach is valid only for a conservative system without friction, i.e., no energy dissipation in the form of heat. Notable examples in physics are planetary motion and harmonic waves, including electromagnetic waves and the atomic spectrum. Two economic features go beyond the scope of the Hamiltonian system: business fluctuations and economic growth. Specifically, the building block in econometrics is random noise, which is the typical feature of energy dissipation or entropy production. In other words, an economic system is more like a biological system than a mechanical system, since they are dissipative systems not Hamiltonian systems in nature.

According to non-equilibrium physics, potential function no longer exists under far from equilibrium conditions, which indicates the limit of the optimization approach (Prigogine, 1984). Nonlinear dynamics told us that nonlinear interaction is the internal deterministic cause of seemingly random movements, an alternative mechanism for external explanation of business cycles. Positive feedback is a constructive force for growth and innovation, which is outlawed by equilibrium economics under the term of non-convexity. The many-body problem (such as social behavior) is essentially different from the one-body (in a representative agent) and two-body (in bilateral bargaining) problems. If we accept these new understandings in complexity science, we will easily realize that many doctrines in mainstream economics are simply equilibrium illusions, which are equivalent to perpetual motion machines against the laws of physics and the history of division of labor.

In this review article, we will examine two central beliefs in equilibrium economics: the self-stabilizing market and institutional convergence. We will see that both computational and natural experiments demonstrate the limits of the equilibrium approach and the potential of an evolutionary perspective based on a nonlinear and non-equilibrium approach.

In section II, we give a brief review of how technical progress in complexity science led to a paradigm shift in economic thinking. In section III, we discuss equilibrium illusions in economics and econometrics. In section IV, we demonstrate the main results of computational experiments in testing competing economic theories. In section V, we study transition economies and their implications to economic theories. In section VI, we address fundamental issues to be solved by the next generation of economists. We hope that a new dialogue between scientists and economists will be fruitful in bridging the gap of two cultures, i.e., the mechanical and living world.

2. From Methodological Debate to Fundamental Thinking in Economic Complexity

The strong link between mathematical simplicity and equilibrium thinking is a major source in economic controversies. I would like to share my own experience with fellow scholars in a dialogue between complexity scientists and equilibrium economists.

I was trained as an experimental as well as theoretical physicist. When I began searching for empirical evidence of economic chaos in 1984, I had no idea about conflicting economic schools of thoughts. After we discovered empirical and theoretical evidence of monetary chaos and color chaos from stock market indexes (Chen, 1988, 1996ab), our discoveries received a warm response from physicists, biologists, and Austrian and Keynesian economists, but a cool reaction from mainstream economists and fierce opposition from econometricians.

On the surface, most debates were concentrated on technical issues, such as noise vs. chaos, linear vs. nonlinear detrending, deterministic vs. stochastic models, etc. After more technical progress, the central debate shifted to basic issues in economic order. Why are mainstream economists more reluctant to accept simple mathematic ideas of nonlinearity and complexity? In addition to mathematical difficulty, we found that equilibrium economists hold a fundamentally different view of life and order. For physicists and biologists, life is better described by cycles rather than noise. The so-called chaos model is simply a more general model of the nonlinear oscillator, which is visible from the biological clock. Brownian motion only plays a minor role in ideal gas without interactions. But for economists believing in laissez-faire policy, the normal economic order is a static equilibrium state plus small random noise. We went back to check if equilibrium assumptions had any empirical foundation. Three discoveries changed our view of equilibrium theory: the so-called Frisch model of noise-driven cycles in econometrics was quietly abandoned by Frisch himself in 1934 and it was a perpetual motion machine in nature (Chen, 1999, 2005); the Lucas model of microfoundations had weak evidence according to the Principle of Large Numbers (2002); and the Coasian world of zero transaction costs was another perpetual motion machine in economics (Chen, 2007). We finally realized that market fundamentalism was a pretty toy in math modeling but just a theoretical illusion in biophysics and economics.

The transition from classical mechanics to relativity theory may provide an enlightening lesson for economists. After the Michelson-Moley experiment failed to detect ether-drift, Dutch physicist Hendrik Lorenz made a technical modification (such as space contraction and time slowdown under high speed movement) to preserve the ether hypothesis, but Albert Einstein made a simple revolution by giving up the ether hypothesis and introducing special relativity. Before Einstein further developed general relativity, scientists widely believed that Euclidean geometry was the only choice for geometry in the real world. But Einstein taught us that there were infinite possibilities of non-Euclidean geometric systems. Which geometry is relevant to our world is an empirical issue, which should be free from constraints in ideology or aesthetics.

Today, economics faces a similar situation to classical physics, or more exactly, astronomy before Copernicus. It is widely believed among economists that equilibrium economics provides a consistent framework in economics, which is capable in explaining almost everything from demand and supply in micro, money and unemployment in macro, corporate finance and asset pricing in finance, even firms and law in institutional economics. There seem only two clouds in the sky: the persistence of business cycles and the recurrence of conflict and war. However, mainstream economists have a good reason to ignore the minority camp on the grounds that heterodox economics is underdeveloped, simply because they rarely use elegant math models as their main language.

Things have changed since the emergence of the new science of complexity. We will see that the equilibrium perspective is challenged by the evolutionary perspective not only by historical and philosophical arguments, but also by theoretical and mathematical analysis.

3. The Economic Beliefs and Equilibrium Illusions in Economics

The development of non-equilibrium thermodynamics and the discovery of deterministic chaos radically changed two basic beliefs in sciences. First, there is a fundamental difference between Hamiltonian and dissipative systems: the former system is reversible and the latter is irreversible while all living and social systems are dissipative system in nature. Second, predictable trajectories in classical mechanics rarely exist in real dynamics when dynamic systems are non-integrable with nonlinear interactions or dealing with a many-body problem. These two discoveries have a tremendous impact on our study of economic systems, since the optimization approach in equilibrium economics is based on Hamiltonian economics, and regression analysis in econometrics is hopeful only under integrable systems.

By equilibrium economics, we mean the simplest version of neo-classical economics, including the assumption of a Robinson Crusoe economy, the optimal condition of convexity, the concept of perfect information and zero transaction costs, and the first-differencing (whitening) filter in econometrics.

In this section, we will give a brief review of where they went wrong and how dangerous they were as policy guidance for a real economy.

3.1 The belief in self-stabilizing markets

The central argument for laissez-faire economics is the belief in a self-stabilizing market.

There are three basic models to depict the self-stabilizing market: the static linear supply-demand curves; the optimization model with convex utility and production functions; and the linear stochastic model of random walk and geometric Brownian motion.

Methodologically speaking, the essential difference is between a single equilibrium state in linear models and multiple equilibrium states in nonlinear models. We will discuss linear stability in this section, and leave structural stability until section 3.2.

3.1.1 The unique equilibrium in linear demand and supply curves

The most influential illusion among economics students is the self-stabilizer characterized by negative-sloped demand curve and positive-sloped supply curve, which assures a unique equilibrium (Fig. 1a). It is easily described by a simple diagram and derived from optimization theory under the condition of a non-increasing economy of scale (Marshall, 1920; Varian, 1984).

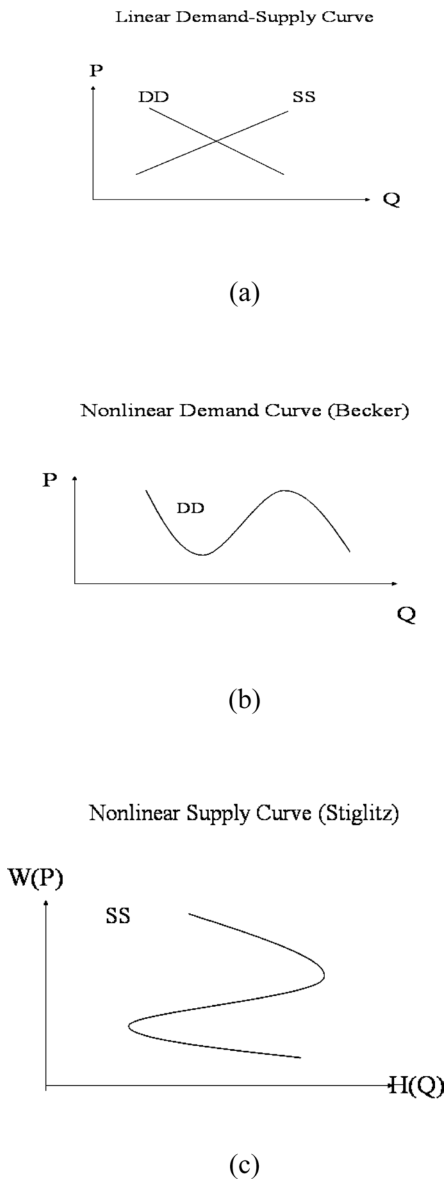


Fig. 1. Linear and nonlinear demand and supply curves. The market mechanism of unique and multiple equilibriums.

It was known that multiple equilibriums exist under nonlinear demand and supply curves. Social interactions (such as fashion and collective behavior among economic agents) introduce an S-shaped demand curve (Fig. 1b, Becker, 1991). Nonlinear limitations (such as the subsistence threshold in minimum income and backward tilted curve in high wage) generate an S-shaped or Z-shaped labor supply curve (Fig. 1c, Stiglitz, 1976; Dessing, 2002). Multiple equilibriums under nonlinear demand or supply curves imply the possibility of persistent cycles and sudden changes.

3.1.2 General equilibrium without non-convexity, social interactions, and product innovations

The unique stable equilibrium was created by the general equilibrium model based on maximization of utility and production function (Arrow and Debreu, 1953; Debreu, 1959). Advanced techniques such as the fixed point theorem in topology were used to justify the existence and stability of unique equilibrium in the Arrow-Debreu model of general equilibrium.

We should point out that the Arrow-Debreu model has its main features in a primitive economy and commanding economy, which are irrelevant to an industrial market economy. There are four basic restraints in most general equilibrium models with unique stable equilibrium. First, increasing return to scale and scope is not permitted so that market-share competition is beyond the scope of “economic rationality.” Second, information diffusion and reaction does not occur among economic agents, therefore no space exists for social interactions and strategic behavior. Third, the dimension of commodity space is fixed, where no product innovations are allowed. Fourth, resource limits and market extent are ignored, which is the root of methodological individualism. All the four missing dimensions are fundamental sources of economic instability and complexity that resulted from Schumpeter’s “creative destruction” (Schumpeter, 1934).

3.1.3 The Frisch utopia of noise-driven persistent cycles: a perpetual motion machine of the second kind

During the Great Depression, Frisch invented a dynamic fantasy to save the collapsed confidence in market stability. He suggested that persistent cycles could be maintained by a stream of random shocks. This scenario has two attractive features: First, it is inherently stable if there are no external shocks, just like the pendulum with friction; second, it attributes persistent business cycles to external shocks, which blames economic fluctuations on external factors (bad guys or bad luck), not internal instability (so no regulation needed).

Frisch made his claim in an informal conference paper on propagation and the impulse problem (Frisch, 1933). Equilibrium economists quickly embraced the Frisch model in macro, finance, and econometrics. However, physicists already knew before Frisch that harmonic Brownian motion could only generate dampened oscillation rather than persistent cycles (Uhlenbeck and Ornstein, 1930).

If the US business cycles could be described by the Frisch model, American business cycles would only last about 4 to 10 years, which was not true in history. It is known that recorded history of US business cycles is more than a hundred years. The Frisch utopia implies a perpetual motion machine of the second kind, i.e., an energy generator by random thermal fluctuations, or a heat engine without releasing any waste heat at a lower temperature. This engine could not exist, since it would violate the second law of thermodynamics (Chen, 1999, 2005).

More surprisingly, Frisch quietly abandoned his model in 1934 but never openly admitted his mistake. Frisch claimed that he had already solved the analytical problem and that this would soon be published. His promised paper was advertised three times under the category "papers to appear in early issues" in 1933, but it never appeared in *Econometrica*, where Frisch served as the editor. Frisch did not mention a word about his prize-winning model in his Nobel speech in 1969 (Frisch, 1981). These facts are still ignored by mainstream economics. This story reveals an alarming truth: there is only one step between belief and illusion.

3.1.4 The Friedman spirits of the risk-free arbitrager for efficient market argument

A thought experiment for basic belief in a stable and efficient market was created by Friedman in discussing the self-stability of a flexible exchange rate regime. The central idea could be characterized by Friedman spirits, which were rational arbitrageurs capable of driving out irrational (destabilizing) speculators (Friedman, 1953). Its central message is that cyclic patterns and unstable structures could not exist in a competitive market. This is the main argument for the efficient market hypothesis in macro and finance dynamical theory.

Friedman spirits behave much like the Maxwell demon in equilibrium thermodynamics. The Maxwell demon is an imaginary gatekeeper trying to create a non-equilibrium order from an equilibrium state by operating a frictionless sliding door between two chambers that are filled with moving molecules. Maxwell assumed that his demon had perfect information about the speed and position of all molecules such that he could allow only a fast molecule into a designated chamber by opening or closing the mass-less valve in perfect timing. In economic language, under the condition of perfect dynamic information, the Maxwell demon could create a temperature difference without doing work, though that outcome is contrary to the second law of thermodynamics. The meaning of perfect information is also essential for a Coasian world with zero information costs (we will return to this issue in section 3.2.4).

Friedman spirits face a similar problem to that of the Maxwell demon but with an opposite task. To eliminate any market instability, Friedman spirits had two problems in achieving their goal.

First, resource limitation is a severe barrier in defending speculative winds with positive feedback strategy, i.e., the recurrent market fads by following the crowd (De Long *et al.*, 1990). For example, foreign reserves in any central bank are limited compared to speculative capital in the global financial market.

Second, the uncertainty principle and dynamic complexity set fundamental limits in duplicating strategy in a competitive market. Friedman implicitly assumed that a winner's imitator could quickly drive down profit margins to zero. This strategy could work only if the winning pattern was replicable. There are two fundamental difficulties in doing so.

One problem is timing uncertainty in the frequency domain. The strategy of buying low and selling high works if the turning points of a speculative wave are predictable with small error. This possibility is limited by the uncertainty principle in terms of the trade-off between time resolution and frequency resolution (Brillouin, 1962; Qian and Chen, 1996).

Another barrier is complexity in the time domain. The sources of complexity in time series analysis include imperfect information (finite data with noise and time delays), information ambivalence (conflicting news and distorted information), unpredictable events (financial crisis and changing structure), and limited predictability (caused by deterministic chaos or wavelets). Information ambiguity is not only associated with bounded rationality but also rooted in dynamic complexity (Simon, 1957; Chen, 2005).

In short, there is no quantitative evidence for an efficient market. Unpredictability and ignorance do not imply market efficiency!

3.1.5 The whitening filter of first differencing and illusion creator in econometrics

The Frisch model of noise-driven cycles is formulated in continuous-time differential equations. The discrete-time model and difference equation are widely used in econometrics because of the mathematical convenience of regression analysis. The first-differencing (FD) filter is an essential device in creating an equilibrium illusion in

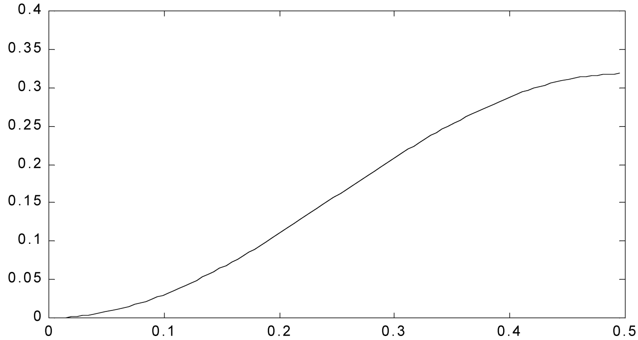


Fig. 2. Frequency response function for the FD filter. Here, X(t)=FD[S(t)]=S(t+1)-S(t), the horizontal axis is the frequency range from zero to 0.5.

econometric modeling.

All scientific analysis has a common problem of noisy data resulting from measurement error and unknown factors. The common solution is developing a proper filter designed for a specific question, which is aimed at reducing noise and amplifying a signal in the form of deterministic patterns. The only exception is econometrics. The FD filter is a whitening device, which reduces signals in low frequencies and amplifies noise in high frequencies. Its frequency response function is shown in Fig. 2, which is a sharp contrast to the band-pass filter in signal processing. Almost all illusionary evidence of efficient markets, including white noise, Brownian motion, unit root (Nelson and Plosser, 1982), and co-integration (Engle and Granger, 1987) etc., are created by the FD filter. In contrast, counter evidence of persistent cycles and color chaos (a nonlinear oscillator with an uneven amplitude but narrow frequency band like a biological clock) emerged through a pertinent filter, such as the HP filter with nonlinear smooth trends and WGQ filter in time-frequency space. We found that about 70% of business fluctuations in stock market indexes were generated by color cycles, while only about 30% of components were characterized by white noise. The majority of macro fluctuations are also dominated by persistent cycles rather than white noise (Chen, 1996a, b).

The question is why econometricians are obsessed by the FD filter. The strange approach of amplifying noise was not only originated by conventional usage of percentage changes, but also rooted in the equilibrium perspective of market order. Friedman clearly realized that erratic time series resulted from the FD filter. He defended the FD filter on the grounds that its result was independent of the choice of historical period (Friedman, 1961, 1969). History does not matter, which is the core belief from equilibrium economics in constructing a Ptolemy-type representation in short-time econometrics In contrast, Schumpeter's picture of a biological clock can only be observed from the detrending perspective, where history does matter in long-term non-stationary time series analysis.

3.2 The belief in social equilibrium and institutional convergence

The second argument for small government is the belief in social equilibrium where unemployment and conflicts can be solved by voluntary choice and market exchange.

We should know that social issues are a many-body problem in nature. For mathematical simplicity, economists often simplify social issues into one-body and two-body problems. Well-known models are the Lucas model of an island economy, which transformed a many-body problem into a representative agent model or one-body problem as an econometric exercise. The random walk and geometric Brownian motion in finance are also typical one-body problems, even though they are linear stochastic dynamic models. The Coase Theorem is essentially bilateral bargaining, a typical two-body problem.

The critical issue is what is the fundamental difference between one-body, two-body, and three-body to many-body problems? What are the limits of these low-dimensional (1- or 2-body problem) models in policy studies? We will see that social equilibrium is mainly built on a so-called Robinson Crusoe economy with just one (Robinson Crusoe) or two (plus Friday) people. When you have three or more players, the social equilibrium may change into multiple equilibrium or complex dynamics. Methodologically, both atomism and reductionism assume that the whole is the sum of all the parts. When complex interactions exist between different elements, the whole is more than the sum of parts, especially for a living organism and social organization.

Two mathematical advancements shattered the illusion created by social equilibrium models based on one- or two-body problems.

For nonlinear deterministic models, chaos theory shows a fundamental difference between two-body (which can be transformed into a one-body problem with a coordinate transformation) and three-body problems (which cannot be transformed into in a one-body problem and may not have any analytical solutions) in nonlinear dynamics (Hao, 1990). The equilibrium state has new variants, including a limit cycle in two-dimensional dynamics and chaos in three- or higher dimensional space. For nonlinear stochastic models, complex features emerge such as U-shaped distribution, its mean may not exist, and variance can be infinite, which are beyond the scope of equilibrium economics.

One essential relation between micro-fluctuations and aggregate fluctuations is crucial for our further understanding the micro-macro relation: the Principle of Large Numbers provides a powerful insight in addressing micro-macro relations in quantum biology and macro economics (Schrödinger, 1948; Chen, 2000, 2005). One useful indicator is the relative deviation, which is the ratio of the standard (absolute) deviation to the mean. For positive variables with a natural origin, such as population, price, and output, the magnitude of the relative deviation (RD) is in reverse proportion to the square root of the size of the population (3.1)

$$RD = \frac{\sqrt{VAR}}{Mean} \sim \frac{1}{\sqrt{N}} \tag{3.1}$$

From this simple relation, we will see that the larger the micro element number N, the smaller the macro fluctuations measured by RD. This is the essence of insurance, since individual independent fluctuations may largely cancel out under large numbers. We will see that this formulation may challenge two equilibrium illusions in economic theory: the Lucas model of microfoundations and Black-Scholes model of geometric Brownian motion.

Human nature is a social animal. Equilibrium models based on a representative agency, one-body or two-body models have severe limitations in explaining multiple equilibriums in social conflicts and evolutionary perspective in social organizations.

3.2.1 The Lucas fantasy of microfoundations and rational expectations

The new classical school led by Lucas launched a counter-Keynesian revolution in the 1970s. Its most powerful argument is calling for the microfoundations of macroeconomic fluctuations. Lucas suggested that independent fluctuations at the level of households (e.g., the inter-temporal substitution between work and leisure) would generate large fluctuations at the aggregate level. To achieve this claim, he used a magic device, the so-called rational expectations, which could generate a mass consensus (on the equilibrium wage rate and other mean values of macro variables) without any social interactions (Lucas, 1972, 1981). The Lucas model can be easily tested by calculating America's relative deviation and take an educated guess about the number of agents according to the Principle of Large Numbers.

To our surprise, there was weak evidence of microfoundations from American macro indexes: the observed American business cycles are at least 20 times larger than the magnitude predicted by the microfoundations models in labor or producer markets. Why couldn't households with rational expectations reduce large business fluctuations in the

US? Clearly, Lucas did not realize that relative prices always move in pairs. If many people choose leisure when the average wage declines, the leisure price would also go up and create an arbitrage opportunity for those who postpone leisure instead. Unfortunately, arbitrage opportunity is well known in finance literature, but does not exist in the Lucas island economy model since economic agents have no single individual degree of freedom. The Lucas island population model is a disguised representative agent model in nature (Chen, 2002).

Our discovery reveals that the three-level model of micro-meso-macro is much better than two-level model of micro-macro (Chen, 2002, 2005). Persistent business cycles and market instability are rooted in the intermediate structure (finance and industrial organization). This is new evidence for financial Keynesians (Minsky, 1985; Dopfer, 2005; Galbraith, 2008).

3.2.2 Structural instability of the random walk and the geometric Brownian motion models as a result of the representative agent model in the stock market

One by-product of our studies in relative deviations was our discovery that the popular models in finance theory, such as random walk and the geometric Brownian motion model are structurally unstable, which cannot explain a sustainable market over time (Chen, 2005). This result paved a new way in financial modeling.

It is a mathematical convention in mathematical economics that stock market fluctuations can be described by a linear stochastic process. The option pricing model based on geometric Brownian motion serves as the benchmark model in the option market (Black and Scholes, 1973). It is known that the geometric Brownian motion has weak evidence from financial markets. In particular, its variance is not constant. Most modifications are confined to the representative agent model of Brownian motion. We found out that both the random walk and the geometric Brownian motion cannot generate sustained fluctuations measured by relative deviation in stock market indexes. Fluctuations in the random walk model are dampened while those of the Brownian motion are explosive. Only the birth-death process (the ups and downs are given in different “birth” and “death” probabilities within the population) is constant over time, which is capable of explaining the observed stability of relative deviations in the US macro indexes.

We are developing a better alternative model of option pricing based on the nonlinear birth-death process. It could explain the volatility smile, herd behavior, and other complex behavior, including a unified explanation of existing models, which serve as special cases of a general theory in behavioral finance (Zeng and Chen, 2008). Recent sub-prime mortgage crisis in US may stimulate us rethinking the unstable nature of the Black-Scholes model in option pricing.

3.2.3 Monetary neutrality and the Ricardo device: A fiction without conflicting interests

One critical issue in monetary economics is the existence of the neutrality of money. We found empirical and theoretical evidence of monetary chaos, which was evidence of an endogenous mechanism of monetary movements, but a challenge to the exogenous monetary fluctuations and neutrality of money (Barnett and Chen, 1988; Chen, 1988).

The Ricardo device is a thought experiment to justify the neutrality of money. It is a hypothetical operation of doubling overnight the cash holdings of all business enterprises and households without changing relative prices. It means that all supply and demand functions are a homogeneous function of zero degree, which is the basic argument against Keynesian economics (Leontief, 1936).

In the history of scientific thought, the Ricardo device in economics is very similar to the Loschmidt reversibility paradox in physics, which was designed for challenging Boltzmann's H theorem of thermodynamic irreversibility. Loschmidt argued that one should be able to return to any initial state by merely reversing the velocity of all molecules under Newton's law. The trouble here is the huge coordination costs. Boltzmannn pointed out that the possibility of reversing all the initial conditions is very unlikely in dealing with a large system with many particles.

One important lesson is that macro changes are almost always an irreversible process. To reverse the macro movements imply infinite coordination costs. This lesson should be useful when we further address the next issue of transaction costs.

In political economy, the Ricardo operation implies regressive taxation. The symmetry-breaking between consumption and investment will introduce irreversibility and history in socio-economic changes. The Ricardo operation may face tremendous opposition both in regressive policy and coordinating costs. Later in section 5.1.1, we will see the real costs of Germany's monetary union in 1990.

3.2.4 The Coase world with zero transaction costs

Coase raised fundamental questions on the firm nature and market solution for social conflicts (Coase, 1937, 1960, 1988). Coase pushes equilibrium economics beyond its traditional boundary, so we have a good chance to study the limits of neoclassical economics.

In fact, more confusion than inspiration was caused by the vaguely defined transaction costs, the ill-formulated Coase Theorem, and the false analogy of a frictionless world in physics. There are many problems with the concept of transaction costs in economics.

First, there is a mismatch in time scale and analytical unit: a transaction occurs in micro and a short time-window between economic atoms while organization and institution are observed in macro and a long time-window. Clearly, the Coase approach is an extreme reductionism, similar to Ostwald energism in late 19th-century physics, i.e., a theory against matter structure. The size of the firm cannot be determined solely by internal balance between transaction and coordination cost. The competitor's scale and the size of the market niche are the basic constraints related to the size of the firm or species (Schmidt-Nielsen, 1984; Stigler, 1951; Chen, 2007).

Second, the concept of transaction costs is vaguely defined and hard to measure, which is unsuitable to serve as any guidance in decision making. The core of transaction costs are information costs. For past information costs such as search costs are limited, so that its measurement is operational. But for future information costs such as ministering and enforcement costs are explosive in time and could not be measured and served as policy guide. Coase made a hidden assumption that market competition would drive down transaction costs. He seems to ignore counter business strategies such as marketing and licensing for expanding market share, creating value, at the cost of increased transaction costs. Technological progress may reduce the unit transportation cost and communication cost. However, aggregate transaction costs as a whole had a clear increasing trend in the history of the industrial revolution and division of labor, which was driven by increasing network complexity and innovation uncertainty. For example, transaction costs in the US GDP increased from about 25% in 1870 to more than 50% in 1970 (Wallis and North, 1986).

Third, the Coasian world of zero-transaction costs cannot exist in the real world since it violates several basic laws in physics. The analogy between a frictionless world in physics and the Coasian world with zero transaction costs is wrong, since zero friction is a realistic abstraction for a theory of planetary motion in space, but zero information cost is impossible according to the uncertainty principle in quantum mechanics (Brillouin, 1962). Any information collection or transmission requires some form of minimum energy. The Coase belief of reducing transaction costs in social evolution is simply against the second law of thermodynamics, since entropy production increases in biological and social evolution. The Coasian world is another example of a perpetual motion machine in equilibrium economics (Chen, 2007).

Fourth, the Coase Theorem implied that institutional changes would converge to an optimal system regardless of initial conditions. This is a mechanical view of the world without history. The emergence of life and social organization is characterized by a time arrow or symmetry-breaking in a non-equilibrium process (Prigogine, 1984). Path-dependence and structural changes are important in legal development.

Fifth, the most controversial assertion in the Coase Theorem is that any social conflicts could be resolved by bilateral bargaining without the third party (law, government, or civic society) intermediation (Coase, 1960, 1988). His argument was based on the symmetry between polluter and victim, and more generally, the symmetry between consumption and investment (Coase, 1960, 1988; Cheung, 1998). If the Coase Theorem is valid, there would be no power, no conflicts, no war, no government, and no regulations. This may be true for primitive society without private property and wealth accumulation, but is not true for a competitive but unequal market economy.

Coase made the claim of observing the real world. After careful examination, we found out that no single case studied by Coase could support his claim. Bilateral bargaining under a specific context could not converge to a (universal) optimal state when asymmetry exists in the form of non-convexity, such as scale economy in a cattle ranch, upward-demand for pollution, and social dissent for commercial bribery. Coase argued that price theory can be applied to the externality problem if the demand curve is always negatively sloped (Coase, 1988). Coase did not understand the simple reason behind the so-called downward demand curve: people usually prefer more pleasure, but less pain.

3.2.5 The myth of knowledge accumulation and endogenous growth without ecological constraints

The beauty of mathematical simplicity and the danger in policy implication can be seen from the recent development of the representative agent model in macro growth theory, the so-called endogenous growth theory (ENGT). It differs with exogenous growth theory (EXGT) both in math framework and in philosophy. EXGT in macro theory was started with simple macro dynamic models (Solow, 1957), while ENGT led by Romer (1987) and Lucas (1988) was a representative agent model. EXGT predicts a convergence story under decreasing or constant return to scale, while ENGT predicts a divergent story under increasing return to scale. In world history, the more likely story is varying return to scale during different development stages and the rise and fall of great powers (Rostow, 1960, 1990; Chen, 1987).

There are several implications in ENGT that are behind the so-called shock therapy.

First, the optimization model in macro growth theory has a strong implication of laissez-faire policy, which was an extension of microfoundations framework in new classical business cycle theory. To some degree, the representative agent model may simply describe some stylized fact of growth levels, such as the two-sector model of transition from an agricultural economy to an industrial economy (Hansen and Prescott, 2001). However, confusing growth features with "development mechanism" has a dangerous message that developing and transition economies can be guided by market forces alone without active government action (Lucas, 1988). ENGT implies a limited role of governments in development. Under the knowledge accumulation and diffusion mechanism, the development mechanism is a one-way street of information flow from rich to poor countries without risk and conflicts. Therefore, the best development policy is liberalization and privatization so that foreign capital and western institutions could freely move into poor regions. This is a main argument behind shock therapy and the Washington consensus (Sachs, 2005; Williamson, 1990).

Second, the concept of knowledge capital is dubious because of its stock nature in accumulation without living nature of birth of new knowledge and the death of obsolete knowledge, which is the root of recurrent unemployment and growth cycles. ENGT and the Coase approach would easily justify the shock therapy that the best development policy is a simply diffusion process without learning and innovation risk. The top-down design approach sounds similar to a commanding approach in market oriented transition.

However, the endogenous growth path is not an exponential curve but an S-shaped logistic curve, which is an alternative perspective developed in ecological biology. This can be observed from sector industrial data, such as the output ratio to GDP in the US automobile industry (Fig. 3). This is a typical feature for any industry or technology, including agriculture, textiles, coal, and steel, etc.

When several technologies (industries) have overlapped in their resources or market,

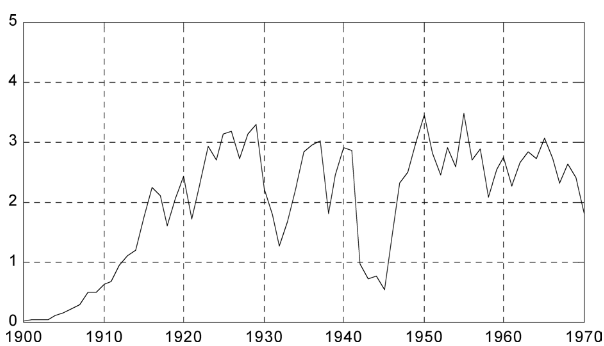


Fig. 3. Output Ratio to GDP for the US Automobile Industry.

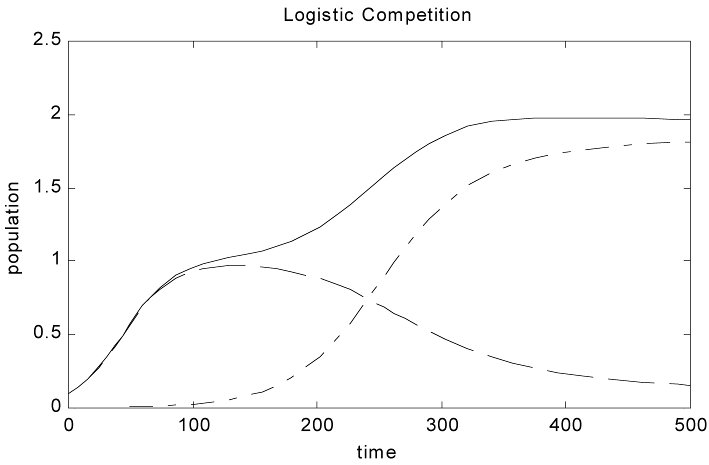


Fig. 4. The rise of new technology/industry and fall of old technology/industry under competing for imited resources and markets.

dynamic competition may have two possibilities: when resource competition is weak, two technologies may co-exist but at the cost of lower market share; when resource competition is strong, one technology will completely drive out the weak one, as shown in Fig. 4. The rising technology still maintains an S-shaped logistic growth to its saturate level, but the dying technology rises and falls like wavelets (only one half of the normal periodic cycle), which are referred to as "logistic wavelets."

Several new insights can be seen from these complex dynamics in Fig. 4.

First, both business cycles and growth cycles are driven by a series of technology wavelets, which resemble the rise and fall of technologies, industries, and powers. In contrast, equilibrium growth theory is characterized by unlimited smooth growth driven by small random shocks, which obscures the dark side of "creative destruction" such as persistent unemployment, excess capacities, financial crisis, and recurrent wars. Government action is needed both at the starting and declining stage.

Second, during the industrial revolution, old technology and associated knowledge is replaced by new technology and new knowledge. In this aspect, knowledge accumulation or learning by doing (Arrow, 1962) is overshadowed by knowledge metabolism or learning by trying (Chen, 1987, 2005). That is why latecomers have the chance to catch and even beat early-movers. This picture of changing economic powers is missing from the permanent divide between rich and poor in ENGT.

We will test these two competing approaches by transition experiments later.

4. Computational Experiments in Testing Economic Theories

Mathematical modeling in current mainstream economics is mainly used as a language for debate in economic policy. Is there any hope for economics as an empirical science, which can be tested by computational experiment and lab experiment? In this section, we will consider the historical events as natural experiments in time series analysis. We will focus on two central issues in contemporary economics: the inherent market instability and the social nature of organizational changes.

Obviously, economics should be more complex than physics, chemistry, and biology. However, dynamical economic models are much simpler than the ideal gas model, the simplest physics model. To bridge the gap between perception and reality, we develop new algorithms based on nonlinear and non-equilibrium approach in quantitative analysis. Mathematically speaking, econometrics analysis is mainly based on discrete-time stochastic models in a time domain, while physics and biology is mainly using continuous-time deterministic model in a frequency domain. We call our computational experiments “economic diagnosis”, just like a cardiogram and X ray scan in medicine for revealing the underlying structure of a living organism.

There are fundamental reasons in methodological differences between econometrics and physics. Econometricians favor discrete time mainly for mathematical convenience in regression analysis, whose qualitative results may change with changing time units. One typical example is the so-called unit-root model in macro econometrics, which was mainly found from annual data, but dubious from quarterly or monthly data. Physics theories have no similar problem, since major physics laws are formulated in continuous-time, which is independent from time-units. Another argument for stochastic models in economics is the false belief that human behavior with free will can only be described by stochastic models. This belief is strengthened by the Frisch model of noise driven cycles. Mathematically, a Fourier transform in a frequency domain can also be applied to a stochastic process. For example, white noise implies a flat spectrum and color noise a fat peak with noisy background. From quantum mechanics, we know frequency domain analysis has more information than time domain; that is why linear and nonlinear time series in frequency domain are widely used in physics, engineering, and medicine. These understanding may benefit future development in econometric analysis.

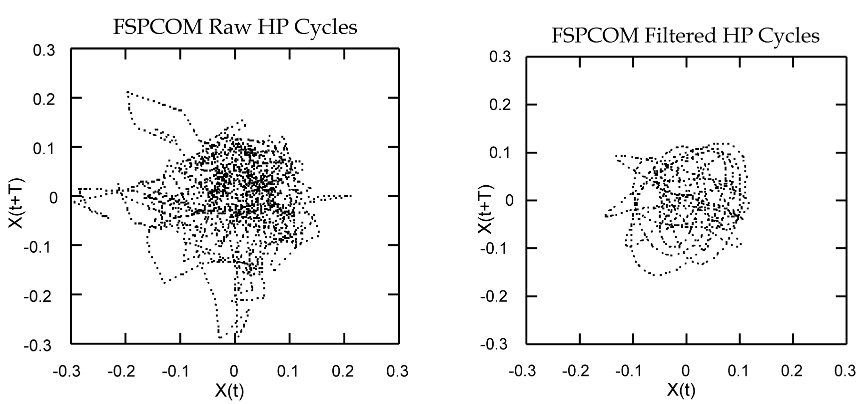
There are three facts revealed from our empirical analysis: the wide existence of persistent cycles, the statistical measure of collective behavior, and the stylized facts of technology wavelets.

4.1 Noisy equilibrium vs. persistent cycles

Equilibrium economics believes that market economy is self-stabilizing, which should be characterized by an equilibrium state plus some white noise, while the normal order of market economy in Schumpeterian economics considers the biological clock in the form of persistent cycles and creative destruction.

Mathematically speaking, how to characterize a moving phenomenon by a stationary model is the essence of the Copernicus problem in economics. The critical choice is the proper time-window and a corresponding filter in separating trends and cycles. When we apply a short-time window such as the FD filter in econometrics, we may easily get the random image of market movements. If we apply the HP filter in terms of a time-window in the range of NBER business cycles, we find persistent cycles whose average period is about 4 years. Because economic data have significant component of noise, we need more advanced technique in non-stationary time series analysis. The raw data look random, but the data filtered by a WGQ transform in time-frequency space revealed a clear picture of a spiral pattern of color chaos, a typical form of the biological clock with a stable and narrow frequency band but irregular amplitude (Fig. 5).

The phase portrait of filtered FSPCOM (Standard & Poor 500 Index) HP cycles shows a clear pattern of deterministic spirals, a typical feature of deterministic color chaos (nonlinear oscillator) in continuous time. Color means a strong peak in the Fourier spectrum in addition to a noisy background (Chen, 1996). We found out that white noise component only counted about 30% in stock market fluctuations. Note: many nonlinear



(a) Noisy image of unfiltered data (b) Complex spiral of filtered data

Fig. 5. The phase portraits of the unfiltered (the left sub-plot) and the filtered (the right sub-plot) FSPCOM HP cycles. The time delay T is 60 months.

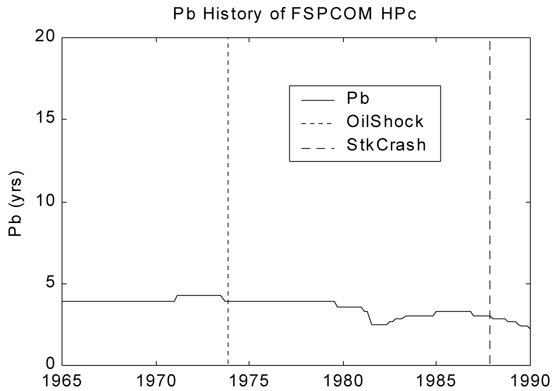


Fig. 6. The time path of the basic period Pb of FSPCOMlIn (the S&P 500 Stock Price Index) HP cycles. The basic period P_b shifted after the oil price shock in October 1973, which signaled an external shock. In contrast, the frequency changes occurred before and after the stock market crash in October 1987, which indicated an internal instability during the crash.

economic models mainly concern white chaos with a flat spectrum in discrete time, such as in the case of a logistic map, which is rarely observed in empirical analysis since the inherent time unit is not known and fixed.

The existence of stable frequency or characteristic period was found from most macro and stock market indexes. This is convincing evidence of Schumpeter's concept of economic order as a biological clock. The history of market frequency or basic period during historical events is shown in Fig. 6.

The time history of basic period is a new tool of economic diagnostics, which is similar to medical diagnostics in terms of heart and breathe frequencies. We can easily distinguish external shocks from internal instability, like the cases of the oil price shock in 1973 and the stock market crash in 1987. Note, here we only use non-parametric computational experiments. Unlike regression analysis in econometrics, we simply project a complex time series onto a time-frequency space without arbitrary assumption on regression function and parameters. This is a common practice in physics and signal processing in information science. The frequency-domain analysis provides a more general picture that market movements are better described by a mixed picture with a dominating component of persistent cycles and a minor component of random noise.

We have to apologize for the misleading name of "chaos", which was coined by mathematicians with a negative tone of "disorder." In fact, a nonlinear oscillator or colour chaos is a higher kind of order than linear harmonic cycles. We prefer to call it "complex cycles" or "biological clock," which is characterized by local instability (also implied adjustment flexibility) but global stability, i.e., a new feature of "resilience." In contrast, white noise is the least order in math models. Economic order can be better understood by going beyond noise models in econometrics.

4.2 Representative agent vs. collective movements

The stable and persistent pattern of relative deviation is observed from major macro indexes (Fig. 7). This is new empirical evidence against the representative agent model in a Robinson Crusoe economy, but in favor of a population model with collective behavior.

We can see that there is no damping trend (for the random walk model) or explosive trend (for the geometric Brownian motion model). Among existing stochastic models, the population model of the birth-death process provides a simple and good explanation for the stable RD pattern in a macro economy.

How can we understand the seemingly conflicting picture of persistent cycles in section 4.1.1. and persistent fluctuations in section 4.1.2? The answer lies in the relation between complexity in reality and the complementary role of simplifying math models. A deterministic model is better for describing predictable patterns such as trajectory and periodic motion while a stochastic model is better for statistical measurement of fluctuations. The real phenomena often fall between these two simplifying models. Taking examples in physics, two extreme cases for ideal gas and ideal crystal are easy for math modelling. The fluid model and condensed matter are more difficult to model because its structure falls between these two extreme simple models. In practice, we may

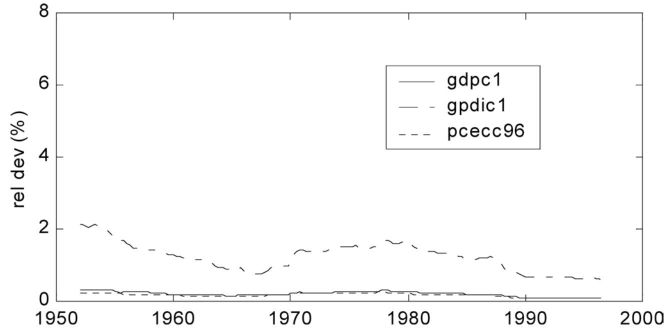


Fig. 7. The RDs of GDPC1 (US real GDP), GPDIC1 (real investment), and PCECC96 (real consumption) for the US quarterly series (1947–2001). N=220. Moving time window is 10 years. Displayed patterns were observed through the HP filter.

use a simplifying model to address some features of a complex system but take caution in its limitations.

To have a unifying picture, we may use the concept of market resilience which includes both dynamic instability in the form of persistent cycles and structural stability in the form of persistent trend.

4.3 Economic interruption and economic depression

We may classify a market crisis into two types: one is a large oscillation in a short time which was observed in the stock market crash in 1987 and dot com bubble (I. T. bubble) in 2000; another is a long and severe economic decline, such as the Great Depression in the 1930s and the recent Transition Depression in East Europe and the former Soviet Union (EEFSU).

We may call them disruption and depression alternatively.

4.3.1 Economic interruption and market resilience

When we study cases of great interruption, we are impressed by the remarkable resilience of quick recovery of market economy. The question is which model could explain market resilience after a great disruption. The American economy after World War II seems resilient under the Oil Price Shock and Stock Market Crash. How can we understand resilience in economic theory?

Among existing economic theories, the efficient market theory (theory of Brownian motion or random walk on Wall Street) is not qualified since an efficient market implies little possibility of large price movement or great interruption (Fama, 1970, 1991).

In contrast, the theory of fractal Brownian motion theory implies high frequency of large price movements or frequent interruptions, so that it leaves little room for market

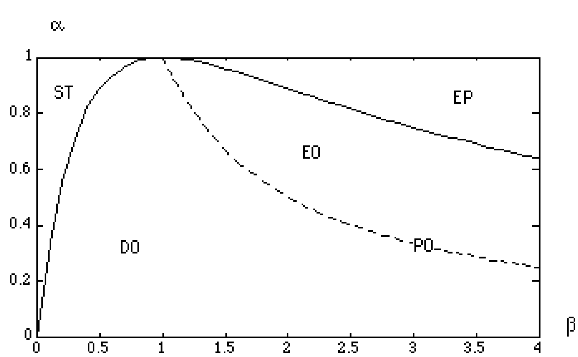


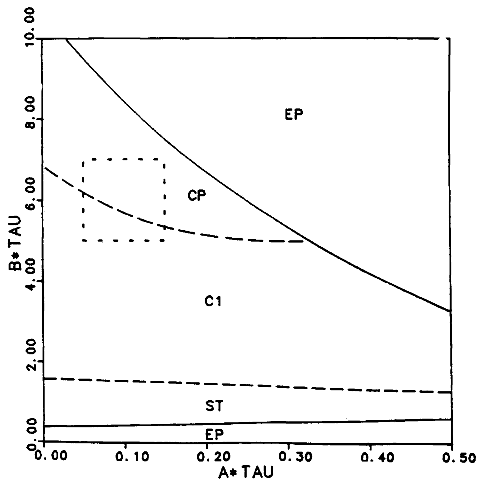
Fig. 8. Stability pattern of Samuelson model in parameter space (1939). Here, ST denotes the steady state; DO, damped oscillation; EO, explosive oscillation; EP, explosive solution; PO, linear periodic oscillation.

resilience (Mandelbrot, 1963). The popular model of unit root also has a big problem, since a small deviation from unit root in parameter space will lead to damping or explosive fluctuations (Nelson and Plosser, 1982). This is a common problem in linear dynamical models including the Samuelson model of the linear accelerator-multiplier, where a periodic regime PO exists only at the border between the explosive oscillation regime EO and the damping oscillation regime DO (see Fig. 8). So, we refer to both unit-root and periodic regime as fragile stability or structural instability in linear dynamics (Chen, 2005).

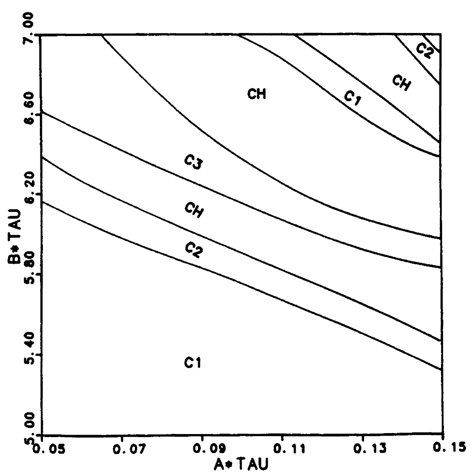
In contrast, structural resilience could be easily described by nonlinear dynamical models in a chaos regime. We have observed the frequency stability under large amplitude oscillations during the Oil Price Shock and the Stock Market Crash in Fig. 9. This feature of a narrow frequency band and erratic amplitude can be described by the colour chaos of a nonlinear oscillator in continuous time (Chen, 1988). The dynamical regimes for a nonlinear oscillator with soft boundaries in target control are shown in Fig. 9. In addition to the linear regime of steady state (ST), there are cyclic regimes C1 (one periodic cycle), C2 (two periodic cycles) and chaotic regimes CH with complex periodic cycles (CP).

From Fig. 9, we can see periodic and complex cycles occur in a bounded area in parameter space in a nonlinear dynamical model, not at a border line with zero area. When a parameter changes within the same regime, we may observe large amplitude changes but small frequency deviation, which resemblances the structural resilience in dynamic behavior. When parameter changes crosses the regime boundary, we will observe a qualitative change (in dynamical behavior) induced by a small change (in parameter), which is called “regime switch.” Therefore, a nonlinear dynamical model has better features of resilience with both structural stability and rich behavior.

We should point out that the so-called “butterfly effect” is also exaggerated. A popular story claimed that a flap of a butterfly’s wings in Brazil would set off a tornado in Texas. This claim is also a mathematical illusion without physics constraint, since it ignores the basic constraint of conservation of enrgy and remarkable feature of structural resilience of nonlinear dynamics under complex interactions between positive and negative feedbacks. A balanced understanding of deterministic chaos has two complementary aspects: on one side, it limits the time horizon of trajectory predictability (in the reverse order of the Liapunov exponent or in the order of de-correlation time) and is sensitive to initial conditions (or time history); on the other hand, its behavior is more rich and resilient than linear models (Chen, 1988, 2005). Evolutionary theory in biology and



(a). Parameter space for soft-bouncing oscillator



(b) The expanded regime in (a).

Fig. 9. The stability pattern in parameter space. Note: ST denotes the steady state; C1, C2, C3 are limit cycles of period one, period two, and period three respectively; CH, the chaos mode in continuous time. The complex regime CP is enlarged in (b) that includes alternative zones of limit cycles and chaos.

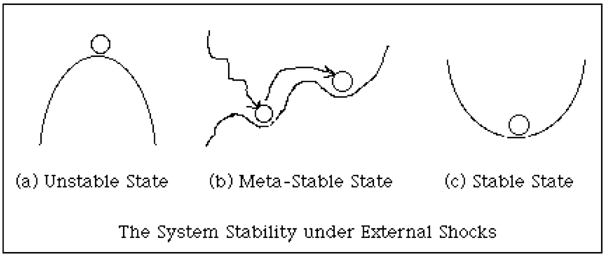


Fig. 10. Three types of system stability. Only the meta-stable state has both the limited stability and potential variability observed in a living system.

economics discover two remarkable features for living organisms: their structural stability and flexibility in adapting to environmental changes. More positive terms, such as biological clock, complex cycles, persistent fluctuations, and color chaos, are better describe different features of economic complexity.

4.3.2 Meta-stability in multiple equilibriums

Game theory has a conceptual problem of how to rank different equilibrium states when multiple or even infinite equilibrium states exist. The optimization approach within Hamiltonian framework is not capable of dealing with evolutionary dynamics. The co-existence of market resilience in economic interruption and market fragility in economic depression reminds us of the concept of meta-stability in quantum biology as shown in Fig. 10 (Schrödinger, 1944; Chen, 1990).

One possible scenario is that economic depression occurs during a series of shocks with complex causes, while economic disruption happens under a single shock with a simple cause. We may apply this perspective in later discussion of the Great Depression and Transition Depression.

5. Natural Experiments: Lessons from the Great Depression and Transition Experiments

Now, we can further examine historical events as natural experiments or case studies in historical perspective. We will study two issues: possible causes of economic instability and crisis; and the relation between economic growth and institutional changes. We will address these questions from comparative studies between EEFSU (Eastern Europa and the former Soviet Union) and China in transition economies.

We should point out that there is a major difference between the Great Depression in 1930s and the Transition Depression in 1990s. The Great Depression mainly occurred in industrial countries under a capitalist system. The Transition Depression emerged in EEFSU, but not in China and Vietnam, even though they have a similar transition from a planned economy to a market economy.

Basic facts about the Great Depression in 1930s and the Transition Depression in 1990s are given in Table 1 (Chen, 2005). We can see that the Transition Depression was more severe and longer-lasting than the Great Depression. This is especially true for former republics in Soviet Union (Table 2).

There were several possible factors contributing to the Great Depression: the stock

Table 1. Great Depression (1929–1942) and Transition Depression (1989–2016).
(Declined was measured by comparing with peak level as 100%)

Country	Decline (%)	Peak-Trough-Date	Recovery-Date	Length (yrs)
US	46.8	1929–1933	1942	14
UK	16.2	1930–1932	1939	10
France	31.3	1930–1932	1938	9
Germany	41.8	1928–1932	1933	6
Italy	33.0	1929–1933	1934	5
Japan	8.5	1930–1932	1935	6
East Europe	63	1989–2016	2016 (est)	27
USSR	47	1989–1998		
Poland	18	1989–1991	1996	7
Russia	43	1990–1998	2007	17
Ukraine	61	1990–1999	2011 (est)	21
East Germany industrial output declined 30% in 1991.				

[Note] Decline in the Great Depression was measured by industrial output (CRomer, 2004); and decline in the Transition Depression was measured by real GDP in constant 1990 dollar (United Nations, 2008). The average recovery rate was 5.8% for East Europe from 1998–2006. The estimated recovery time was estimated if the future growth rate could keep 6%.

Table 2. Russia's Economic Performance in 20th Century.
(Each period started with 100%)

Period Russia/USSR	1913–22 WWI&CW	1940–45 WWWII	1990–96 Transition
National Income	55.6	83.1	54.7
Industrial Output	31.0	91.8	47.5
Agriculture Output	66.3	57.0	62.5
Capital Investment	40.3	89.0	24.3

Source: Tikhomirov (2000).

market crash in 1929, banking panic, monetary contraction, first preserving then abandoning the gold standard, and the impact from World War I (Romer, 2004). One puzzling fact was that the United States had the longest and the most severe depression among industrial countries, while the US had the most advantages during World War I. Clearly, economic forces, rather than political factors, mainly contributed to the Great Depression in U.S. One possible cause was industrial concentration driven by the rise and saturation of the automobile industry in the U.S. where auto-related business accounts for about 16–18% of GDP in 1970s (Rostow, 1978). As seen from Fig. 3. American automobile industry already reached a mature stage in the 1920s. The credit contraction triggered by the stock market crash and banking crisis may have a tremendous impact on car sales.

In comparison, the recent transition depression in EEFSU revealed more clear pictures of economic depression. There are two advantages in studying transition depressions in the 1990s: first, the causes of transition depression is much simpler in theoretical analysis, since its international environment was much quieter than the situation before and during the Great Depression; second, there is a counter case of transition without depression in China, whose dual-track reform strategy provided sharp contrast with the shock therapy or so-called Washington Consensus. Therefore, transition experiments provide us with a better test of competing economic perspectives in studying instability and complexity in market economies (Chen, 2006). Basic facts in EEFSU and China during the economic transition from a planned economy to a market economy are given in Table 3.

Table 3. Economic Performance during Transition.
(Each period started from 100%)

Region	Date	1978	1989	1990	1998	2006
China		100	272	282	651	1327
			100	104	239	488
				100	230	471
East Europe		100	151	82.6	55.7	87.1
			100	54.7	36.9	57.7
				100	67.4	105
Russia			(100)	50.7	31.5	53.1
				100	57.4	96.6

Data source: United Nations Statistics (in constant 1990 dollar). Russia (1989) was estimated from USSR (1989).

We were surprised by the depth of the Transition Depression. The magnitudes of the Transition Depression were more severe than wars and the Great Depression in the US. More puzzlingly, China's open-door reform succeeded in very poor initial conditions with high population pressure, scarce resources, backward infrastructure, large regional disparity, low human capital, traditional culture, and underdeveloped institutions (mixed property rights and lack of rule of law). In contrast, China had sustained economic growth since 1978 at an average rate of 9% and increased to more than 1300% in 2006. How can we understand the historical events by economic reasoning?

Theoretically speaking, the shock therapy of price liberalization can be justified by the microfoundations theory in new classical macro economics, if the market could be characterized by unique and stable equilibrium in microeconomics. The free-trade policy is supported by ENGT if the development mechanism is a simple diffusion process by importing western technology and institutions. The bold policy of liberalization and privatization is also encouraged by the efficient market theory and Coase approach if institutional changes would quickly converge to optimal, regardless of initial conditions. We will see how these theories are far from reality.

5.1 Instability and complexity in price mechanism

Price mechanism is the central issue in economics. Belief in price stability is certainly behind the liberalization policy in price and foreign trade in EEFSU, while dual-track price system during China's transition was aimed at avoiding price instability. Historically, price control and quantity rationing are widely used in wars and crises for managing social stability, while price deregulation exists in peaceful environments.

Transition experiments clearly demonstrate price instability during economic transitions. There are several factors in the price mechanism: network structure, product cycles, and adjustment speed in price dynamics.

5.1.1 Price structure and network effect

One claim in an efficient market hypothesis is that price contains all information. The rational expectations school further believes that people will forecast price movements correctly by using market information efficiently. However, we observed a great variety of price inflation from transition countries (Table 4).

It was a well-known story of Ludwig Erhard, then Economic Minister in West Germany, who created a miracle in 1948, when the market prospered after price liberalization overnight from the ruin of World War II (Dornbusch, 1993). Why did the price mechanism fail to make more magic in transition economies? The best case scenario for shock therapy was not Poland where there was "shock without therapy" but

Table 4. Peak Inflation Rate during the Transition.
(Measured by the implicit price deflator in national currency)

Country	Peak Inflation (%) (Year)	Length of High Inflation (>40%)
China	13 (1988), 20 (1994)	0
E. Germany	9 (1990)	0
Poland	400–581 (1989–90)	5 yrs (1988–92)
Bulgaria	334–1068 (1991–97)	7 yrs (1991–97)
Romania	295–300 (1991–92)	9 yrs (1991–2000)
Ukraine	3432 (1993)	6 yrs (1991–96)
Russia	1590–4079 (1992–93)	8 yrs (1991–98)

Data source is the United Nations Statistics Database.

East Germany (Kolodko, 2000; Chen, 2006). West Germany offered a generous exchange ratio of a 1 (East German Mark) to 1 (West German Mark) exchange rate to East German residents, while the black market exchange rate was about 5–20 to 1. The monetary union induced high hopes of economic progress when it started in July 1990. Instead, East German output fell more than 50% from the 1989 level in just 6 months, and the unemployment rate rose from near zero to above 20% in many sectors. Several thousands of East German firms closed. East Germany received the largest financial aid in history from West Germany, which was about 65% of East Germany's real GDP from 1991 to 1998 (von Hagen and Strauch, 2001). In comparison, the Marshall Plan to West Germany after World War II was much less than 5% of its National Income. The East German population declined 10% in 5 years after 1990.

The causes of East Germany's decline were quite simple. First, German monetary union broke the traditional trade networks of East Germany with CMEA (Council for Mutual Economic Assistance) countries that had little hard currency for trade. Second, trade liberalization gave little space for East German firms in adapting new market environment, so that East German firms lost both international and domestic market at the same time. Third, East German workers lost their competitiveness when German unions demanded premature wage convergence ahead of productivity growth. In short, East German industries suffered tremendous loss after monetary union and trade liberalization.

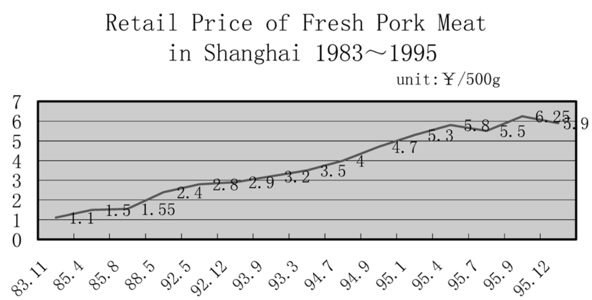
The negative impact of price and trade liberalization was more severe in the former Soviet Union than in East Europe, since the network effect was more significant for vertical integrated industries in the former Soviet Union.

5.1.2 Product cycle and adjustment speed

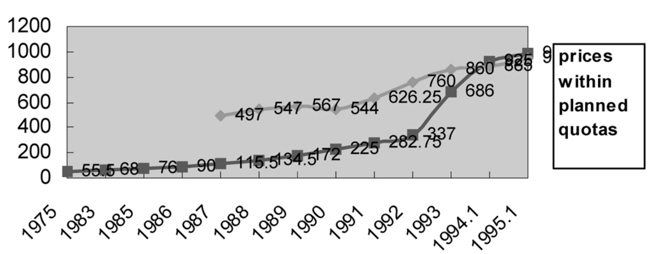
Transition experiments also provided important information on adjustment speed in price fluctuations.

Diversified patterns were observed during China's dual-track price reform. The most rapid price convergence and output growth was achieved in the market for farm products such as meat and vegetables. Foodstuff prices did increase initially; but several months later, the prices quickly stabilized or even fell after a rapid growth in farm supply. For basic goods such as grain and cotton, price controls were on and off for more than 10 years, and never fully liberalized. The prices of industrial products were rapidly liberalized and deflation for consumer goods and luxury products occurred caused by hot competition. However, market liberalization for basic consumption goods was much slower. The prices for energy, utility, education, and health are still under tight control despite a persistent trend of price inflation, since their supply falls far behind social demand when income grows rapidly (see Fig. 11).

These differences can be easily understood by differences in lengths of product and



(a)



(b)

Fig. 11. Price History in China's Shanghai Local Market. (a) Fresh pork meat price in the retail market (1983–1995). (b) Heavy oil dual-track price in the industrial market (1975–1995).

investment cycles: agricultural product cycles are typically several months, industry investment cycles vary from months to years. Building education and infrastructure may last decades.

From these observations, we could say the Arrow-Debreu model is more relevant to atomic agriculture than industrial economy. Product cycles and price complexity can be understood from roundabout production in division of labor (Hayek, 1935).

5.2 Macro foundation of micro behavior and soft-budget constraints in financial market

The causal relation between micro and macro is an open issue in economics. There are three implications from microfoundations theory for macro and development policy. First, equilibrium pricing is the best mechanism for efficiency and growth. Second, privatization is a pre-condition of market-oriented reform. Third, cutting government assistance to firms may improve SOE (State-Owned Enterprise) efficiency under the doctrine of so-called hard-budget constraints. These assumptions are essential in promoting liberalization, privatization, and stabilization programs. We will see that these policies are directly responsible for economic declines in EEFSU.

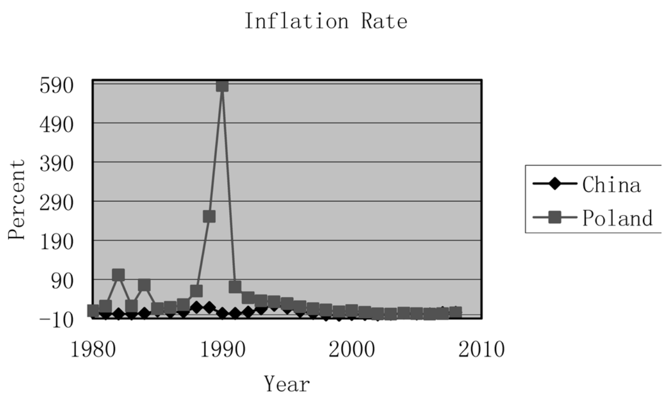
5.2.1 Equilibrium pricing vs. disequilibrium growth in transition strategies

The striking difference in reform policy is revealed from equilibrium and disequilibrium strategy in price mechanism and growth dynamics. Both China and EEFSU started their economic reform and transition from shortage economies. Clearly, you have two possibilities to eliminate shortage: you may increase supply with a disequilibrium policy for growth, or you may reduce demand with an equilibrium policy for the re-allocation of resources.

From Chinese historical experience, shortage results from insufficient supply constrained by resource and productivity. Therefore, China's economic reform started with technology imports in the industrial sector and an incentive mechanism (in the form of a family contract system) in the rural sector. High economic growth was achieved under a slowly converging dual-track price system for three decades. As result, China has improved people's living standard and increasing savings and investment rapidly.

In contrast, price liberalization under shock therapy created tremendous inflation and currency devaluation that simply wiped out people's saving under the socialist system. High unemployment and increasing poverty emerged during the transition depression in EEFSU.

Shock therapists argued that price equilibrium improves economic efficiency by reducing waiting time under a shortage economy. This argument raises a fundamental



(a) Inflation rate in China and Poland during transition

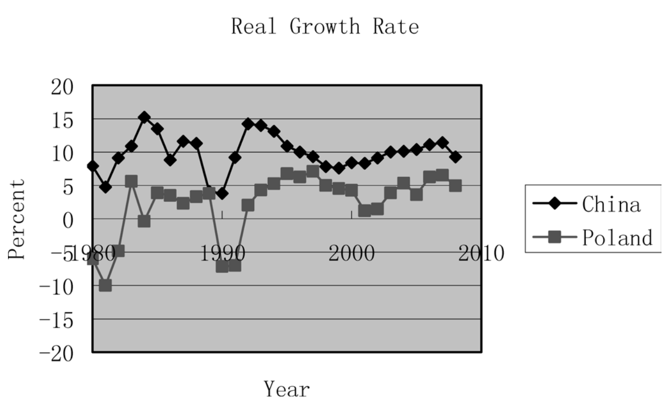


Fig. 12. A comparison in macro stability and growth in China and Poland during transition.

question about the social meaning of economic efficiency. Neoclassical economics implicitly assumes that price equilibrium in micro is associated with growth in macro. This assumption is not true from the transition process (Fig. 12).

We can see that China's average growth rate was much higher than Poland's while China's inflation rate was much lower and more stable than Poland's. These facts told the simple story that disequilibrium growth strategy under stable macro foundations was socially more desirable than equilibrium laissez-faire policy under unstable micro foundations.

A more visible case is the rapid expansion of China's export and technology

Table 5. Devaluation of Currency (Exchange Rate set at 1980 or 1991).

Year	1980	1985	1990	**1991**	1993	1995	2000
China	**1**	1.96	3.19	3.55	3.85	5.57	5.52
Germany	**1**	1.62	0.89	0.91	0.91	0.79	1.17
Czech			0.77	**1**	1.04	0.95	1.38
Slovakia			0.61	**1**	1.04	1.01	1.56
Hungary	0.44	0.67	0.85	**1**	1.23	1.68	3.78
Poland		0.01	0.90	**1**	1.71	2.29	4.11
Bulgaria				**1**	1.55	3.78	0.12
Romania	0.22	0.24	0.29	**1**	9.95	26.62	284
Belarus			0.51	**1**	191	47937	108
Russia				**1**	195	897	5534
Ukraine			0.5	**1**	634	20602	76087

The exchange rates are measured against the dollar. All exchange rates are re-scaled by the base year, which are 1980 for Germany and China and 1991 for the rest. Data source: Penn World Table 2002.

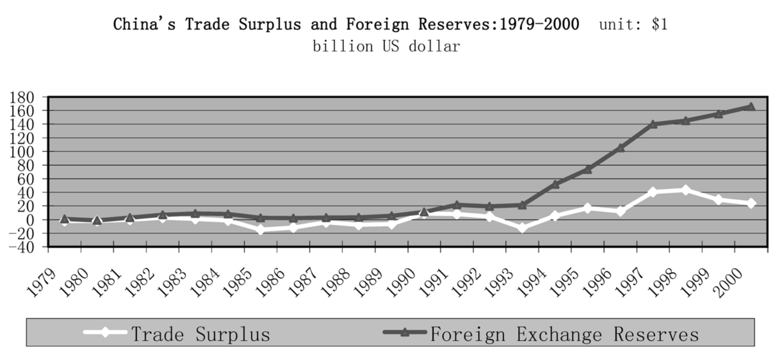


Fig. 13. China's Trade Surplus and Foreign Reserves.

Data Sources: China Statistics 2001.

advancement. Let us study the magnitude of currency devaluation during transition in Table 5.

It seems that tremendous currency devaluation in Romania and the former Soviet Union was caused by political instability. The lost value of effective government can be seen from the sheer magnitude of currency devaluation in the former Soviet Union. For example, from 1990 to 1998, real GDP measured by the 1990 US Dollar declined 43% for Russia and 61% for Ukraine, but their currency depreciated 5534 and 76087 times respectively!

Both China and Central European countries such as Czech and Poland maintained currency stability with two differences: China managed its currency stability by managing foreign trade and controlling capital accounts without large scale foreign assistance; China also rapidly turned from trade deficits into trade surplus as shown in Fig. 13.

The interaction between macro growth and micro adjustment can be seen from the slow price convergence in the foreign currency market. China's dual exchange rate system lasted 15 years, which started in 1980 when the trade deficit was $1.8 billion and ended in 1995 when the trade surplus reached $5.4 billion in 1994. China's foreign reserves also increased from $800 million in 1979 to $51.6 billion in 1994 and more than $1.6 trillion in 2008. Within this period, China's export growth rate was 26%, more than double the real GDP growth rate of 9.5%. As observed by a leading Polish economist, "the more rapid the liberalization of trade, the bigger the initial shock and the deeper the ensuing recession" (Kolodko, 2000).

5.2.2 Hard-Budget constraints for firms and the credit crunch during recession

One influential theory in transition economics is that of so-called soft budget constraints by the Hungarian economist Kornai, who wrongly blamed the state subsidy as the cause of the inefficiency of state firms (Kornai, 1979, 1986). This logic is true only for a closed economy but not true for an open economy with innovation competition. In industrial societies, soft-budget constraints widely exist in various forms, including bank credit, venture capital, and bankruptcy laws. The Long-Term Capital and rescue effort in the recent sub-prime loan crisis are well-known example of soft-budget constraints in the US. In practice, the credit crunch by imposing "hard budget-constraints" is an additional cause of the output decline in EEFSU (Calvo and Coricelli, 1992).

China's rapid economic growth during transition made a good example of growth under soft (but creative) budget constraints (Chen, 2005). When open-door policies introduce international competition to domestic firms, the critical choice is how to upgrade technology for a domestic firm's survival. Access to bank credit and capital market is crucial to a firm's survival in a globally competitive market. China's rapid technology progress benefited by state-insurance during a learning process. A farmer's down-side risk is protected by collective ownership of land. China's public workers were encouraged by state policy, which preserved positions for those in business adventures. Whether China's growth under soft budget-constraints can be continued, the answer does not depend on the cost of soft budget constraints, but the productivity gain over the social cost. China's growth-oriented development strategy is a new type of Keynesian policy for encouraging innovation, while the Kornai policy of hard-budget constraints in the name of stabilizing program was simply a new form of counter-Keynesian-revolution.

Theoretically speaking, the theory of soft-budget constraints is a naïve exercise in microeconomics, but a dubious theory in macroeconomics. If the survival of large numbers of socialist firms only depends on state subsidies, socialist countries would have much higher inflation than market economies; this is not true historically. Persistent budget deficits and hyper inflation rarely occurred in planned economies but frequently occurred in market economies such as in Latin America. Kornai made a misleading diagnosis of the planned economy. As Schumpeter pointed out, capitalism is driven by innovation, which is intrinsically unstable. Socialism is more stable in a closed society. The main weakness of planned economies is not economic inefficiency but stagnation of technology resulting from the closed-door policy in the Stalin era.

5.3. Structure of mixed economies and essence of institutional changes

Two ideas behind privatization policy: private ownership was the optimal form and a private property rights system is a precondition for a successful market economy. The rise of the Chinese economy under mixed property rights sheds new lights on the proper structure of mixed economies and basic lessons in institutional changes. New institutional economics based on Coase theory and the property rights school has one implicit implication: the Anglo-Saxon system of a capitalist economy is the optimal institution, so that world development converges on this system regardless of ecological and historical conditions. We will see this belief is challenged by transition experiments.

5.3.1 Trade-Offs between private and non-private economies

Samuelson pointed out that the essence of a market economy is a mixed economy (Samuelson, 1969). However, after the fall of the Berlin Wall in 1989, there was a wide

Table 6. World Economy, Historical Statistics.
(Annual average compound rate of GDP growth)

	WEuro	EEuro	Asia	US	Japan	fUSSR	China
1913–50	1.19	0.86	0.82	2.84	2.21	2.15	−0.02
1950–73	4.79	4.86	5.17	3.93	9.29	4.84	5.02
1973–2001	2.21	1.01	5.41	2.94	2.71	−0.42	6.72

Source: Maddison (2007) at http://www.ggdc.net/Maddison/
Asia data excluded Japan.

belief that the collapse of the Soviet Union signaled the superiority of private ownership. The success of China's economic transition stimulated us to have a second look at historical facts (see Table 6).

There is no empirical evidence that a socialist economy is less efficient than a capitalist economy. Yes, the US did best in 1913–1950 and Japan did best in 1950–1973 under favorable international conditions. Socialist economies performed above average in 1950–73 and China did best in 1970–2001. It was more likely that political rather than economic causes led to the collapse of the former Soviet Union.

From the view of the property rights school, both SOEs and TVEs have no clearly defined property rights. In financial practice, shares of local governments could enhance a firm's credit for a bank loan. Certainly, growth under soft-budget constraints does have costs in the form of non-performing loans (NPL) accumulated in state banks. China's growth under soft-budget constraints creates a trial and wins through informal privatization: if SOEs or TVEs succeed in new product markets, you privatize it; when you fail, the state own banks absorb a large financial cost. In this way, China's state sector took the main cost in technology learning and business ventures generated in the non-state sector. The NPL contains both components of efficiency loss and social burden. The recent estimation of China's NPL of state banks was about 2.1 trillion RMB or $300 billion dollars. After restructuring and IPO, China's state banks created more social value above the cost, which was about 1 trillion RMB or $140 billion (New Beijing News, March 6, 2008). In contrast, East German industry had much better technology and human resources than China in its initial condition. Before German unification in 1990, total asset value of East German SOEs was estimated in the range of several hundred billion DM. After rapid privatization under Treuhand, a state agency directed by West German officials, the total loss was $200 billion in 5 years (Stack, 1997).

China's booming economy is characterized by strong competition among all types of ownership structures, including private, collective, state, foreign, and joint-stock firms. Even in advanced technology such as the automobile industry, more than a dozen newly emerged private and local state companies are successfully competing with multinational companies in domestic and international markets.

One important lesson from transition is the priority between competition policy and privatization policy. China greatly improved competitiveness and efficiency by breaking the state monopoly into competing state firms before transforming them into joint-stock companies. Notable examples are China Airlines and the China People's Bank, which were broken up into several competing firms. But many of Russia's giant state monopoly firms came to be owned by private oligarchs after privatization. As a result, China attracts more foreign direct investments because China's market is more open and competitive than EEFSU.

The Washington Consensus did compile a large to-do list including public investment in healthcare, education, and infrastructure but failed to consider how to finance them in developing countries (Williamson, 1990). Sachs complained that insufficient aid was the ultimate cause of poverty and failure of shock therapy (Sachs, 2005). China's innovation in public financing is selling user right while preserving public ownership of land, which creates increasing public assets during economic growth. American strength in R&D is based on its land-grant state universities. By the same token, China's labor is not cheap if you count the tremendous training cost in transforming farm kids into skilled workers and technicians. China's competitiveness in the global market is a low-cost social security system based on collective ownership of land for farmers and infrastructure investment financed by state-owned land rent in cities (Chen, 2006). Wholesale privatization in EEFSU not only created a large scale of unemployment and poverty, but also shrunk state ability in maintaining macro stability and public investment.

5.3.2 The driving force of institutional changes: Top-Down Design vs. Decentralized Experiments

The logic of rapid privatization was political rather than economic. Market fundamentalists argued that creating a capitalist class was a precondition to establish market institution (Shleifer, 2005). Unfortunately, creating oligarchs as well as mass poverty created more public enemies than political supporters in economic transition. China's market-oriented reform won more public support than EEFSU simply because the majority of China's people rapidly improved their living standard while EEFSU suffered significant decline in living standard and even life expectancy.

One visible dilemma is the top-down design approach by market fundamentalists who claim a belief in decentralized competition, while China's decentralized experiment in economic reform was conducted under a centralized government. The main difference is: market fundamentalists believe they have perfect knowledge on optimal-universal market institutions, but Chinese leaders realized that they knew little about a working market model under China's historical constraints. The real issue in transition economics is not reform speed and sequence as in the debate between shock therapy and gradualism. The central issue is about the nature or driving force of institutional changes.

Two examples show the nature of institutional changes. One big mistake for East

German worker unions was the premature demand for a wage standard close to West German workers before increasing their productivity. The outcome was loss of their competitiveness to East European workers. Another problem is German regulation pro existing giant firms but discouraging innovation from small firms. This is an important reason that German industry fell behind American and Japan in newly developed industries such as the Internet and digital equipment. China's new industries rapidly emerged in SEZ (Special Economic Zone) simply because they are not bounded by obsolete regulation and are supported by innovative local governments. There is no equal and fair competition under complex regulation in division of labor. The issue is the asymmetric nature of the selection mechanism. China's priority is pro innovation for job creation and technology advancement, while the Washington Consensus looks like pro law and order. In fact, multi-national companies are the real winners of liberalization and privatization in EEFSU, even at long-term costs for the western world as a whole.

The tremendous costs of Transition Depression stimulated another way of thinking: social evolution is more like biological evolution, which is a divergent process characterized by bifurcation trees. There is no universal model in a market system. In addition to the Anglo-Saxon model, we already witness the emergence of a Germany-Japan model, a Scandinavia model (Hall and Soskice, 2001), and perhaps a China model in near future.

6. Evolutionary Perspective as a Better Alternative in Theoretical Foundation of Economics

From the above discussion, we can clearly see that simple models in equilibrium economics are not capable of characterizing the main features of a market economy, such as persistent cycles and creative destruction. The equilibrium illusion of market equilibrium and institutional convergence was created by linear models and representative agents without nonlinear interaction and collective behavior. The main pillars of equilibrium beliefs, such as the Frisch model of noise-driven cycles, the Lucas model of microfoundations, and the Coasian world of zero transaction costs are mathematical illusions that violate basic laws in biophysics and mathematics.

There was a wrong perception that evolutionary economics is not scientific since it mainly counts on historical interpretation and philosophical arguments. Now, we can see that the advancement of nonlinear dynamics and complexity science provides powerful tools not only in empirical analysis but also theoretical modeling. Here, we propose a preliminary outline for further development.

6.1 Biophysical foundation and mathematical framework

Economic systems are dissipative system in nature. An optimization approach based on a Hamiltonian framework should shift to evolutionary dynamics with nonlinear resources and market constraints. Asymmetric preference in micro behavior, social interaction in financial markets, persistent cycles and fluctuations in macro, and path-dependence in historical evolution are nonlinear phenomena that must be considered in theoretical analysis. Oversimplifying concepts in equilibrium economics, such as unlimited want in utility function, perfect information, zero-transaction costs, perfect markets, perfect foresight, or rational expectations, should be analysed and eventually abandoned in textbook economics, since they are not only impossible for finite life with finite resources or finite ability to process information, but also dangerous as policy guidance. Existing anomalies in equilibrium theory, such as scale economy, collective behaviour, persistent unemployment, large fluctuations, and economic crisis, can be better understood by economic complexity with ecological constraints and social interactions.

In mathematical economics and econometric analysis, new analytical tools should be introduced to economics students, including nonlinear non-stationary time series analysis in frequency domain, nonlinear dynamics, wavelets, statistical mechanics, and network models. Continuous-time models and differential equations are better than discrete-time models and algebra equations in dynamic modelling. Economic thinking in mathematics faces a revolutionary transition from the pre-Newtonian era (in the sense of discrete time) and low-dimensional Euclidean geometry, such as Edgeworrth box and linear demand-supply curves, to complexity science, including nonlinear dynamics, high-dimensional non-Euclidean space, network, and new algorithms in signal processing.

In empirical analysis, there is no such thing as perfect information. The critical issue is asking pertinent questions and designing proper filters to select relevant information, so that a better dialogue between theoretical modeling and empirical observation can be fruitful in decision-making. The better analytical base function for time series analysis is the logistic wavelet rather than the noisy pulse.

For academic economists, a fundamental shift in theoretical tastes is essential for advancement of economic science. In the era of complexity science, we have a rare chance to find an analytical solution for nonlinear systems. Computer simulation and graphic representation will play an increasing role in theoretical and empirical analysis. Economic study cannot be simply judged by mathematical simplicity or logical beauty without empirical support and theoretical relevance. Many policy discussions in textbook economics are based on the concept of so-called market distortion by regulation, which is operating in an economic vacuum without ecological constraints, macro fluctuations, international competition, and social interactions. A better approach is studying market interactions with both positive and negative feedback loops, which are familiar in system dynamics but rarely used in atomic economics.

6.2 Three levels of economic structure: micro-meso-macro in economic organism

The microfoundations approach, a two-level micro-macro model, is not capable of understanding large and persistent business cycles and financial crisis. A three-level model of micro-meso (financial intermediate and industrial organization)–macro is a better framework for policy analysis.

A critical issue is proper time scale in economic analysis. Currently, the time scale in micro analysis is static; financial analysis ranges from an extremely short time-window such as seconds in econophysics to several decades in corporate finance; macro analysis mainly studies the range of business cycles about 2–10 years to a so-called long-run equilibrium of a hundred years. In our framework, macro research should extend the time scale from business cycles to ecological cycles from decades to a thousand years, which is necessary to study interactions between population, resources, technology, culture, and economic policy. Micro and meso research should focus on business cycle periods for studying micro behaviour under business cycles and financial constraints. The most difficult is the meso level. Financial economics cannot be confined within a closed economy. Interactions among trends, cycles, and fluctuations are needed in understanding alternative value creation and bubble collapse in boom and bust cycles.

6.3 Unsolved problems in theory and policy

The best way to advance empirical science is addressing unsolved problems, which are fundamental for the next generation of economists. New questions may open a new field for economic study.

6.3.1 Population dynamics with resource constraints and culture factors

The question of why some countries are rich and some poor is a naive question within a short historical perspective. A more fundamental question is how to build a sustainable economy with peace and prosperity. Wealth is a function of resources, technology, and population. Currently, developed countries have a high living standard but an aging and even shrinking population; while developing countries have young and growing populations with diminishing job opportunities.

Many factors may have a profound impact on population dynamics: culture orientation, resource limitation, women education, healthcare system, economic incentive, income distribution, welfare system, world trade, and immigration. The difficulty is: this is a global problem which cannot be solved by national policy. Failure in international coordination in population policy may increase conflicts, crisis, and war under the intensive pressure of an environmental crisis.

6.3.2 Trend-Cycle separation in growth dynamics and scenario analysis in production, distribution, and development

Microeconomics is started with resource allocation under perfect competition. Economic efficiency is represented as static equilibrium under a fixed market price. The static concept of market efficiency cannot be distinguished from the equilibrium trap in underdevelopment with numerous primitive producers without scale economy in division of labour. The concept of Pareto efficiency simply denies the needs of social reform when poverty results from a large disparity in wealth distribution.

Both in developing and developed countries, an important question in macro policy and institutional arrangement is studying trend-cycle relations in macro dynamics. New classical macroeconomics considers all types of cycles are waste, while Schumpeter realized the positive aspect of creative destruction. Keynesian economics mainly concerns stabilization policy while development and supply-side economics pays more attention to growth. The real issue is trade-offs between growth trends and cyclic instability under ecological and historical constraints. Prescott reinvented the HP filter, which separates a nonlinear smooth trend with cycles in 2–10 years (Hodrick and Prescott, 1997). Schumpeter identified three different cycles. Further decomposition business cycles with sector analysis may reveal deep structure changes driven by technology wavelets, which may shed more light on development policy based on technology metabolism (Chen, 2005).

6.3.3 Pricing strategies and price-expectation dynamics

The textbook micro theory of marginal pricing is rarely observed in economic activity. Cost plus pricing is widely used under financial constraints. Strategic pricing has many varieties for increasing market-share, establishing entry barriers, or brand building. Interaction between image shaping and price trend is critical in price-expectation dynamics, which is observed in an IPO in financial markets.

6.3.4 Origin of the coordinated hand and disciplined hand

In contemporary industrial society, the invisible hand rarely functions even in developed countries. The real issue is how to deal with market failure and government failure under economic complexity. The more relevant question is the origin of the coordinated hand for market and disciplined hand for government, including culture norms, regulation mechanisms and their trade-offs. A culture norm may develop mutual trust and cooperative behavior or discourage innovation or competition. Regulation needs a careful balance in promoting stability and innovation. Multi-factor analysis in a short and long time perspective is needed in institutional study, mechanism design and experiment. Coordination and interactions among market, government, and civil society may be a better mechanism than antagonism between market and government or checks and balances among competing interest groups. Evolutionary dynamics with asymmetric constraints and asymmetric behavior may provide a better alternative than game theory based on symmetric rule and symmetric information.

6.3.5 Rethinking human nature and economic wellbeing

The human is a social animal with limited material wants and unlimited intellectual capability because human activity is subject to the biological constraints of finite life but an essentially infinite combination of human characters. The real challenge for economics is to define a sustainable system in ecology and choice range for the welfare of the majority of people, not just a few. Current technology is capable of feeding the world population, but current incentive mechanisms and rules of the game cannot maintain peace and prosperity. A new trinity is needed for a proper balance among private, government, society (including NPO and NGO) in a mixed economy, and a new international order for rich and poor countries. For developing a diversified global economy, a more realistic issue is developing an open global economy with diversified culture and economic systems, where varying types of regulation in trade, capital, immigration, and welfare systems may compete and co-evolve in a more constructive way.

Western civilization made great contributions in developing science and technology. However, it also created tremendous uncertainty regarding ecological and cultural systems. A new dialogue and experiments among different civilizations is needed for a new economy and a new science of complexity.

7. Conclusion

Neo-classical economics laid down the starting base in mathematical economics and econometric analysis, which are useful in explaining simple phenomena in a short time window but limited as policy guidance or strategic choice. Lessons from the Transition Depression told us that equilibrium thinking created idealized illusions for free trade and laissez-faire government but few solutions in dealing with market instability and social problems. A new science of complexity will devote more effort for studying nonlinear dynamics and non-equilibrium mechanisms, which are new tools for better understanding economic development and social evolution.

References

Arrow, K. J. (1962) "The Economic Implications of Learning by Doing," *Review of Economic Studies* 39: 155.

Arrow, K. J. and G. Debreu (1954) "Existence of an Equilibrium for a Competitive Economy," *Econometrica* 22. 3: 265–290.

Barnett, W. A. and P. Chen (1988) "The Aggregation-Theoretic Monetary Aggregates Are Chaotic and Have Strange Attractors: An Econometric Application of Mathematical Chaos," in W. Barnett, E. Berndt, and H. White (eds) *Dynamic Econometric Modeling*, Cambridge University Press, Cambridge, pp. 199–246.

Becker, G. (1991) "A Note on Restaurant Pricing and Other Examples of Social Influences on Price," *Journal of Political Economy* 99: 1106–1116.

Black, F. and M. Scholes (1973) "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 81: 637–654.

Brillouin, L. (1962) *Science and Information Theory*, Academic Press, New York.

Calvo, G. and F. Coricelli (1992) "Stabilizing a Previously Centrally Planned Economy: Poland 1990," *Economic Policy* 14: 175–208.

Carter, S. *et al.* (eds) (1997) *Historical Statistics of the United States, Colonial Times to 1970 Bicentennial Edition*, Cambridge University Press, New York.

Chen, P. (1987) "Origin of the Division of Labor and a Stochastic Mechanism of Differentiation," *European Journal of Operational Research* 30: 246–250.

——— (1988) "Empirical and Theoretical Evidence of Monetary Chaos," *System Dynamics Review* 4: 81–108.

——— (1996a) "A Random Walk or Color Chaos on the Stock Market?–Time-Frequency Analysis of S&P Indexes," *Studies in Nonlinear Dynamics & Econometrics* 1.2: 87–103.

——— (1996b) "Trends, Shocks, Persistent Cycles in Evolving Economy: Business Cycle Measurement in Time-Frequency Representation," in W. A. Barnett, A. P. Kirman, and M. Salmon (eds) *Nonlinear Dynamics and Economics*, Cambridge University Press, pp. 307–331.

——— (1999) *The Frisch Model of Business Cycles–A Spurious Doctrine, But a Mysterious Success, IC*^{2} Working Paper 99-05-01, University of Texas at Austin.

——— (2002) "Microfoundations of Macroeconomic Fluctuations and the Laws of Probability Theory: the Principle of Large Numbers vs. Rational Expectations Arbitrage," *Journal of Economic Behavior & Organization* 49: 327–344.

——— (2005) "Evolutionary Economic Dynamics: Persistent Business Cycles, Disruptive Technology, and the Trade-Off between Stability and Complexity," in K. Dopfer (ed) *The*

Evolutionary Foundations of Economics, Cambridge University Press, Cambridge, pp. 472–505.

——— (2006) "Market Instability and Economic Complexity: Theoretical Lessons from Transition Experiments," in Y. Yao and L. Yueh (eds) *Globalisation and Economic Growth in China* World Scientific, Singapore, pp. 35–58.

——— (2007) "Complexity of Transaction Costs and Evolution of Corporate Governance," *Kyoto Economic Review* 76. 2: 139–153.

Cheung, S. N. S. (1998) "The Transaction Costs Paradigm," *Economic Inquiry* 36: 514–521.

Coase, R. H. (1937) "The Nature of the Firm," *Economica* 4.16: 386–405.

——— (1960) "The Problem of Social Cost," *Journal of Law and Economics* 3.1: 1–44.

——— (1988) *The Firm, the Market, and the Law*, University of Chicago Press, Chicago.

De Long, J. B., A. Shleifer, L. H. Summers and R. J. Waldmann (1990) "Positive Feedback Investment Strategies and Destabilizing Rational Speculation," *Journal of Finance* 45. 2: 379–395.

Dessing, M. (2002) "Labor Supply, the Family and Poverty: the S-shaped Labor Supply Curve," *Journal of Economic Behavior and Organization* 49. 4: 433–458.

Dopfer, K. (2005) *The Evolutionary Foundation of Economics*, Cambridge University Press.

Dornbusch, R. (1993) "The End of German Miracle," *Journal of Economic Literature* 31.2: 881–885.

Engle, R. F. and C. W. J. Granger (1987) "Co-integration and Error-correction: Representation, Estimation and Testing," *Econometrica* 55: 251–276.

Fama, E. F. (1970) "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance* 25: 384–433.

——— (1991) "Efficient Capital Market II," *Journal of Finance* 46. 5: 1575–1617.

Friedman, M. (1953) "The Case of Flexible Exchange Rates," in M. Friedman (ed) *Essays in Positive Economics*, University of Chicago Press, Chicago, pp. 157–203.

——— (1961) "The Lag in Effect of Monetary Policy," *Journal of Political Economy* 69. 5: 447–466. [see page 454 on two choices of detrending; in M. Friedman (ed) (1969) *Optimal Quantity of Money and Other Essays*. Aldine, Chicago.]

Frisch, R. (1933) "Propagation Problems and Impulse Problems in Dynamic Economics," in *Economic Essays in Honour of Gustav Cassel*, George Allen & Unwin, London, pp. 171–206.

——— (1981) "From Utopian Theory to Practical Applications: The Case of Econometrics," *American Economic Review* 71. 6: 1–16.

Galbraith, J. K. (2008) "Inequality, Unemployment and Growth: New Measurement for Old Controversies," *Journal of Economic Inequality* (in press). [also see: University of Texas Inequality Project working paper (http://utip.gov.utexas.edu)]

Hall, P. and D. Soskice (2001) *Varieties of Capitalism*, Oxford University Press, Oxford.

Hansen, G. D. and E. C. Prescott (2002) "Malthus to Solow," *American Economic Review* 92. 4:

1205–1217.

Hao, B. L. (1990) *Chaos II*, World Scientific, Singapore.

Hayek, F. A. (1935) *Prices and Production*, Routledge, London.

Hodrick, R. J. and E. C. Prescott (1997) "Post-War US. Business Cycles: An Empirical Investigation," *Journal of Money, Credit, and Banking* 29. 1: 1–16.

Kolodko, G. W. (2000) *From Shock to Therapy: The Political Economy of Postsocialist Transformation*, Oxford University Press, Oxford.

Kornai, J. (1979) "Demand versus Resource Constrained Systems," *Econometrica* 47.4: 801–819.

——— (1986) "The Soft Budget Constraints," *Kyklos* 39. 1: 3–30.

Kydland, F. E. and E. C. Prescott (1990) "Business Cycles: Real Facts and a Monetary Myth," *Federal Reserve Bank of Minneapolis Quarterly Review* 14: 3–18.

Lentief, W. W. (1936) "The Fundamental Assumption of Mr. Keynes' Monetary Theory of Unemployment," *Quarterly Journal of Economics* 51: 192–197.

Lucas, R. E. Jr. (1972) "Expectations and the Neutrality of Money," *Journal of Economic Theory*, 4: 103–124. [also in Lucas (1981).]

——— (1981) *Studies in Business-Cycle Theory*, MIT Press, MA: Cambridge.

——— (1988) "On the Mechanics of Economic Development," *Journal of Monetary Economics* 22: 3–42.

Maddison, A. (2007) *The World Economy: A Millennial Perspective/Historical Statistics*, OECD: Development Center Studies.

Marshall, A. (1920) *Principles of Economics*, 8th ed., Porcupine, Philadelphia.

Minsky, H. P. (1985) "The Financial Instability Hypothesis: A Restatement," in P. Arestis and T. Skouras (eds) *Post Keynesian Economic Theory*, Sharpe.

Münter, M. and R. Sturm (2005) "Economic Consequences of German Unification," in W. Gellner and J. D. Robertson (eds) *Berlin Republic: German Unification and a Decade of Changes*, Frank Cass, London.

Nelson, C. R. and C. I. Plosser (1982) "Trends and Random Walks in Macroeconomic Time Series, Some Evidence and Implications," *Journal of Monetary Economics* 10: 139–162.

New Beijing News (2008) "China's State Bank Reform under Central Bank: Costs 2.1 trillion Yuan, Generated Benefits 1 trillion Yuan in 4 years," March 6, 2008) at: http://finance.sina.com.cn/roll/20080306/02062047268.shtml

Prigogine, I. (1984) *Order Out of Chaos*, Bantam, New York.

Qian, S. and D. Chen (1996) *Joint Time-Frequency Analysis*, Upper Saddle River Prentice-Hall, NJ.

Romer, C. D. (2004) "Great Depression," *Encyclopedia Britannica*, Chicago.

Romer, P. M. (1986) "Increasing Returns and Long-Run Growth," *Journal of Political Economy* 94: 1002–1038.

Ross, S. (1976) "Return, Risk, and Arbitrage," in I. Friend and J. Bicksler (eds) *Risk and Return in Finance*, Ballinger, Cambridge, pp. 189–218.

Rostow, W. W. (1960/1990) *The Stages of Economic Growth*, Cambridge University Press, Cambridge.

——— (1978) *The World Economy: History & Prospect*, University of Texas Press, Austin, p. 675.

Sachs, J. D. (2005) *The End of Poverty*, Penguin Books, New York.

Samuelson, P. A. (1939) "Interactions between the Multiplier Analysis and the Principle of Acceleration," *Review of Economic Statistics* 21: 75–78.

——— (1961) *Economics, An Introductory Analysis*, 5th ed., McGraw-Hill, New York.

Schmidt-Nielsen, K. (1984) *Scaling: Why Is Animal Size So Important?* Cambridge University Press, Cambridge.

Schrödinger, E. (1944) *What Is Life, The Physical Aspect of the Living Cell*, Cambridge University Press, Cambridge.

Schumpeter, J. A. (1934) *The Theory of Economic Development*, Harvard University Press, Cambridge.

Shileifer, A. and D. Treisman (2005) "A Normal Country: Russia after Communism," *Journal of Economic Perspective* 19. 1: 151–174.

Stack, H. M. (1997) "The 'Colonization' of East Germany?: A Comparative Analysis of German Privatization," *Duke Law Journal* 46. 5: 1211–1253.

Stigler, G. J. (1951) "The Division of Labor Is Limited by the Extent of the Market," *Journal of Political Economy* 59: 185–193.

Stiglitz, J. E. (1976) "The Efficient Wage Hypothesis, Surplus Labor, and the Distribution of Income in L.D.C.s," *Oxford Economic Papers* 28. 2: 185–207.

Tikhomirov, V. (2000) *The Political Economy of Post-Soviet Russia*, St. Martin, New York.

Uhlenbeck, G. E., and L. S. Ornstein (1930) "On the Theory of Brownian Motion," *Physical Review* 36. 3: 823–841.

Von Hagen, J. and R. R. Stauch (2001) "East Germany: Transition with Unification, Experiments, and Experiences," in M. I. Blejer and M. Skreb (eds) *Transition, the First Decade*, MIT Press, MA: Cambridge.

Wallis, J. J. and D. C. North (1986) "Measuring the Transaction Sector in the American Economy, 1870–1970," pp. 95–148, and "Comments" by Lance E. Davis, pp.149–161, in Engerman, Stanley L. and Robert E. Gallman (eds) *Long-Term Factors in American Economic Growth*, Studies on Income and Wealth, vol. 51 (National Bureau of Economic Research), University of Chicago Press, Chicago, pp. 95–148.

Williamson, J. (1990) "What Washington Means by Policy Reform?" in J. Williamson (ed) *Latin America Adjustment: How Much Has Happened? Institute for International Economics*, Washington D.C..

Zeng, W. and P. Chen (2008) "Volatility Smile, Relative Deviation, and Trading Strategy—A General Diffusion Model of Stock Pricing Based on Nonlinear Birth-Death Process (in Chinese)," *China Economic Qurterly* 7.4 (to appear)