

Economic Complexity and Equilibrium Illusion

The Principle of Large Numbers indicates that macro fluctuations have weak microfoundations; persistent business cycles and interrupted technologies can be better characterized by macro vitality and meso foundations. Economic growth is limited by market extent and ecological constraints. The trade-off between stability and complexity is the foundation of cultural diversity and mixed economies. The new science of complexity sheds light on the sources of economic instability and complexity.

This book consists of the major work of Professor Ping Chen, a pioneer in studying economic chaos and economic complexity. The chapters are selected from works completed since 1987, including original research on the evolutionary dynamics of the division of labor, empirical and theoretical studies of economic chaos, and stochastic models of collective behavior. Offering a new perspective on market instability and the changing world order, the basic pillars in equilibrium economics are challenged by solid evidence of economic complexity and time asymmetry, including Friedman's theory of exogenous money and efficient market, the Frisch model of noise-driven cycles, the Lucas model of microfoundations and rational expectations, the Black–Scholes model of option pricing, and the Coase theory of transaction costs.

Throughout, a general framework based on complex evolutionary economics is developed, which integrates different insights from Smith, Malthus, Marx, Hayek, Schumpeter, and Keynes and offers a new understanding of the evolutionary history of division of labor. This book will be of interest to postgraduates and researchers in Economics, including macroeconomics, financial economics, advanced econometrics and economic methodology.

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Economic Complexity and Equilibrium Illusion

Essays on market instability and macro
vitality

Ping Chen

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Preface

We are in the midst of the Grand Crisis (this is a term in parallel with the Great Depression in the 1930s). In Chinese, crisis (*wei-ji*) means danger (*wei*) and opportunity (*ji*). This is the main idea of order out of chaos introduced by the late Belgian physicist Ilya Prigogine (Prigogine and Stengers 1984). In economic literature, instability is mainly used as a negative term. But the physics concepts of nonequilibrium, complexity, and chaos imply not only the destruction of an old order, but also the emergence of a new structure. From this perspective, the current Grand Crisis may bring about a new world of economic order and a new era of economic thinking.

“The whole intellectual edifice collapsed in the summer of last year,” the perplexed former Federal Reserve Chairman Alan Greenspan confessed in congressional testimony on October 23, 2008 (Greenspan 2008). Changing historical currents demand changes in economic paradigm. Media commentaries and prominent economists soon identified two failed theories in mainstream economics: the efficient market hypothesis in finance and the microfoundations theory in macroeconomics, which is the core of the counter Keynesian revolution in last three decades. Among critics of market fundamentalism, only some weak voices of information asymmetry and behavioral finance have been heard. Justin Fox, an economics columnist for *Time* magazine, documented a series of intellectual failures in a recent book on the myth of rational markets (Fox 2009). He laments the lack of any alternative “grand new theory” and finds that the debate has resulted in a “muddle.”

However, Fox’s complaint is not quite true. His bounded knowledge is a good example of incomplete information or even distorted information in the mainstream media. This book of collected essays demonstrates that there are better alternatives in understanding market instability and economic crisis, and a new paradigm has been developing for the last three decades. Only the exclusive attitude of mainstream economics has marginalized new ideas and new approaches in economic literature and university textbooks.

This Grand Crisis revives old philosophical debates between Keynes and classical economists, between Hayek and Friedman, between Schumpeter and Frisch, between Minsky and Lucas, on the nature of business cycles and financial crisis. Moreover, it revitalizes new methodological contests among econometricians,

mathematicians, and physicists in analyzing economic time series. Generally speaking, there are at least three, not just two competing schools of thoughts.

The first is the equilibrium economics or neo-classical school. Its core belief is the so-called efficient market with rational expectations, which is self-stabilizing without need of government intervention. Any disturbance in the market is external and temporary in nature. Brownian motion or random shocks are their mathematic formulation of laissez-faire policy. There is a long cast of prominent names associated with this school: Ragnar Frisch, Milton Friedman, Eugene Fama, Robert Lucas, etc. Their arguments are based on methodological individualism, often in the form of a representative agent. Their main instrument in creating an equilibrium illusion is the first differencing (FD) filter in econometric practice, which wrongly targets the short-term fluctuations outside the business cycle frequency. Its deficiency is parallel to the geocentric system of the Ptolemy model in astronomy.

The second is the disequilibrium economics or Keynesian school. Its central theme is a fragile market, which frequently collapses under irrational panic or historical events. Known scholars in this camp include John Maynard Keynes, Hyman Minsky, Benoît Mandelbrot and behavioral economists. Their main effort is introducing social psychology into economic behavior (Akerlof and Shiller 2009). However, they have not yet developed a consistent theoretical framework. They experiment with various mathematical models, ranging from Levy distribution, fractal Brownian motion, unit roots, co-integration, sunspot, sand-pile, to power law in econophysics. Monetary and fiscal policies are the main tools for restoring market confidence from time to time. Their weakness is a lack of structural analysis and historical perspective. They often shared the problem of the whitening device (FD) in analyzing economic time series.

The third school is the self-organization economics or evolutionary school. Its perception of market economy and division of labor can be characterized as a viable market. Schumpeter's ideas of creative destruction, economic organism, and biological clock, and Hayek's concept of spontaneous order, are remarkably similar to Prigogine's idea of self-organization and dissipative structure in complexity science. Their characteristic is a biological view in an historical perspective for understanding human society. The term "viable market" was inspired by the observation of a firm's "viability" by Justin Lin, a former colleague at Peking University and now the Chief Economist at the World Bank (Lin 2009). Before the late 1970s, this school was overlooked by the new wave of econometrics and mathematic economics since the evolutionary perspective is difficult to be formulated by a linear stochastic model and optimization algorithm. Since the late 1970s, the new science of nonlinear dynamics and complex systems provided new tools in modeling biological and economic behavior. Our discovery is that a proper separation of trend and cycles is critical in studying an endogenous mechanism in business cycles. Our contribution is introducing nonlinear population dynamics with resource constraints as a unified framework in modeling micro, macro, finance, and historical evolution. Market movements do not like random walk with stable mean value but short correlations. The linear stochastic model in macro and finance economics implies no internal structure and historical con-

straints in industrial economy. The equilibrium illusion of self-stabilizing market is created by a white looking glass, the first differencing (FD) filter, which distorts any colorful picture into a white image. In the history of science, the telescope helped Galileo to prove the Copernicus heliocentric theory of planet motion. In economic analysis, our discovery of economic color chaos (color means a narrow frequency band against a noisy background) reveals a new world of macro vitality. The movements of stock market and macro indexes can be better understood by a mix of nonlinear trend, persistent cycles, plus minor noise. The market trend is mainly driven by technological wavelets and changing economic structure. Persistent cycles in the US economy are endogenous and nonlinear in nature, which fall within the stable range of NBER business cycles from two to ten years. The sources of business cycles are not microfoundations, but meso foundation in financial intermediate and industrial organization. Financial market is inherently unstable because of collective behavior, financial leveraging, nonlinear pricing, and power concentration. For a viable market with resilient frequency but erratic fluctuations, the government's role in managing and regulating economy should be more like a family doctor treating his patients rather than a school teacher dealing with pupils. He should care more about the system's health and structural malfunction than day to day instructions to pupils. It was Paul Samuelson, who predicted as early as 1995 in an evaluation letter of our work that new innovative paradigms might have a chance to stand an historic test in mainstream economics (Samuelson 1995).¹

Unlike dramatic events of the Great Depression and the Grand Crisis, our adventure quietly started from two fundamental issues: the first is the so-called Joseph Needham's question of why science and capitalism emerged in Western Europe, not in China or other civilizations. The second is studying the nature of business fluctuations. Should we characterize them by random noise or deterministic chaos? The first issue shifted my interest from the heights of the culture revolution in China to Ilya Prigogine's new thermodynamics of evolution in 1973. I ended up studying and working with Prigogine from 1981 until his death in 2003. My studies of evolutionary dynamics were inspired by Peter Allen (a member of the Brussels school led by Prigogine), while my research of economic chaos was initiated by Ilya Prigogine. Without the intellectual culture at the Ilya Prigogine Center for Statistical Mechanics and Complex Systems at University of Texas at Austin, our endeavor cannot survive under the monotone atmosphere dominated by neo-classic economics. When I started teaching at Peking University in 1997, my focus moved from technical algorithms to fundamental principles behind policy issues. The striking difference between China and EEFSU (East Europe and former Soviet Union) during the economic transition induced me to examine basic assumptions in equilibrium economics, which turned out to be mathematic toy models rather than scientific theories.

With a basic knowledge in calculus and science, college students, economic teachers, and general readers alike should easily follow our journey to explore economic complexity and test competing economic theories. Here, complexity means nonlinear interaction, nonequilibrium diversity, many-body problem,

nonstationary dynamics, and path dependence, while simplicity implies linearity, equilibrium convergence, stationary model, and one-body problem (of representative agent). Nonlinear modeling of economic complexity provides new tools in understanding economic structure, history, and evolution. You may realize that an economy is more like a living system. Its vitality is characterized by life rhythms. Thoughtful economists may be surprised that the dominant belief in self-stabilizing market, promoted by Frisch, Friedman, Fama Lucas, and Coase, are purely an equilibrium illusion, made up by the FD filter, the representative agent, the bilateral exchange, and even a perpetual motion machine in economic theory. Economic complexity, with emerging property and resilient dynamics will completely reshape our framework of economic thinking.

Like biology and physiology, structure matters immensely in understanding economic dynamics as a whole system. Adam Smith realized that division of labor is limited by market extent (1786, 1981), while Thomas Malthus pointed out the biological constraint to human activity (1798). Therefore, market-share competition is more fundamental than price competition, which serves a business strategy in market-share competition. Competition policy and structural reform are more essential than fiscal and monetary policy for developing a sustainable economy. The conventional micro–macro analysis ignores the middle layer of meso economics, i.e., financial intermediate and industrial organization, which are the foundations of creative destruction and business cycles. The irrational fads and panics in behavioral finance can be understood by interactions among individual actors. A consistent framework of ecology-socio-economic dynamics in continuous time is developing for micro, meso, macro, and Clio economics. Readers could judge if there is a better alternative to equilibrium economics based on individual rationality in discrete time.

Policy makers and the general public would find fresh ideas for understanding historical puzzles and contemporary events, such as the cultural diversification between East and West in the Middle Ages, the rise of China, the decline of EEFSU, and policy effectiveness in dealing with an economic crisis.

We are witnessing ongoing events of the Grand Crisis which originated in the core of a capitalist economy and turned into a global crisis. It is an historical moment to advance our economic knowledge. Economics in the twenty-first century will stand on the shoulders of giants. We have learned from visionary thinkers like Schumpeter, Keynes and Prigogine, as well as failed attempts by Frisch and Lucas. Economics as an empirical science will reach a new height and go beyond the scope of physics and biology in the future.

Finally, I should point out that all the papers here are kept in the original form as much as possible. I made some corrections in symbols and English for clarity and consistency. I also updated the references. If readers find mistakes in my book, please email: pchen@ccer.pku.edu.cn. I appreciate your critique and comments.

Ping Chen

July 27, 2009 at Austin, Texas

The 20th birthday of my younger daughter Vivian, a vibrant and critical student

Epilogue

What went wrong with economics?

A clash of doctrines is not a disaster – it is an opportunity.

(Alfred Whitehead 1925)

In a recent lecture at the London School of Economics, Paul Krugman, the 2008 Nobel Laureate in economics, said that “most work in macroeconomics in the past 30 years has been useless at best and harmful at worst” (*The Economist*, 2009a). One week later, *The Economist* magazine organized a cover story “What went wrong with economics,” discussing major debates in macroeconomics and financial economics.

In a dramatic event, the British Queen visited the London School of Economics in November 2008. She asked why so few economists had noticed that a credit crunch was on its way. The British Academy called a forum in June 2009 and wrote a formal reply on July 22nd. Two Fellows of the British Academy, Tim Besley at the London School of Economics and Peter Hennensey at the University of London summarized the main findings from 33 participants including experts from academia, business, government, and regulators (2009). They listed many causes contributed to this financial crisis, especially the “failure to understand risk as to the system as a whole” and “a psychology of denial” (of market instability). However, another ten leading British and Australian economists led by evolutionary economist Geoffrey Hodgson at the University of Hertfordshire voiced a minority view against the mainstream explanation by the British Academy (2009). In their separate letter to the British Queen, they called for a fundamental reform in training economists. They blame the blind trust in market forces and financial innovations that were deeply rooted in economic education. Mathematic models with a “highly questionable belief in universal rationality and the efficient market” led economic students to be detached from the real world. In the US, Simon Johnson, the former chief economist at IMF and current MIT professor, argues that the root of the financial crisis to be that the US government was captured by financial oligarchs, and that breaking financial oligarchs apart is the only way out of this recession (2009).

In the face of the waves of criticism, Robert Lucas, the 1995 Nobel Laureate in economics at the University of Chicago, rebuts criticisms in a guest article

(*The Economist*, August 6, 2009). His article is republished here at the permission of *The Economist*. We ask our readers to read the Lucas defense first, and then conduct our analysis with what went wrong with Mr. Lucas, the best example of current mainstream thinking. For the reader's convenience, we use italics for the original statements from Robert Lucas.

Robert Lucas (2009): "*In defense of dismal science*"

There is widespread disappointment with economists now because we did not forecast or prevent the financial crisis of 2008. The Economist's articles of July 18th on the state of economics ("What went wrong with economics," Economist 2009b) were an interesting attempt to take stock of two fields, macroeconomics and financial economics, but both pieces were dominated by the views of people who have seized on the crisis as an opportunity to restate criticisms they had voiced long before 2008. Macroeconomists in particular were caricatured as a lost generation educated in the use of valueless, even harmful, mathematical models, an education that made them incapable of conducting sensible economic policy. I think this caricature is nonsense and of no value in thinking about the larger questions: What can the public reasonably expect of specialists in these areas, and how well has it been served by them in the current crisis?

One thing we are not going to have, now or ever, is a set of models that forecasts sudden falls in the value of financial assets, like the declines that followed the failure of Lehman Brothers in September. This is nothing new. It has been known for more than 40 years and is one of the main implications of Eugene Fama's "efficient-market hypothesis" (EMH), which states that the price of a financial asset reflects all relevant, generally available information. If an economist had a formula that could reliably forecast crises a week in advance, say, then that formula would become part of generally available information and prices would fall a week earlier. (The term "efficient" as used here means that individuals use information in their own private interest. It has nothing to do with socially desirable pricing; people often confuse the two.)

Mr. Fama arrived at the EMH through some simple theoretical examples. This simplicity was criticised in The Economist's briefing, as though the EMH applied only to these hypothetical cases. But Mr. Fama tested the predictions of the EMH on the behaviour of actual prices. These tests could have come out either way, but they came out very favourably. His empirical work was novel and carefully executed. It has been thoroughly challenged by a flood of criticism which has served mainly to confirm the accuracy of the hypothesis. Over the years exceptions and "anomalies" have been discovered (even tiny departures are interesting if you are managing enough money) but for the purposes of macroeconomic analysis and forecasting these departures are too small to matter. The main lesson we should take away from the EMH for policymaking purposes is the futility of trying to deal with crises and recessions by finding central bankers and regulators who can identify and puncture bubbles. If these people exist, we will not be able to afford them.

The Economist's briefing also cited as an example of macroeconomic failure the "reassuring" simulations that Frederic Mishkin, then a governor of the Federal Reserve, presented in the summer of 2007. The charge is that the Fed's FRB/US forecasting model failed to predict the events of September 2008. Yet the simulations were not presented as assurance that no crisis would occur, but as a forecast of what could be expected conditional on a crisis not occurring. Until the Lehman failure the recession was pretty typical of the modest downturns of the post-war period. There was a recession under way, led by the decline in housing construction. Mr. Mishkin's forecast was a reasonable estimate of what would have followed if the housing decline had continued to be the only or the main factor involved in the economic downturn. After the Lehman bankruptcy, too, models very like the one Mr. Mishkin had used, combined with new information, gave what turned out to be very accurate estimates of the private-spending reductions that ensued over the next two quarters. When Ben Bernanke, the chairman of the Fed, warned Hank Paulson, the then treasury secretary, of the economic danger facing America immediately after Lehman's failure, he knew what he was talking about.

Mr. Mishkin recognised the potential for a financial crisis in 2007, of course. Mr Bernanke certainly did as well. But recommending pre-emptive monetary policies on the scale of the policies that were applied later on would have been like turning abruptly off the road because of the potential for someone suddenly to swerve head-on into your lane. The best and only realistic thing you can do in this context is to keep your eyes open and hope for the best.

After Lehman collapsed and the potential for crisis had become a reality, the situation was completely altered. The interest on Treasury bills was close to zero, and those who viewed interest-rate reductions as the only stimulus available to the Fed thought that monetary policy was now exhausted. But Mr Bernanke immediately switched gears, began pumping cash into the banking system, and convinced the Treasury to do the same. Commercial-bank reserves grew from \$50 billion at the time of the Lehman failure to something like \$800 billion by the end of the year. The injection of Troubled Asset Relief Programme funds added more money to the financial system.

There is understandable controversy about many aspects of these actions but they had the great advantages of speed and reversibility. My own view, as expressed elsewhere, is that these policies were central to relieving a fear-driven rush to liquidity and so alleviating (if only partially) the perceived need for consumers and businesses to reduce spending. The recession is now under control and no responsible forecasters see anything remotely like the 1929–33 contraction in America on the horizon. This outcome did not have to happen, but it did.

Not bad for a Dark Age

Both Mr Bernanke and Mr Mishkin are in the mainstream of what one critic cited in The Economist's briefing calls a "Dark Age of macroeconomics." They are exponents and creative builders of dynamic models and have taught these "spectacularly useless" tools, directly and through textbooks that have become industry standards, to generations of students. Over the past two years they (and

many other accomplished macroeconomists) have been centrally involved in responding to the most difficult American economic crisis since the 1930s. They have forecasted what can be forecast and formulated contingency plans ready for use when unforeseeable shocks occurred. They and their colleagues have drawn on recently developed theoretical models when they judged them to have something to contribute. They have drawn on the ideas and research of Keynes from the 1930s, of Friedman and Schwartz in the 1960s, and of many others. I simply see no connection between the reality of the macroeconomics that these people represent and the caricature provided by the critics whose views dominated The Economist's briefing.

When I got the early released version of the Lucas defense on August 6, 2009, I immediately posted a comment at the Lucas Roundtable at *The Economist* on August 7, 2009, which is ranked number one by reader's recommendation (Chen 2009b). Robert Lucas is considered one of the greatest macroeconomists after Keynes. A dialogue with Lucas will help us to clear the clouds in economic thinking. The following is my comments at the Lucas Roundtable with further minor modifications and elaborations.

Ping Chen's comments to "In defense of the dismal science" by Robert Lucas

The Lucas defense of dismal science is vividly contrasted with the sharp criticism by Simon Johnson, the former IMF chief economist, and the painful assessment by Paul Krugman, a Nobel Laureate in 2008.

Lucas was silent about the major questions, which were brought about by the current crisis: what is the nature of this financial crisis, what is the role of government in macro management, and which school of thought should be responsible for economics' ill prevention and preparation for crisis.

Lucas has been the leader of the so-called counter Keynesian revolution under the banner of rational expectations and microfoundations since the 1970s. According to his simplistic but elegant theory, unemployment is the worker's rational choice between work and leisure even during the Great Depression. The source of business cycles is uncorrelated external shocks in nature. There is little room for government intervention, since the market system is inherently stable and rational expectations will defeat government interference. Lucas made his name mainly by modeling technique in macro stochastic dynamics, whose main merit is mathematical simplicity and theoretical convenience, but not economic reality. In policy arena, Lucas effectively turned the linear technique into a rational belief, which was the very foundation of "mistaking beauty for truth" (Krugman 2009).

We found out that the Lucas theory of microfoundations had weak evidence under the Principle of Large Numbers (Chen 2002). This financial crisis gave a historic blow to his microfoundations theory, since the financial crisis was rooted not from microfoundations at a household level, but meso foundation, i.e., the financial intermediate itself. There is little motivation of voluntary

unemployment during the depression, since few American households have enough savings to cushion the lost income in an uncertain period. The Great Depression and the current crisis show clearly that the financial market is inherently unstable, as many economists realized a long time ago, including Schumpeter, Hayek, Keynes, Minsky, and behavioral economists, but marginalized by the so-called new classical macroeconomics led by Lucas. Lucas had no courage to defend his theory of microfoundations, but tried to shift the debate from macroeconomics to financial economics, so that he could still play the magic device of rational expectations.

Surprisingly, Lucas claimed that the current crisis even strengthened the credit of the efficient market hypothesis (EMH). His argument was that no one could make a short-term forecast of crisis and make a profit from the right forecast. Mr. Lucas seems to have more belief in *laissez-faire* economics than his mathematical knowledge of financial theory.

The fundamental assumption behind EMH is that the financial market is ruled by random walks or Brownian motion (Fama 1970, 1991), which is also the very foundation of portfolio diversification strategy and theory of option pricing. The godlike claim of “prices reflecting all available information” is only a simple mathematical assumption of an error term with zero mean in stochastic modeling. If this theory is true, then it is very unlikely that large correlated price movements occur, like the boom–bust cycle or a financial crisis. Eugene Fama, the founder of EMH, himself realized the limit of regression analysis in econometric tests. EMH is not capable of proving or rejecting any nonlinear models of business cycles. New tools in complexity science reveal better alternatives to the Brownian motion model behind EMH. We had solid evidence of persistent cycles dominating the financial market, which is endogenous and chaotic in nature (Chen 1996a). The sub-prime crisis was started by underestimating risk by rating agencies and excess risk-taking by over-paid executives in the financial market. Housing bubbles emerged by investors failed to realize the changing price trend under the Fed’s monetary policy, a typical failure of rational expectations. Diversification strategy does not work when persistent cycles amplify irrational herd behavior or waves of optimism and pessimism. Financial engineering such as credit swaps would fail if the trading strategy follows a wrong theoretical model of geometric Brownian motion, which was explosive in nature (Chen 2005).

When Lucas argued that “If an economist had a formula that could reliably forecast crises a week in advance, say, then that formula would become part of generally available information and prices would fall a week earlier.” He did not know that linear thinking ruled out several possibilities of price-falling mechanisms in real economy. If the price-fall triggered by the Lehman failure was perceived as an accidental event as described by EMH and rational expectations, it would not change the market confidence and the stock prices should quickly return to normal by arbitrage activity. In fact, even Lucas acknowledged that the market response was “fear-driven” (a nonlinear social action within the market mechanism as Keynes pointed out before). When the Fed and Finance Ministry failed to intervene, waves of selling off led to market squeezing (a nonequilib-

rium phenomenon). The price movements are no longer random or short-correlated. Irrational expectations may change price trend and market fundamentals (Soros 2003). Lucas' description of the Fed's actions was clearly a nonlinear process with two stages (before and after the Lehman failure) while the Fed's intervention was over-cautious or over-reacted. Lucas himself told us a vivid story, which contradicts the picture of random walk in the financial market and monetary policy. The essence of EMH and rational expectations is the unique stable equilibrium for market movements. Arbitrage activity would quickly restore market equilibrium without the need for interference from the Fed and Finance Ministry. Lucas was just like Paulson and Bernanke during the ongoing crisis in that they did not fully know what they were doing and how the market would change.

There is abundant evidence from numerous crises before that asset prices may not reflect all relevant information, or even worse, that asset prices may distort relevant information by greedy investment bankers (Fang 2004). Robert Shiller warned of the danger of inflated housing prices before the housing market meltdown (Shiller 2005). The difficulty in the short-term forecast of a financial crisis has nothing to do with market efficiency. The empirical evidence of nonlinearity and complexity widely exists in the financial market. Simple mechanisms, such as over-reaction and delayed feedback, would generate deterministic chaos, which imposes a limitation on trajectory forecast but increases volatility of price movements (Chen 1988a). Financial leverage plays a key role in generating boom–bust cycles (Semmler and Bernard 2009).

Lucas was too early to name Frederic Mishkin and Ben Bernanke as model students of the dynamic general equilibrium model, the main tool of the Dark Age macroeconomics. Technically speaking, they can always explain observed time series by introducing enough shocks and lags in linearized models (Lucas 1972; Bernanke *et al.* 1999). The general equilibrium framework abstracts away market instability, which does not go away in reality (Galbraith 2009). When Simon Johnson's criticism of America's oligarchs and their capture of the government's rescue policy, Lucas seems satisfied by the Fed's unconventional monetary policy. They all ignore the system risk and conflicting interests between the financial and real sector, a scenario certainly missing in the Dark Age macroeconomics and financial economics.

Mr. Lucas did raise a fundamental issue in laissez-faire economics, when he declared:

The main lesson we should take away from the EMH for policymaking purposes is the futility of trying to deal with crises and recessions by finding central bankers and regulators who can identify and puncture bubbles. If these people exist, we will not be able to afford them.

This is the new version of the Lucas impossibility theorem in crisis management. However, this impossibility theorem is not valid both in theory and practice. There are reliable methods to identify and prevent asset bubbles in our

theory of the viable market (Chen 2008, 2009a). For example, sudden changes of trading volumes in Wall Street signal speculative activities by big investors and herd behavior of noise traders. The regulating agency could easily take counter cyclic measures, such as increasing the capital reserve requirement, restricting leverage ceiling, increasing the transaction tax rate. Breaking market monopoly is the most effective way to prevent market manipulation.

As Alfred Marshall said, economics should be closer to biology than mechanics (1920). Business cycles behave more like a freeway driver than a drunken man. From historical experiences, a protracted long period of expansion is an engine to feed bubbles, even if the inflation rate is low during the economic expansion before bursting bubble like the situation before the Great Depression and the current crisis. Central bankers cannot forecast both the recession length and the turning point under the uncertainty principle in time and frequency, which imposes a lower limit in time resolution and frequency resolution. In other words, if you try to make an accurate forecast of business-cycle turning point as Lucas wished, you will lose the larger picture of how long the recession would last. Based on our observation of viable market, government policy is capable of managing the normal range of business cycles within four to five years if we shift policy goal from inflation level targeting to business cycle monitoring. Just like the heart beats in animals, too fast or too slow rhythms signal potential troubles in the biological organism. Maintaining a normal life rhythm can improve the immune system against external shocks. Therefore, structural adjustments with a policy mix of monetary and fiscal policy should be design and experiment under historical constraints and uncertain environment during the crisis. We may test the new perspective of macroeconomic policy in future events.

The only symbolic compromise Lucas did make is his last sentence, which barely mentioned the name of Keynes along with Friedman and Schwartz, but not Hayek and Minsky. For a serious reader of *The Economist* magazine, the only lesson of the Lucas defense of the dismal science is that economic theory should connect with economic reality. The fundamental lesson from this Grand Crisis is that the rational individual with unlimited want is not compatible with ecological constraints (such as global warming) and social solidarity. The human being is a social animal seeking security, happiness, and companionship. Division of labor is driven by a disciplined hand (both for individual and government) in the modern economy. Classical economics is a beginning not the end of understanding the evolving economy. Complexity science developed in physics and biology is a complementary tool with philosophy, history, and psychology in studying economic behavior and organization. There is plenty of new thinking in economics and social sciences developed in the last three decades. Hopefully, mainstream economists would open their minds and experiment with fresh ideas after this crisis.

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For any mistakes we made and new ideas readers have, please send your email to pchen@ccer.pku.edu.cn.

Enjoy your journey in a complex but colorful world!

(The comments on Lucas' defense were written on September 8, 2009 in Austin, Texas. Final modification of the Epilogue was completed on December 9, 2009 in Beijing, China.)