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*MESO FOUNDATION OF BUSINESS CYCLES AND
MARKET VITALITY FOR MACRO POLICY:
A NEW TRINITY OF MICRO-MESO-MACRO ECONOMY*

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Abstract

New science of complexity provides more advanced tools in analyzing macro and financial indexes. Two discoveries changed current view of macro and financial economics. First, major source of business fluctuations lies in the meso level (financial intermediates and industrial organization) with little contribution from micro foundations (households or firms). Second, financial market is more stable in frequency domain rather than in price level domain. Business cycles are more like biological clock with endogenous instability and systematic resilience (the Schumpeter's view). We develop a new framework of economy with three layers and new policy target in business cycle management. A general theory of collective movement in financial market could explain complex features in option pricing and financial crisis.

I. Introduction: two fundamental lessons from this financial crisis

This ongoing financial crisis triggered a rethinking in economics. Paul Krugman criticized macroeconomics in past three decades as “dark age” and “mistaken beauty for truth” (Krugman 2009a, 2009b). We will further argue that equilibrium models in macro and finance were not beauty but wrong both in theoretical modelling and in empirical analysis (Chen 2010).

This crisis has two clear features that can be considered as natural experiments in testing competing economic theories. First, it is endogenous in nature, since there were no visible shocks such as the oil price shock in 1970s. Therefore, exogenous theory of business cycles cannot be applied to this crisis (Frisch 1933, Friedman and Schwartz 1963). Second, it originated from sub-prime crisis and intensified by meltdown of derivative market. These facts challenged three economic theories including Fama's efficient market hypothesis (EMH), Lucas theory of microfoundations and rational expectations (MRE), and Black-Scholes (BS) model of option pricing (Fama 1970, 1991, Lucas 1981, Black and Scholes 1973, Daffie 1999), since financial market failed to evaluate market risk in mortgage and credit swap market, rational expectations failed to neutralize Fed action of raising interest rate, and arbitrage activities failed to maintain market equilibrium during the early stage of financial crisis. Most importantly, there is no empirical evidence of voluntary unemployment during the crisis, since American households have little saving to cushion lost jobs during

uncertain time. This salient factor was missing in Lucas microfoundations theory (Lucas 1972, 1980).

Our criticism is not confined to philosophical arguments or qualitative facts. Instead, we have both empirical evidence and theoretical alternatives against exogenous theory of business cycles and random models behind EMH and Lucas theory of microfoundations. The alternative models are persistent cycles, colour chaos, and birth-death process, which are better than white noise, random walk, and Brownian motion in business cycle theory and option pricing (Chen 1988, 1996a, 2002, 2005, 2008).

In last two decades, we apply the new science of complexity that provides new tools in economic analysis. We found a series of new facts that are briefly discussed below:

1) The issue of proper detrending is the Copernicus problem in macro and financial economics. FD filter creates random illusion while HP filter reveals dynamical structure. The controversy of exogenous vs. endogenous school in business cycle theory is originated in competing detrending methods in dealing with growing trends in macro and financial time series. We found out that the FD (first differencing) filter amplifies high frequency noise by means of the shortest time window of one time unit; while the HP filter identifies a smooth trend so that cyclic movements around the trend fall within the frequency range of NBER business cycles. Major discoveries in economic nonlinearity and complexity, including economic color chaos, persistent cycles, meso foundation, are found from HP detrended data (Chen 1999a, 1999b, 2002, 2005). Almost all random images with short correlations, including random walk, Brownian motion, unit root, co-integration, and power laws, are based on FD detrending.

FD detrending fails to provide a consistent framework in understanding macro and financial dynamics (Chen 2008, 2010). For example, so-called unit root was mainly found from yearly data, but the outcome would change if using quarterly data from the same index. Theoretically speaking, FD detrending is a discrete-time framework, whose dynamical pattern depends on the choice of time unit, while HP detrending is a continuous-time framework, so that dynamical pattern is independent of time unit. All physics laws are formulated and confirmed in continuous-time framework. Finding a proper reference system is the very beginning of an empirical science of economic dynamics.

2) Modern market is a complex system with many faces. Price alone does not reflect all available information. In physics term, price does not like gravity which is a scalar field. Market economy is more like an electro-magnetic field, which is a vector or tensor field (Chen 2008). Current economic theories provide conflicting measurements in economic

analysis. In micro theory, it is the price level clear the market described by demand and supply. In finance theory, it is the rate of changes in financial prices that are matters in risk management. In reality of decision-making, at least many pertinent variables are important in financial investment, market regulation and macro management. This is why Keynes called for a “general theory” which integrates classical theory as a special case (Galbraith 1990).

3) **Random noise only plays a minor role in macro and financial movements, while persistent cycles dominate macro and financial fluctuations.** The endogenous nature of persistent cycles in financial macro-indexes is discovered by nonlinear dynamics and WGQ transform in time-frequency analysis (Friedman 1953, Fama 1970, Chen 1996a, 1996b). That is why monetary is not an exogenous instrument without structural constraints and why diversification strategy may fail when market has changing trend or crisis expectations (Chen 1988, 2010).

4) **The meso-foundation of macro-fluctuations revealed by the Principle of Large Numbers in analysing relative deviations of macro and stock indexes** (Chen 2002), there is weak evidence of microfoundations in business cycles (Friedman 1953, Fama 1970, Browning, Hansen and Heckman 1999, Chen 2002, 2005). Market variability is mainly generated by financial intermediates and industrial organization, but little influenced by households and small firms. It is known that the numbers of households are several orders larger than the numbers of firms. Market economy is better characterized by a three level model: micro-meso-macro economies.

5) **Financial movements are generated by collective behavior. The population model of birth-death process is a better alternative model to geometric Brownian motion in option pricing.** Persistent and stable relative deviation in macro and financial indexes can be described by birth-death process while random walk and Brownian motion model are incapable of generating persistent market variability (Chen 2005). The more general stochastic models based on birth-death process is capable of explaining volatility smile, option pricing with interactive trend and volatility, and financial crisis with high moment risk (Chen 2005, Zeng and Chen 2008, Tang and Chen 2010).

6) **Belief in self-stabilizing market and financial de-regulation is mainly based on Frisch model of noise-driving cycles and Coase world of zero transaction costs, which are perpetual motion machine in nature** (Frisch 1933, Coase 1988, Chen 2005, 2007). In fact, Frisch himself quietly abandoned his noise-driven cycle model since 1934. He never formerly published his promised paper in *Econometrica*. He did not mention a word to his Nobel-prize winning model in his 1970 Nobel lecture (Chen 2005, 2010).

In short, structure and history matter tremendously in economic and institutional analysis. This is the main difference between complex evolutionary economics and neoclassical equilibrium economics. Therefore, competition policy, innovation policy and structural adjustment are more critical than fiscal and monetary policy in dealing this crisis and globalization. Our understanding of modern division of labor is a synthesis of Smith-Schumpeter-Keynes.

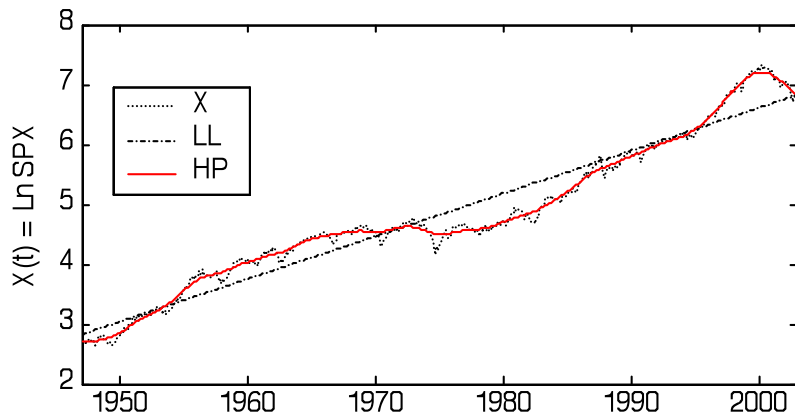
In this short seminar, let me briefly introduce empirical analysis and related theories: the time window in observing autocorrelations from FD and HP detrending, persistent cycles observed by WGQ transform in time-frequency analysis and nonlinear tests, persistent relative deviation observed under the Principle of Large Numbers. The deterministic model of color chaos and stochastic model of birth-death process is useful in studying business cycles and option pricing theory (Chen 2010).

II. The role of time window in business cycle analysis: endogenous features by HP filter and random illusion by FD filter

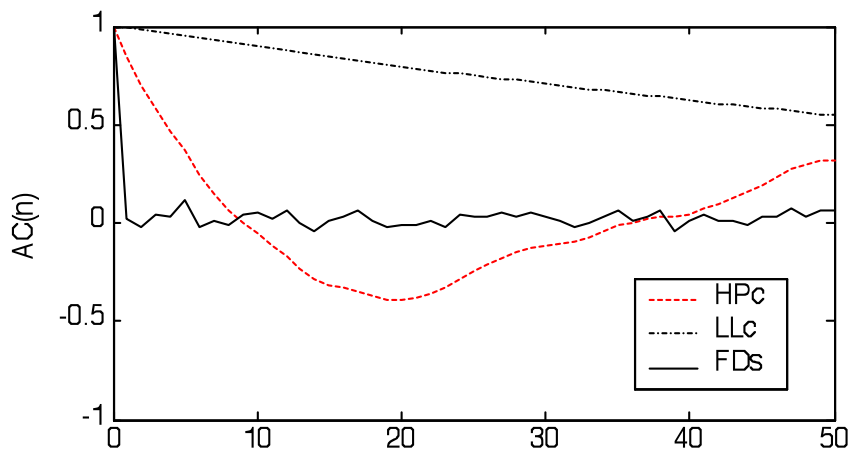
The proper time window in business cycle analysis is critical for Copernicus problem in macro dynamics. The short time-window with only one time unit is used by the FD (first differencing) filter in econometrics, which is a geocentric system generating random illusion, while the medium time-window of 2-10 years is used by the HP filter, which is a heliocentric system revealing endogenous collective movements, such as persistent cycles and persistent fluctuations (Chen 1996a, 1996b, 2002, 2010).

2.1 Trend-cycle separation and time window observed from autocorrelations

In mathematical representation, stochastic process has short-term autocorrelations, while deterministic process has long-term cyclic autocorrelations. In analysing business cycle time series, the length of autocorrelations depends on both the underlying mechanism and the observation reference. The econometric evidence of random walk or Brownian motion model of business cycles is obtained by the FD filter, while the empirical evidence of persistent cycles and persistent fluctuations is revealed by the HP filter (Chen 1996a, 1996b, 2005, 2010). The different images obtained by FD and HP filter are shown in Fig.1.



(1a). The HP trend and LL trend of $X(t)$, the logarithmic time series



(1b). Autocorrelations of detrended cyclic series.

Fig.1. Three detrending filters and their auto-correlations of detrended cyclic series. The time series is the logarithmic SPX (the Standard and Poor 500 Price Index) monthly series (1947-2002), $N=672$. Source: yahoo.finance.

From Fig.1b, FDs series look like white noise, but HPc series seem to be damped cycles, which could be color noise or color chaos. Color implies deterministic frequency.

One special feature of economic time series is their high level of noise. Signal processing applies various filters in separating deterministic signals and random noise. The linear filter such as the band-pass filter is widely used to obtain desired signal within some frequency range. However, the FD filter is a high-frequency noise amplifier, which can be seen from Fig.2.

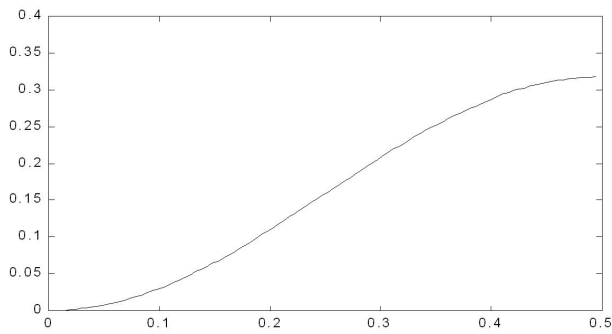


Fig.2 The frequency response function for the FD filter. Here, $X(t) = \text{FD}[S(t)] = S(t + 1) - S(t)$. The horizontal axis is the frequency range from zero to 0.5. The vertical axis is normalized signal intensity.

From Fig.2, we may see that FD filter suppresses low-frequency signals in business-cycle range but amplifies high-frequency noise. This is the key instrument in creating a white illusion of an “efficient market” (Chen 2008).

2.2 Non-parametric analysis based on WGQ transform in time-frequency analysis: persistent cycles and color chaos

The application of a new technique of time-frequency analysis based on WGQ (Wigner-Gabor-Qian) transformation in time-frequency space is a powerful tool for non-parametric analysis of non-stationary time-series, which is capable of dealing with noisy signals (Chen 1996a, 2005, 2008). Solid evidence of endogenous persistent cycles is shown in Fig.3 (Chen 2008). The spiral feature of deterministic color chaos for S&P 500 HPc filtered series is shown in Fig.4.

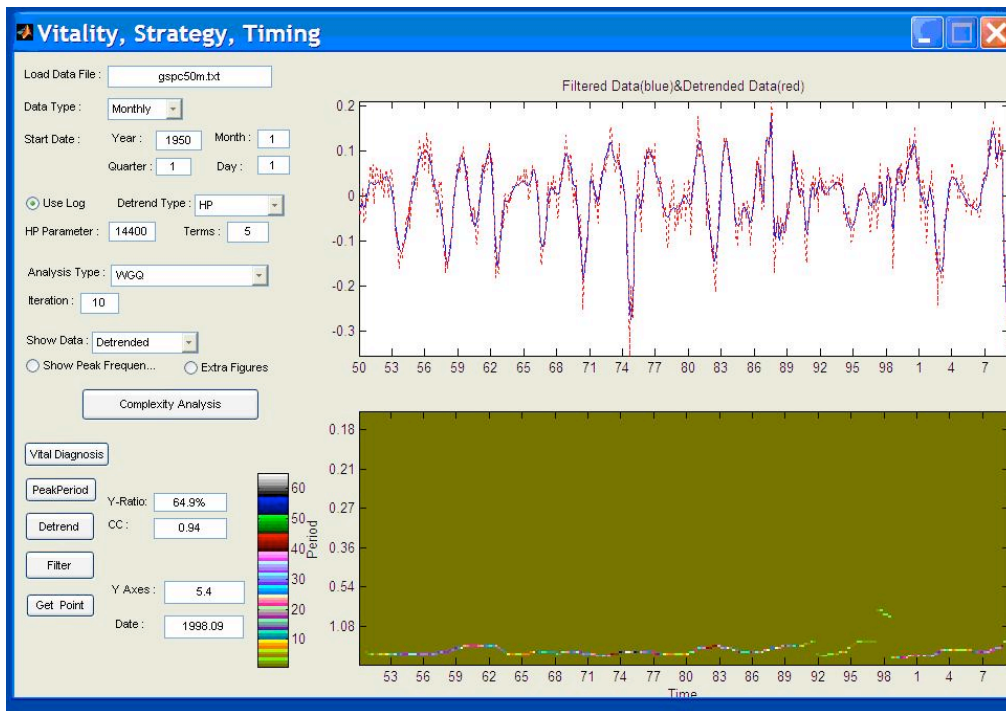
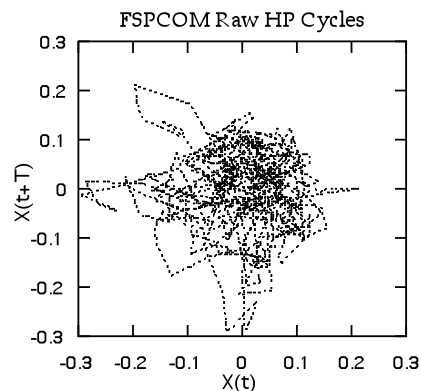
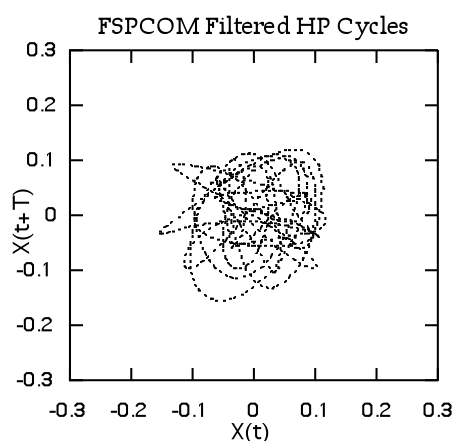


Fig.3 Nonstationary time series analysis based on WGQ(Wigner-Gabor-Qian) transformation. Data used is GSPC (Standard & Poor 500 Index) monthly (Jan.1950-Apr. 2009), data source is yahoo.finance. The upper diagram shows the original(the dotted line) and filtered (the solid line) HP cyclic time series. Y-ratio is the variance of the filtered time series to the variance of the the original one, which is 64.9% here. CC is their cross-correlation, which is 0.94 here. The lower diagram shows the time trajectory of the characteristic period of the HP cyclic series. The vertical axis is the period in years, the horizontal axis is time from 1950 to 2009. The period trajectory is more or less moving around the NBER business cycle frequency.



(4a) Noisy image of unfiltered data



(4b) Complex spiral of filtered data

Fig.4. 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.

From Fig.3, deterministic cycles can explain 64.9 per cent of variance from HP-detrended cycles filtered by WGQ transformation in time-frequency space. The cross-correlation with original cycles is 0.94. We found these persistent cycles can be explained by color chaos. Color means that its intrinsic period is about 4 to 5 years. Color chaos is deterministic chaos in continuous-time. Its correlation dimension is 2.5 (Chen 2005). Color chaos can be considered as the nonlinear model of Schumpeter's biological clock, a better alternative model of random walk or white noise in equilibrium theory of business cycles.

2.3. Sources of observed growth cycles: logistic wavelets from technology competition

We may ask a question why persistent cycles rather than white noise play major role in business cycles. The question can be answered by logistic wavelets of technology progress.

Schumpeter's theory of creative destruction can be described by Lotka-Volterra model of technology competitions (Chen 1987, 2005). For a new technology without competitor, its growth trajectory is a S-shaped logistic curve. For a old technology in face of competition from a new technology with higher resource ceiling, it will decline into a LV wavelet as in Fig.5.

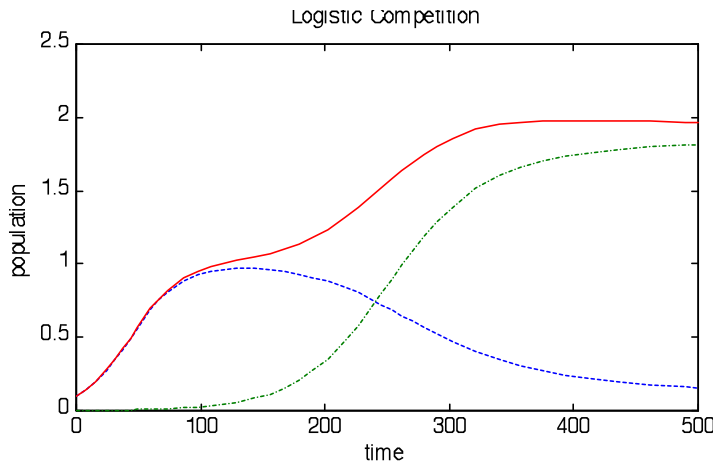


Fig.5. Rise of new technology/industry and fall of old technology/industry under competing for limited resources and markets. The S-shaped curve denoted by green dashed line is a rising new technology, while the blue LV wavelet represents a falling old technology. The red solid line is the aggregate growth cycles including output from two technologies.

The picture in Fig.5 can also be described by stages of economic growth driven by leading technology (Rostow 1960, 1990).

From comparison between Gabor wavelet and LV wavelet, we may understand that business cycles are driven by technology wavelets rather than technology noise. This is our difference with RBC school. WGQ transform is better than econometric analysis, since its base function is wavelets rather than noise pulse. This is important direction for non-parametric analysis. A good indicator of internal dynamics is not judged by minimum errors in regression analysis, but by catch essential feature in dynamical patterns. This is what we learn from WGQ transform of business cycles.

III. The meso-foundation of persistent fluctuations and collective model of stochastic process

Lucas (1972) made a strong claim that business cycles could be explained by an equilibrium (rational expectations) mechanism of workers' choices between work and leisure. His micro-foundations theory has, however, been rejected by empirical observations based on the principle of large numbers (Chen 2002). It was Schrödinger (1946), the founder of quantum mechanics and quantum biology, who found a salient relationship between the number of micro-elements and the variability of aggregate fluctuations.

Consider a macro system with N elements: $X_N = x_1 + \dots + x_N$. Its micro element $x_i (i = 1, \dots, N)$ are random variables with positive values. Many economic variables, such as population, output, price, and working hours are positive variables in their origin. For simplicity, assume micro elements follow i.i.d. with standard deviation σ and mean m . Their ratio is a constant without scale, which is called the “coefficient of variation” in statistics. We prefer the term of the “relative deviation,” since the conventional standard deviation can be considered as the “absolute deviation.” According to probability theory, the mean of the macro system is Nm , the variance of the macro system is $N\sigma^2$. The relative deviation of the macro system is $\Omega_N = \frac{std[X_N]}{mean[X_N]}$ and the relative deviation of the micro

element is $\varpi = \frac{\sigma}{m}$. We have:

$$\Omega_{N,ST} = \frac{std[S_N]}{mean[S_N]} = \frac{\sqrt{N\sigma^2}}{Nm} = \frac{\sigma\sqrt{N}}{Nm} = \frac{\varpi_{ST}}{\sqrt{N}} \sim \frac{1}{\sqrt{N}} \quad (1)$$

We call this relation the **Principle of Large Numbers** (Chen 2002, 2005). It implies that more micro elements, more stable for the macro system. That is why the large molecule of DNA with many atoms needed for genetic stability.

For an empirical macro system, we can measure macro’s relative deviation: $\Omega_N = \frac{std[X_N]}{mean[X_N]}$, then we may determine the lower bound of N , when we assume micro’s relative deviation is one.

However, this relation is derived for static stochastic system. It is an empirical question if the Principle of Large Numbers is applicable for dynamical economic systems. For empirical investigation, we may define a measure of the market variability (MV) by the relative deviation from an empirical economic index with positive values; its corresponding N_c is called the effective cluster number, since its micro structure may consists of clusters rather than individual units:

$$MV = \Omega_{macro} = E\left[\frac{STD(S_N)}{E(S_N)}\right] = \frac{1}{\sqrt{N_c}} 100\% \quad (2)$$

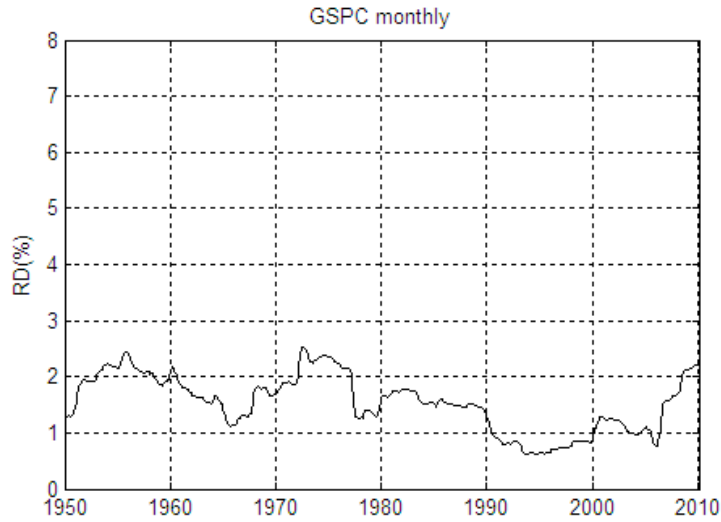
From Equation (2), MV must be within $[0,1]$. For single monopoly, $N_c=1$, $MV=1$, for perfect competition, $N_c=\infty$, $MV=0$. Therefore, MV is a measure of market instability as well as market concentration. However, we have a new understanding of perfect competition. If there are large number of independent units, but their behavior is highly correlated such as the case of rational expectations, their cluster number $N_c=1$, i.e. they behave like one representative agent, which leads to largest macro fluctuation. Therefore, empirical measurement of MV provides a direct test of competing economic theories. Let's consider how to measure MV .

3.1 Persistent pattern of relative deviations and structural asymmetry in investment and consumption

For a non-stationary time series, the HP filter is applied to separate the trend and cycle series. The relative deviation is measured within a finite moving time window. The standard deviation is calculated by the cycle series within the time window; and the mean is calculated by the trend series within the same moving time window. The S&P 500 index and its relative deviations is shown in Fig.6, while relative deviations for macro indexes is shown in Fig.7..

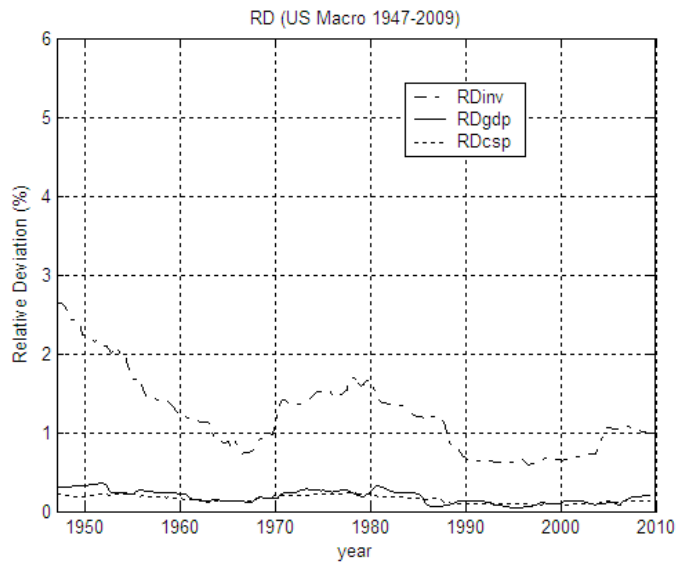


(6a) GAPC(S&P500) monthly series $X(t)$ (Jan.1950 – Jan.2010).



(6b) Relative Deviation observed from a moving time window. The window width is 5 years. HP control parameter for monthly index is: $\lambda = 14400$. $MV = E[RD(t)] = 1.5\%$, cluster number $N_c = 6000$.

Fig.6 S&P 500 logarithmic index and its relative deviation.



(5c)

Fig.7. Relative deviations of macro quarterly indexes (1947Q1 -2008Q3). RDinv in broken line is relative deviation of US real private investment (GPDIC1); RDgdp in solid line is relative deviation of US real GDP (GDPC96); RDcsp in dotted line is relative deviation of US real personal consumption expenditure (PCECC96); all are measured by billions of 2005 chained dollars. The HP control parameter for quarterly

data is: $\lambda = 1600$ (Hodrick and Prescott 1997). Note: RDinv declined from 2.5% in 1940s to about 1% since 1950s. RD gdp and RDcsp were stabilized at 0.2% level, which are 5 times smaller than RDinv.

From Fig.6 and Fig.7, we can see several features from the relative deviation of macro and stock indexes. First, its time trajectory is more stable than the original indexes. It has no explosive or damping trend in history. Second, it provides a visible indicator of market instability. Third, the magnitudes of relative deviations can be classified into two classes: those related to investment and financial indexes are much larger than those related to consumption and GDP. These three features are very useful in analysing macro economy and financial market.

Empirically speaking, since we can measure market variability (MV) from aggregate indexes, we can also infer the effective cluster number (Nc), at the micro-level. Therefore, we have a powerful tool to identify the source of aggregate fluctuations—if there is an explanation for micro-foundations (the structural level of households and firms) or an explanation for meso-foundations (the structural level of financial intermediates and industrial organisation in the form of clusters). The empirical results are shown in Table 1.

Table 1 Market variability and effective cluster number for various aggregate indexes

Item	MV (%)	Nc
Real personal consumption	0.15	800 000
Real GDP	0.2	500 000
Real private investment	1.2	10 000
Dow Jones Industrial (1928–2009)	1.4	9000
S&P 500 Index (1947–2009)	1.6	5000
NASDAQ (1971–2009)	2.0	3000
Japan–US exchange rate (1971–2009)	6.1	300
US–Euro exchange rate (1999–2009)	4.9	400
Texas crude oil price (1978–2008)	5.3	400

Notes: For non-stationary time series, market variability is measured via the HP filter; the average is estimated from a moving time window in the range of the average length of

business cycles, here is five years (Chen 2002). Data sources: US aggregate indexes and exchange rates are from the Federal Reserve Bank at St Louis; stock indexes data are from <yahoo.finance>; the oil price index is from the US Energy Information Administration.

From Table 1, we immediately find out that there is no evidence for rational expectations and representative agent models in macro dynamics, since the observed cluster numbers are much larger than one.

In fact, there are two possible scenarios of microfoundations for macro fluctuations. If rational expectations prevail among economic agents, their behavior should be perfectly correlated, so that $N_c=1$ and MV is the largest, which is near 100%. If rational expectations do not exist and correlations among agents are near zero, then MV is the smallest according to the Principle of Large Numbers. In reality, correlations among agents may lie between zero and one. Therefore, the cluster numbers will be less than real numbers of micro elements. The cluster number N_c provides an indicator of degree of freedoms in industrial organization and behavior divergence in economic decision-making.

Since empirical evidence easily rejects the rational expectations theory. The remaining question is how to understand the various magnitudes of cluster numbers in investment, consumption, and real GDP. We should examine the real numbers in the US economy.

The number of households, corporations and public companies and their implied orders of market variation (MV) in 1980 are given in Table 2 if we assume that these economic units make independent decision without rational expectations.

Table 2 Numbers of households and firms in the United States, 1980

Micro-agents	Households	Corporations ^a	Public companies
N	80 700 000	2 900 000	20 000
MV (%)	0.01	0.1	0.7

^a Here, we count only those corporations with more than \$100 000 in assets. The data source is the U.S. Bureau of Census.

From Tables 1 and 2, we can see that household fluctuations contribute only about 5 per cent of fluctuations in real gross domestic product (GDP) and less than 1 per cent in real investment; and small firms can contribute 50 per cent of fluctuations in real GDP or 8 per cent in real investment, while public companies can generate about 60 per cent of aggregate

fluctuations in real investment. Clearly, there are very weak ‘micro-foundations’ but strong evidence of a ‘meso-foundation’ in macroeconomic fluctuations. The doctrine of ‘too big to fail’ might be true at the micro-level in the cases of external shocks, but it is not true at the macro-level in terms of the meso–macro relationship. This fallacy of composition still fools equilibrium economists in their representative model of macro behaviour.

More surprisingly, the order of market variability in the oil and currency markets is much higher than real investment and the stock market, which indicates the ugly fact of financial concentration generated by giant financial corporations. This is the real root of this grand crisis!

Dan Gilligan, President of the Petroleum Marketers Association (PMA), has revealed that financial giants such as Morgan Stanley, Goldman Sachs, Barclays and JP Morgan were manipulating the oil price (Gilligan 2009). They put hundreds of billions of dollars in the oil futures market, in addition to money invested by large institutional fund managers such as the California Pension Fund, the Harvard University Endowment, and other institutional investors. They started their speculation in 2000, when the US Congress deregulated the futures market, granting exemptions for complicated derivative investments called oil swaps, as well as electronic trading on private exchanges. Volatility in the price of oil increased dramatically. Later in the decade, within one year, the oil price rose from \$67 a barrel to \$147 a barrel, then collapsed back down to \$45. On one occasion, the oil price jumped \$25 in one day! Surprisingly, changes in oil demand and supply in this period were less than 5 per cent, while changes in the price of oil were larger than 100 per cent! From the middle of June to the end of November 2008, when a US congressional investigation started, about \$70 billion of speculative capital left the future markets. At that time, demand for oil dropped 5 per cent, but the price of oil dropped more than 75 per cent to \$100 per barrel. Gilligan estimated that about 60–70 per cent of oil contracts in the future markets were controlled by speculative capital at the peak. In the past five years, hedge funds and global banks have poured capital into the oil market. Their ‘investment’ rose from \$13 billion to \$300 billion.

Clearly, competition policy at micro economy and financial market is essential to achieve macro stability.

3.2 Empirical selection of stochastic models for macro and financial dynamics

In theoretical economics, three stochastic models are widely used in economic literature: random walk (Cootner 1967, Hall 1978), Brownian motion (Black and Scholes 1973), and birth-death process (Cox and Ross 1976, Kou and Kou 2004). Mathematicians used to

consider the three stochastic models are equivalent to each other. Theoretical selection is mainly based on mathematical convenience. When we calculated their relative deviations, we found essential differences among them (Chen 2002, 2005, Li 2002, Table 3).

Table 3 Relative deviations of linear stochastic processes

Order	Drifted Diffusion	Birth-Death	Random-Walk
Mean	$\sim \exp(rt)$	$\sim \exp(rt)$	$\sim t$
Variance	$\sim \exp(2rt)\{e^{\sigma^2 t} - 1\}$	$\sim e^{rt}(e^{rt} - 1)$	$\sim t$
RD	$\sim e^{\frac{\sigma^2}{2}t} \sqrt{1 - e^{-t\sigma^2}}$	$\sim \frac{1}{\sqrt{N_0}}$	$\sim \frac{1}{\sqrt{t}}$

Here, N_0 is the size of initial population of micro agents in the birth-death process and $r > 0$ for economic growth.

From Table 3, we found out that the stochastic models of representative agent have no stable pattern in their relative deviations: random walk is damping and Brownian motion is explosive over time. Only population model of birth-death process has stable relative deviation, which is capable of understanding the Principle of Large Numbers in a growing process.

There are two implications from this theoretical analysis. First, sustainable market is characterized by persistent fluctuations, which is collective behavior in nature. Second, representative model in financial economics is not capable in understanding endogenous fluctuations and resilient market. The birth-death process is a better alternative to geometric Brownian motion in option pricing (Chen 2005). It is possible to modify the option-pricing model based on the population model of the birth-death process in stock-price movements (Zeng and Chen 2008). The complexity in competing trading strategies might exhibit the so-called volatility smile (changing market volatility driven by irrational herd behaviour in financial market) observed in option prices.

3.3. Pitfalls in equilibrium theory of option pricing and new understanding of financial crisis

The most fruitful application of neoclassical economics is the parallel development of derivative market and the BS model of option pricing (Black and Scholes 1973, Merton

1973). BS model is based on several assumptions: first, the CAPM model (Sharpe 1964) only considered a constant trend (the risk-free interest rate) and the second moment (volatility); second, the arbitrage-free portfolio in asset pricing; third, the geometric Brownian motion model for stock price changes. A simplified model of binomial tree can simplified the Brownian motion model in price evaluation (Cox, Rubinstein and Ross 1979). However, these equilibrium models did not specify the equilibrium condition, which could reveal the possibility of market breakdown. This financial crisis indicated several pitfalls in equilibrium theory of option pricing.

In the 2008 financial crisis, credit default swaps (CDS) played an important role after the fall of Lehman Brothers generated a tremendous loss for AIG. The CDS options model is based on geometric Brownian motion or binomial tree which abstract out market instability (Duffie 1999). We speculate that the explosive model of geometric Brownian motion may cause the meltdown of the derivative market in 2008 financial crisis (Chen 2010).

From our empirical and theoretical analysis, we found out several factors that may explain the dynamical mechanism of financial crisis.

First, the simplest assumption in equilibrium theory is a static trend, such as the rational expectations or long-run equilibrium of wage rate or unemployment rate in macro model and risk-free interest rate in CAPM and BS model. Second, only the first (mean) and second (variance) moment are considered in market risk. Third, there is no interaction between trend (drift term) and volatility (diffusion term) in price movements. In reality, all the three assumptions are should be modified in a more realistic and more general model of option pricing, which is capable of giving market conditions for financial crisis. Because of limited space, we only discuss our main results in developing general theory of option pricing and financial crisis based on population model of birth-death process and master equation (Tang 2009, Tang and Chen 2010a, 2010b).

First, a time-dependent probability function, which can be solved by a master function by means of high moment expansion. For a simplified population model of birth-death process, the transition probability can be determined from empirical observations. The condition for the existence of probability distribution indicates the possibility of market meltdown (Tang and Chen 2010a).

Soros observed the reflectivity between market sentimental and market fundamentals (1987, 2003), which can be studied by interaction between drift trend and diffusion volatility. We replace the static trend (the risk-free interest rate) by moving HP trend, which can be determined from empirical analysis. We found that the emergence of financial crisis can be

understood by collapse of expectation trend and sudden rise of high moment risk (Tang and Chen 2010a).

When we modify the option pricing model by the birth-death process, we find new solutions in option pricing theory (Tang and Chen 2010b). The general solution of option pricing is similar to BS model in formulation with one exception. Its solution contains multiple frequencies that are consistent from our previous studies of persistent cycles.

If we consider only the first and second moment (i.e. mean and variance in portfolio theory), the solution will converge to that of the Black–Scholes model, in which an arbitrage-free portfolio can be constructed. If, however, we add the third and fourth moments, the model solution might produce complex patterns, such as a trend collapse and market crisis

IV. Conclusion

Equilibrium models in macro and financial crisis cannot understand the endogenous nature of business cycles and regime switch between normal market and financial crisis. Their portrait of self-stabilizing market is based on linear equilibrium thinking, including linear model of representative agent, such as random walk and Brownian motion. Their random evidence is derived from the FD filter with short-term time window. Therefore, regression analysis in econometrics is not capable of discovering nonlinear and non-stationary features of economic dynamics.

Based on WGQ transform in time-frequency analysis and persistent patterns in relative deviations from macro and stock indexes, we find out that persistent cycles and persistent fluctuations are endogenous nature of collective movements. As a first approximation, color chaos model is a better alternative to white noise in business cycle theory, while birth-death process is a better alternative to geometric Brownian motion in option pricing.

From complementary analysis by means of deterministic and stochastic approaches of macro and financial indexes, we find out that structure and history matters in macro and financial studies. A three level model of micro-meso-macro economy is better than two-level model of micro-macro economy. Macro business cycles are rooted in financial intermediates and industrial organization, which insight can be traced back to Hayek, Keynes, and Minsky.

There is weak theoretical and empirical evidence of efficient market, rational expectations, and microfoundations of business cycles, since white noise only has minor role in business cycles. Economic indicators show clear feature of collective behaviour, which is confirmed by behavioural economics.

Business cycles have positive and negative impacts to three levels of economy. For sustainable growth under ecological constraints, innovation policy and competition policy is more important than fiscal and monetary policy for creative destruction and macro stability. Business cycle management can be better greatly improved by frequency domain analysis in addition to time domain analysis.

New science of complexity provides us new tools in studying complex economic systems and new thinking in economic perspectives. An interdisciplinary dialogue would be fruitful both for economists and scientists.

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