Invited Paper

Interacting Psycho-economics Expectations Ratios with Equity/debt Realities Suggests a Crisis Warning Method

Barry Thornton[1,2*], Elysia Thornton-Benko[3], Layna Groen[1]

[1]*University of Technology Sydney, Mathematical Sciences*
E-mail: fthornton@ozemail.com.au

[2]*University of Sydney, School of Physics*

[3]*University of Technology Sydney*

[*]*Corresponding author*

Received: November 11, 2011 **Accepted: December 27, 2011**

Published: January 31, 2012

Abstract: *The recent April 2011 meeting of the G20 countries considered possible development of a global early warning system to avoid any future financial crisis. Psycho-economic factors are strong drivers of greed, fear and non-rational behavior and experience shows that they should not be excluded from such a project. Rational, logical behavior for attitude and actions has been an assumption in most financial models prior to the advent of the 2008 crisis. In recent years there has been an increasing interest in relating financial activity to phenomena in physics, turbulence, neurology and recent fMRI experiments show that cortical interactions for decisions are affected by previous experience.*

We use an extension of two Lotka-Volterra (LV) interactive equations used in a model for the 2008 crisis but now with fluctuation theory from chemical physics to interact the two previously used heterogenous interacting agents, the psycho-economic ratio C_E *of investor expectations (favourable/unfavourable) and the reality ratio of equity/debt. The model provides a variable, M, for uncertainties in* C_E *arising from the ability of the economy to affect the financial sector. A condition obtained for keeping rates of change in M small to avoid divergence of spontaneous fluctuations, provides a quantifiable time dependent entity which can act as a warning of impending crisis. The conditional expression appears to be related to an extension of Ohm's law as in a recently discovered "chip" and memory – the memristor. The possible role of subthreshold legacies in* C_E *from the previous crisis appears to be possible and related to recent neurological findings.*

Keywords: *Psycho-economics, Financial crises, Interacting heterogenous agents, Lotka Volterra equations, Fluctuation theory, Non stationary resonances, Memristor "chip" analogy, Fluctuation theory.*

Introduction

The 2010 perceived gradual recovery from the 2008 financial crisis is still uneven and far from equilibrium across regions and countries with some situations vulnerable to relapse from unexpected or sudden economic fluctuations despite earlier rescue efforts. The Euro debt network and unease from the increasing debt in the US economy are two of the current serious concerns.

The recent April meeting of the G20 countries considered possible development of a global early warning system to avoid any future financial crises. Psycho-economic factors are strong drivers of greed, fear and non-rational behaviour and experience shows they should not be excluded from such a project. Rational, logical behavior for at attitude and actions has been an assumption in most financial models prior to the advent of the actions leading up to (and followed up from) the recent 2008/2009 crisis. Motivated by Bouchard [4], and others in recent years there has been an increasing interest in relating financial activity to phenomena in physics, such as by Aoki and Yoshikowa [1], turbulence, neurology, Stix [17], and more recently fMRI experiments by Gilbey, Caceda and Kitts [12] revealing the cortical interactions for strategic action. The latter experiment showed that expectation performance can depend not only on the insula (emotions) and superior temporal sulcus (anticipating other peoples' attitudes) but also on the accesses to the anterior cingulate cortex which is crucial for new decisions based on results from previous expectations. Observation of activities during and following the 2008 crisis led to our initial model involving human expectations interacting with equity and debt.

In an initial study with these variables in the earlier global financial crisis we used a type of coupled interactions model which reasonably portrayed the record of their changes during the crisis and recovery during 2009 with the US economy reasonably steady.

We found how an extension of two Lotka-Volterra (LV) interactive equations, Murray [14], plus fluctuation theory, can then be used to interact two heterogeneous interacting agents (HIA) such as those discussed by Delli-Gatti et al. [9] and Chalry et al. [5]. We used the psycho-economic ratio C_E investor expectations (favourable/unfavourable) and the reality ratio of equity/debt C_D. Their interaction represented the occurrences of transactions.

The foregoing is the basis of a new model for practical development of a warning system and now includes a variable *M* for a rating of the overall economy for its influence on the attitude of the financial sector as in the current "recovery" period. With IT technology for collecting progressive data for the resulting warning expression we find (in Section *A proposed method for warnings*) that the model can indicate and help in dampening of divergence of unexpected spontaneous fluctuations, which may also be triggered from sub-threshold legacies which are now indicated as possible from the new model. The cross-disciplinary method presented for warning and control may interest economic specialists to investigate the topic further.

Developments from the initial crisis model for current situations

From financial media during and following the 2008 crisis, we sought data for use with the proportions of participants involved with two heterogenous interacting entities in the initial LV model for the crisis and the subsequent period:

(i) The psycho-economic ratio of investors' favourable to unfavourable expectations, C_E at time *t*.

(ii) The associated ratio of equity to actual reality debt (C_D).

As in LV models the density of transactions was represented by the interaction product $C_E C_D$ for stock exchange transactions which occurred from late 2007/2008 to the 2009/2010 recovery. From regular progressive financial media reports and other avenues enough collected data was considered to have applied for what appeared to be segments of an LV

orbit for us to test an LV model, at least over ranges of low-low, low-high, high-low and high-high conditions of C_E and C_D.

The two variables C_E and C_D were used as heterogeneous interacting agents, in the initial model based on two LV Eqs. (1) - (2).

$$\frac{d\bar{C}_E}{dt} = b_1 \bar{M}\bar{C}_E - c_1 \bar{C}_E \bar{C}_D \quad (1)$$

$$\frac{d\bar{C}_D}{dt} = -c_2 \bar{C}_D + b_2 \bar{C}_E \bar{C}_D \quad (2)$$

The *b* and *c* parameters can, in principle, be time dependent (Williamson [20]) and adjusted from initial conditions as time progressed.

The barred notation for $\bar{C}_L$, $\bar{C}_D$ and $\bar{M}$ was used for averaged values based on prevailing conditions at the start of the crisis. $\bar{M}$ was used as market operators' assessment rating of the ability of changes in the economy to affect investors $\bar{C}_E$ for decisions but not the actual reality of the equity/debt ratio itself nor the subsequent actual transactions interaction $\bar{C}_E \bar{C}_D$ done in the market. The average value $\bar{M}$ was taken as steady (unity) at the early stage.

Eq. (1) shows the rate of change of the initially fast rising expectations ratio C_E near late 2007 was quickly reversed in the start of the crisis by the recognition of the reality of the true equity/debt in the transactions interaction density term proportional to $C_E C_D$. The decline of the true equity/debt ratio C_D in Eq. (2) was moderated by a proportion of transactions being made. Whereas $\bar{M}$ was initially taken as constant it now needs to be a variable, $\bar{M}(t)$, for conditions in the present recovery period as will be seen in Section 4 because of interactions now occurring between $\bar{C}_E$ in the financial sector and $\bar{M}$ for the economy's effects (late 2010 onwards).

In Fig. 1 the X axis is C_E, Y axis C_D both scaled 0 to 1 and the Z axis ordinate is a scaled density of transactions represented from the product $C_E C_D$ as in LV formulation of interaction of species. There was a short lag time between C_E and C_D seen in separate C_E and C_D graphic plots from Eqs. (1) - (2), as awareness of debt reality leaked out.

The sequence of selling, 2008. Overlapped global components in the orbit

Our initial model started with the known conditions at the end of 2007 from a successive and progressive number of individual starts (top left corner of Fig. 1). To show how the rapid onset of selling transactions of overlapping global pathway inputs was represented, we show an example in Fig. 1 with 25 global stock exchanges with correlated transactions to represent 20 different commercial and industry sectors with small time delays between the Exchanges from different countries (left hand downwards orbit pathways). The short delays between each transaction group gave a slightly different starting value for each entry into the pathway. Correlations in equity sectors and major currencies were reported in later studies by Aslanidis [3]. The correlated groups had a spectral range of frequencies in these selling transaction sequences. We interpreted results as representative of a $1/f^{\alpha}$ type of noise

$(1<\alpha\leq 2)$ sequence $\psi(t)$. It had correlations of power spectra over a range of frequencies and acted as $1+\psi(t)$ on the interactions term for $C_E C_D$ in Eqs. (1)-(2). Such interactions are discussed by Doering and Horsthemke [19], Arnold et al. [2]. The results were reasonably consistent with observations during the crisis (2008) and for the low level recovery (2009/2010) as seen in Fig. 1. Exogenous bailouts and stimuli had then almost stopped the global noise in the orbit trajectory.

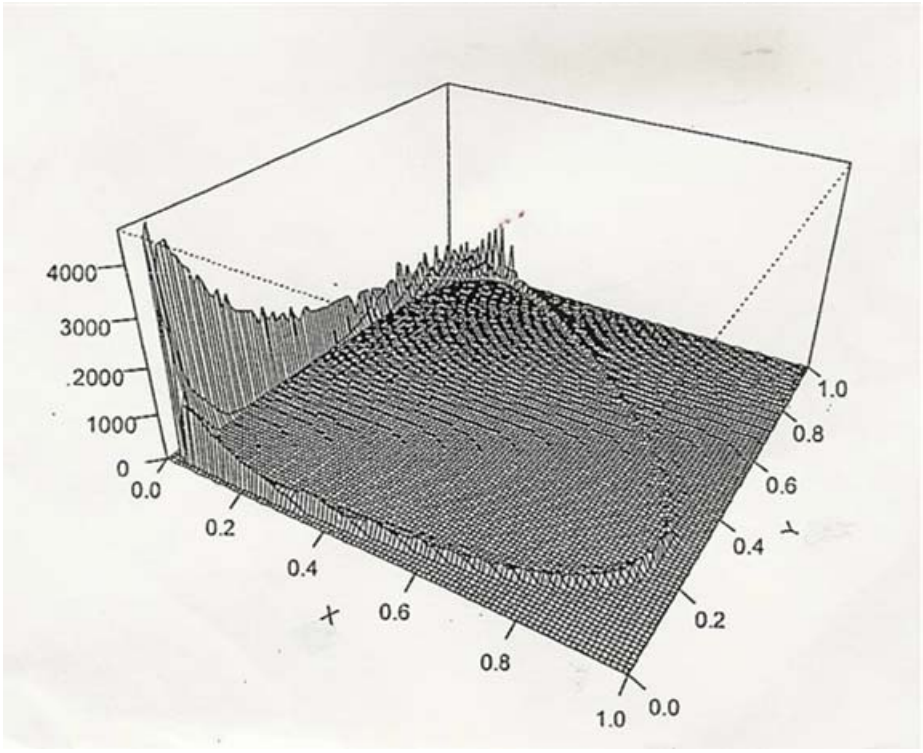

Fig. 1 LV orbit showing scaled density of $C_E C_D$ values (vertical axis) legacy late 2007 (top left corner). X axis gives C_E and Y axis C_D scaled 0 to 1. Transactions span years 2008, 2009, 2010 returning ready for 2011. Closely spaced individual global selling sequences 2008 Z axis represent transactions sequences with $1/f$ type correlated power spectrum subsiding in 2009 in recovery. Fluctuations increasing in late 2010 near orbit end. Initial b_1, b_2, C_1, C_2 and M at late 2007 were 0.5, 1.5, 0.2, 1.0 and M = 1.0, $C_E(0)$ = 0.2, $C_D(0)$ = 0.9 (adjusted for temporal conditions). 2008 crisis selling transactions started down left vertical axis from left hand corner of Fig. 1. The late 2011 fluctuations are shown at inner pathway top left hand corner.

However, the post-crisis large scale re-evaluations of inter-bank transactions and derivatives for new debt and equity results from large scale disentanglements (Rosenblat [15]) would have a Brownian noise type property in the resulting sequences separated by white noise gaps. Brownian noise separated by white noise gaps is known to provide a spectral power behaviour of $1/f^2$ (Crandell [7]).

The declining $1/f^2$ type noise sequences gave a smaller effect on the transaction densities in the recovery (2009 onwards). However, the small fluctuations in levels of expectations in 2009 and 2010 would be susceptible to spontaneous fluctuations as noted by Keizer [13] from exogenous (or internal) sources, such as instabilities in the overall economy which affect $\bar{M}\bar{C}_E$.

Small fluctuations in the late recovery period

Any additional spontaneous fluctuations in the C_E or $\bar{M}$ variable can, from fluctuation theory, produce instability. Such fluctuations from uncertainty and fear could be triggered from previous experience via media and communication systems which report daily on global economics. Even a small number of sub-threshold levels can, if accessed from such fluctuations, produce non-stationary stochastic resonances as shown by Fakir [17]. We suggest that such resonances could be possible even at a late recovery period, as follows:

Signs of fluctuations increasing in late 2010 (top left hand inner orbit) suggest a possible legacy occurring by using properties of the windowed wavelet transform integral F on the earlier $1/f^{\alpha}$ noise effect on $\bar{C}_E\bar{C}_D$ during the 2008 global crisis. The $\bar{C}_E\bar{C}_D$ values from noise sequences had close, tight components at scales s_1 in 2008. This was seen from the localised densities in 2D plots of superimposed pathways for the sequence of slightly delayed selling in global exchanges. Therefore a windowed wavelet transform could reveal, Daubechies [8] and Crandell [7b] where, and at what scales, appreciative contributions could occur again at a quite different later time locale where scales s_2 are close in size to s_1. The peaks and troughs in $\bar{C}_E\bar{C}_D$ appearing in the orbit model plot near the end of 2010 may be explained in this way. If so, they could have been susceptible to any spontaneous fluctuations at that time and become unbounded if sub-threshold levels of $\bar{C}_E$, had they existed, had been accessed by spontaneous fluctuations in $\bar{C}_E$. However, new strategic plans were announced by Governments at that time but serious fluctuating uncertainties in $\bar{M}$ and $\bar{C}_E$ have since been increasing in Europe and USA. We must allow for changes in $\bar{M}$, for the perceived ability for transference of unstable effects in the economy to expectations in the financial sector, i.e. $\bar{M}$ should now be a variable for its effect on $\bar{C}_E$ in Eq. (1).

The mathematics changes significantly but statistical physics and fluctuation theory then provide a method, as shown below, to avoid unbounded development of spontaneous fluctuations in such conditions which are occurring far from equilibrium.

A proposed method for warnings

A method from stoichiometric chemical reaction physics, as used by Keizer [13] for compensating for undesirable effects from any spontaneous fluctuations, can be applied to prevent development of such occurrences as indicated above. If the time rate of change of the averaged value of $\bar{M}$ could be brought close to zero in a third equation, Eq. (3), shown below, by introducing a compensating function $G(t)$ to keep $\bar{M}$ steady, it would allow LV equations for averaged variables to still apply. $G(t)$ can act as an early warning indicator by virtue of the magnitude of its increase or decrease in value, required to keep $\bar{M}$ steady.

$$\frac{d\bar{M}}{dt} = -b_1\bar{M}\bar{C}_E + G(t) = zero \qquad (3)$$

The application from fluctuations theory and chemical physics requires extended "chemical bath" conditions and this resource requirement is represented by the large number of market operators in our case.

Time scale for recovery

Relevant examples in the Keizer [13] paper using the foregoing approach in chemistry, show the stability achievable using several examples corresponding to our $\bar{M}/c_2$ values of 10, 5, 1 over time t scaled as $c_2 t/3$. Computations of $G(t)$ from progressive data for $\frac{d\bar{M}}{dt} + b_1 \bar{M}\bar{C}_E$, from Eq. (3), could provide a warning from the changes in the value required for $G(t)$. Also we note that $\bar{M}/c_2$ can provide a time scale for recovery. The c_2 relates to the proportion of debt ratio $\bar{C}_D$. Our variables have then been utilized for use in a warning system.

Legacy, neurology and Ohm's law

We note an interesting analogy of the required condition $G(t) = b_1 \bar{M}\bar{C}_E$, to the recent extension of Ohm's law in the form $V = \mathrm{I}.R(q)$, in the earlier prediction by Chua [6] and now found and actually produced by Strukov et al. [18], Versace and Chandler [19] as the "memristor" (memory resistor) chip. The symbol q is the charge which has passed through the resistance R. The resistance $R(q)$ retains memory of the previous charges q which have passed through it. It has instigated new neurology research into human decision making processes (see foregoing references). We ask the question, in our case, could $\bar{C}_E$ be analogous to $R(q)$ and $b_1\bar{M}$ (relative influence of the economy on C_E) be analogous to a current I. If so, it would enable recent neurological findings to be incorporated in new economic studies.

Conclusion

The values for warnings of possible occurrence of the type of financial problem considered could be generated for regulatory agencies of the type suggested by Stiglitz [16]. At present financial strategy appears to be planned without considering the importance of psycho-economic entities and genuine debt reality, along with the stability of the economy.

Current Government financial strategies have appeared to be mainly for "stand-by", when troubles appear. Information on changes in the required variables presented could be of value in developing a warning system based on the value of $G(t)$. Recently available ICT facilities and some from "social networking" now increasingly applied to business could be of value for the data required. A number of organizations are now handling many thousands of conversations and reports per second, extracting and converting information to quantitative forms for dedicated classes of data for business and technology.

Acknowledgement

We thank Professor Carl Chiarella, School of Finance and Economics, University of Technology Sydney for providing related financial references for new approaches to macro-economics.

Authors Research Contributions

Professor Barry Thornton was the major researcher. Dr Elysia Thornton-Benko provided neurological information from her earlier research at the University of Technology Sydney and medical experience. Dr Layna Groen assisted with economic discussions and review of the article.

References

1. Aoki M., H. Yoshikawa (2007). Reconstructing Macroeconomics. A Perspective Statistical Physics and Combinatorial Stochastic Processes, Cambridge University Press.
2. Arnold L., W. Horsthemke, J. Stucki (1979). The Influence of External Real and White Noiseon the Lotka-Volterra Model, Biomed J, 21, 451-471.
3. Aslamidis N. (2010). Modelling Asset Correlation during the Recent Financial Crisis: A Semiparametric Approach, Research Seminar presentation, School of Finance and Economics, University of Technology Sydney.
4. Bouchaud J.-P. (2009). The (Unfortunate) Complexity of the Economy, Physics World, Institute of Physics, 82(4), 28-32.
5. Chalet D., M. Marshall, Y.-C. Zhang (2004). Minority Games: Interacting Agents in Financial Markets, Oxford University Press.
6. Chua L. (1971). Memristor – the Missing Circuit Element, IEEE Transactions on Circuit Theory, 18, 507-519.
7. Crandell R. E. (1994). Projects in Scientific Computation, (a) p. 161, (b) p. 202, Springer-Verlag, New York.
8. Daubechies I. (1992). Ten Lectures on Wavelets, SIAM, Philadelphia, PA.
9. Gatti D. D., C. Di Guilins, E. Gaffeo, M. Gialini, A. Palestrini (2005). A New Approach to Business Fluctuations: Heterogeneous Interacting Agents, Scaling Laws and Financial Fragility, Journal of Economic Behaviour and Organisation, 56, 489-512.
10. Doering C., W. Horsthemke (1984). Non-equilibrium Phase Transitions Induced by Multiplicative Noise, Physics Letters, 81, 24-50.
11. Fakir R. (1998). Nonstationary Stochastic Resonances, Phys Rev E, 57, 6996-7001.
12. Gilbey R., R. Caceda, C. Kilts (2010). When Emotional Reasoning Trumps IQ, Harvard Business Review, 27, HBR Reprint F100D.
13. Keizer J. (1976). An Observation on the Effect of Fluctuations far from Equilibrium: The Lotka-Volterra Model, Journal of Statistical Physics, 15(6), 477-483.
14. Murray J. D. (1995). Mathematical Biology, Springer, Verlag.
15. Rosenblat D. (1960). On Some Aspects of Models of Complex Behavioural Systems in Information and Decision Processes (Ed. R. E. Machol,. McGraw Hill), New York.
16. Stiglitz J. (2008). The Way Out. How the Financial Crisis Happened and How it Must be Fixed, Time, 52.
17. Stix G., (2009). The Science of Bubbles and Busts, Scientific American, 301(1), 64-71.
18. Strukov D., G. Snider, D. Stewart, S. Williams (2008). The Missing Memristor Found, Nature, 453, 80-83.
19. Versace M., B. Chandler (2010). The Brain of a New Machine, IEEE Spectrum, 47, 30-37. (Also see Mullias J. (2009). Memristor Mind, New Scientist, 40-43).
20. Williamson R. E. (1997). Introduction to Differential Equations and Dynamical Systems, International Edition, McGraw-Hill, 338-339.

Dr Barry Thornton
E-mail: fthornton@ozemail.com.au

Dr Barry Thornton is an Emeritus Professor at the University of Technology Sydney, Faculty of Science and Honorary Professor (research) at the University of Sydney, School of Physics. His work has been in a wide range of disciplines, mathematics, physics and IT development and applications in industry. He has been a consultant to Boeing and the US Air Force and major commercial organisations in Australia.

Dr Elysia Thornton-Benko

Dr Elysia Thornton-Benko is an honours graduate in medicine, University of Western Australia and has research Ph.D. experience in medical physics in neurological applications at the University of Technology Sydney.

Dr Layna Groen

Dr Layna Groen is a Senior Lecturer at the University of Technology Sydney with research degrees in mathematical finance.