Multi-Agent Financial Network Analyses For Systemic Risk Management Post 2007 Financial Crisis: A New Complexity Perspective For G10 and BRICs

Sheri M. Markose [1]
Economics Department, University of Essex, Wivenhoe Park, Colchester C034SQ
First Draft 16 Nov 2010

Abstract:
As with the US Office of Financial Research that aims to overcome problems of balkanization of financial and banking data and to have better models to provide quantitative oversight of the financial system nationally or globally, institutions such as the European Central Bank, International Monetary Fund and newly set up financial stability divisions in different countries have intensified efforts to investigate new modelling tools such as financial network analysis. These can yield bottom up holistic visualizations of interconnections of financial obligations that can help identify systemically important players and more importantly model the threats to system stability from the growing interconnectedness between banks and financial derivatives markets. This paper gives an overview and critique of reform efforts in this direction drawing on an exemplar based on an empirical network mapping of the US Credit Default Swap (CDS) market which stands implicated as a key propagation mechanism in the 2007 crisis. The discussions are relevant for BRICs as they are en route to monetary and financial transformations similar to those in the developed countries which include reduction in inflation and growth of cashlessness in payments with electronic or mobile phone fund transfers at point of sale, securitization of bank loans and the proliferation of financial derivatives, especially CDS. The paper highlights the paradigm shift and skills gap involved in implementing large scale data base driven multi-agent financial network models where strategic behaviour of financial intermediaries and regulatory incentives and constraints shape the structure and stability of the complex interconnected system. The dichotomy between money and finance that has been a dominant feature of G10 policy has placed and continues to place barriers for new thinking on cashlessness and financialization of monetary systems and systemic risks thereof.

Keywords: Systemic Risk, Financial Network Analysis, Multi-agent Models, Complex Adaptive Systems, Regulatory Arbitrage

---

[1] Sheri Markose is the corresponding author. Her email address is scher@essex.ac.uk.
Sheri is a professor of Economics at the University of Essex and founder director for the Centre for Computational Finance and Economic Agents where a complexity and networks perspective for an Economics and Finance MA and PhD curricula has been pioneered. This is based on her talks on 22-23 August 2010 at the Reserve Bank of India for the Financial Stability Group. It also draws on the Markose *et. al* (2010) paper first prepared for the ECB Workshop on *Recent Advances in Modelling Systemic Risk Using Network Analysis",* 5 October 2009 and also presented with updates at the IMF Workshop *On Operationalizing Systemic Risk Monitoring* 26-28 May 2010. This paper represents her views alone and not of any of the institutions mentioned above. She is grateful for inputs from Johannes Linder, Olli Castren, Morten Bech, Juan Solé , Inci Okter-Robe, Manmohan Singh, Greg Fisher, Robert May and Steve Spear. This research has benefited from EC funding for the COMISEF RTN which supported the research assistance from Simone Giansante.

Multi-Agent Financial Network Analysis For Systemic Risk Management: New Complexity Perspectives Post 2007 Financial Crisis For G10 and BRICs

Sheri M. Markose

1.Introduction

The 2007 financial crisis with its epicentre in the US has had severe global repercussions. The crisis has exposed shortcomings of so called state of the art monetary economics (Buiter, 2009) and the regulatory framework of Basel II. Most of all the absence of a quantitative modelling framework to provide an integrative picture of the financial system has impeded progress in the monitoring and management of systemic risk. On the eve of the collapse of Lehman Brothers in September 2008 when the American Insurance Group (AIG) also stood imperilled due to its inability to make good on collateral calls for credit guarantees on assets of large financial intermediaries (FIs), a lack of data or models at the US Treasury and the Federal Reserve on the possible knock on effects in the US and globally, forced officials to fly blind at the critical juncture. The outright market failure manifested as a run on short term repo markets when liquidity providers failed to lend against collateral, referred to as the liquidity or credit crunch, signalled impending collapse of banks globally. The US, UK and European tax payer bailout of key financial intermediaries that ranged from full and partial nationalization to financial guarantees under the rubric of '*too interconnected to fail*' reached unprecedented amounts of over $14 Trillion (see, Alessandri and Haldane, 2009). This accounts for over 20% of world GDP. A whole asset class of mortgage backed securities (MBS) which had grown to over $8 trillion in the US alone, surpassing US securities and corporate bonds, has suffered considerable impairment. The extraordinary transfer of $1.5 trillion MBS from balance sheets of US FIs directly on to that of the Federal Reserve in March 2010 to purge the system of toxic assets is an on going fall out of the crisis. Systemic risk consequences which include real side impact or social costs, often measured as permanent losses in GDP, have been very large in that the 2007 recession in US, UK and Europe is recorded to be the worst since the Great Depression. [2]

Systemic risk in financial systems refers to the failure of a single financial institution, a sector such as a clearing house or a particular market that can lead to serial failures of other units, sectors or markets and eventually to a global collapse of the system. Generically, systemic risk in financial intermediation for which we seek an institutional solution, can be viewed as a negative externality that arises from an oversupply of leverage and/or unfunded insurance that result in losses from default on obligations that go beyond the financial sector and ultimately have to be borne by the tax payer. Decisions that are individually rational at the level of the financial intermediary (FI) in that it helps expand market share or short term profits may lead as a result of competition among intermediaries to aggregate levels of financial obligations that cannot be sustained by liquid assets that back private debt creation. At a substantive level, the main threat from private credit based liabilities is no different from well known problems with fractional deposit banking with its potential to collapse when convertibility to more liquid forms of regulated funds (ultimately fiat money of the state) is at stake. Operational aspects of managing systemic risk relate to a cascade of insolvencies of FIs from failure of key liquidity suppliers which threatens to precipitate both a financial and economic collapse.

The origins of the financial contagion from the sub-prime[3] crisis in the US have been traced to the transformation of bank balance sheet components with the development of financial products such as off balance sheet (remote) and on balance sheet synthetic securitization of mortgages and other bank loans, Collateralized Debt Obligations (CDOs) and Credit Default Swaps (CDS). [4] These innovations were subjected to little or no regulatory scrutiny and consumer protection for investors such as pension funds. If the extent of the subprime crisis was confined to mortgage providers who faced the brunt of defaulting mortgagees, the problems would not have exceeded the sort encountered during the Savings and Loans crisis in the 1980's. Reforms aimed at strengthening regulation of mortgage lending, by addressing issues on predatory lending and poor underwriting practices that characterized sub-prime mortgages, may have sufficed. However, it is the need to answer the question as to how initial losses in 2007 totalling no more than $300 billion on $2trillion US subprime mortgages got magnified and globally distributed to the point where the demise of few key financial players threatened global financial markets that has led to the growing view that new tools have to be harnessed to study financial system wide interconnections, product design and the role of regulatory inputs for their capacity to exacerbate or reduce instability of the system.

[2] Haldane (2010) gives estimates of losses in terms of world GDP of between $60 trillion to $200 trillion. The US Census Bureau of 2009 reported that the median income in 34 US states declined by upto 10% in a year from 2007-2008. These falls are the largest ever recorded. The size of the losses to securities, pension fund and real estate equity that constitute US household sector net worth from the peak in 2007 Q3 is placed at about $11 trillion (source, Federal Reserve Board).

[3] By 2006, subprime mortgages supplied to those with poor credit history and often with no income or dubious self-certified credentials grew to about 20% of the $10 trillion US mortgage market.

[4] The growth of the subprime segment of mortgages occurred primarily because, despite their high probability of default, these mortgages could be packaged into a seemingly attractive and marketable investment product by a process of tranching inherent to CDOs. Senior CDO tranches were structured in such a way to be last to be hit in terms of the cash flows entailed in the pool of mortgages as defaults burnt through the lower equity and mezzanine tranches. The equity tranches which suffered the first hit were soon characterized as 'toxic'. Investors in the senior tranches relied on asset protection offered against default on the reference assets underpinning the CDOs either through the vehicle of credit default swaps (CDS)or other credit enhancements. CDS involve a bilateral contract between a buyer and the CDS protection seller who pays the buyer the gross notional value of the reference asset less the recovery rate at the time of the credit event which is typically default. The CDS buyer pays periodic premia called the CDS spread.

More worrying is the longstanding failure of academe in economics and the regulatory bodies to keep abreast of the institutional and technological innovations in monetary and financial sectors. These have created unprecedented volumes of 'inside' money via securitization and other forms of private credit creation, a shrinking of state supplied 'outside' notes and coins in circulation or M0 in so called cashless economies with an IT based payments technology which has changed payments habits irrevocably, Markose and Loke (2003), and a vast interconnected system of digital transference of financial liquidity in real time with very low latency. Over the period of the last two decades or so, when financial innovations were progressing at a rapid rate, there has been a marked lack of urgency to develop modelling tools capable of mapping and studying the massive interrelationships in the financial system implied by the workings of new financial products. In studies and surveys which aimed, for instance, to provide guidance for regulatory concerns on the concentration of broker-dealers and increased systemic risk from financial derivatives (see, Darby,1994), one is struck by a lack of any quantifiable framework. However, a major conundrum marks the 2007 financial crisis and its aftermath and may account for why the threats from private sector leverage (that grew to about $12 trillion in the shadow banking sector in the US) or loose monetary conditions engineered by authorities were obscured and continue to be so. From experiences of double digit stagflation in the 1970's and early 80's in many countries, inflationary overheating (in the consumer price index, CPI) was the sure sign of growing monetary and economic instability. The epochal reduction in inflation in a number of OECD countries starting from about 1994 – gives a semblance of calm and also of ritualistic complacency in some regulatory circles.

From the vantage of 21st century ICT (Information and Communication Technology) based tools, a non-economist may be forgiven for painting the following picture of how regulators manage systemic problems in the financial system. Mark Buchanan (Aug 2010) in a recent paper in *Nature* gives an account of what advanced IT based tools can deliver : *"A screen on the wall maps the world's largest financial players — banks, governments and hedge funds — as well as the web of loans, ownership stakes and other legal claims that link them. High-powered computers have been using these enormous volumes of data to run through scenarios that flush out unexpected risks. And this morning they have triggered an alarm.... Flashing orange alerts on the screen show that a cluster of US-based hedge funds has unknowingly taken large ownership positions in similar assets. If one of the funds should have to sell assets to raise cash, the computers warn, its action could drive down the assets' value and force others to start selling their own holdings in a self-amplifying downward spiral. Many of the funds could be bankrupt within 30 minutes, creating a threat to the entire financial system. Armed with this information, financial authorities step in to orchestrate a controlled elimination of the dangerous tangle."* Needless to say, such web based visualization of financial data and real time operations relating to financial crisis management is far from being implemented. The technological ICT aids of the 'zoom' that can navigate between the coarse grained bird's eye view and the fine grained ones can mitigate the well known befuddling aspects of not being able to see 'the woods for the trees'. The 'probe' can automate and highlight behind the scenes hidden links of each FI in other markets. Unfortunately, such enabling technologies of advanced ICT economies, of which some BRICs such as India and China are also preeminent pioneers, have yet to be harnessed for economic analysis and systemic risk monitoring.

In the aftermath of the crisis there has been extensive new financial legislation in the US, reforms to Basel II capital adequacy regulation and a plethora of financial stability oversight councils to implement macro-prudential regulations aimed at curbing systemic risk of financial intermediation. As with the US Office of Financial Research that aims to overcome problems of balkanization of financial and banking data and to have better models to provide quantitative oversight of the financial system nationally or globally, institutions such as the European Central Bank, International Monetary Fund and newly set up financial stability divisions in different countries have intensified efforts to investigate modelling tools such as financial network analysis. [5] While this approach can yield bottom up holistic visualizations of financial interconnections, one of the main messages of this paper is that these exercises should not be reduced to one of identifying systemically important FIs in terms of their aggregate financial obligations with little understanding of the network structures in key markets and the drivers behind financial network instability.

A lack of a holistic perspective on the linkages between constituent elements can be blamed for so called *fallacy of composition* [6] famously cited by Brunnemeir *et. al.* (2009) for why Basel II regulatory authorities encouraged bank behaviour which may appear sound at an individual level nevertheless contributes to system wide failure. As Sheng (2010) noted that while there have been excellent and detailed verbal narratives on the 2007 crisis, where factors such as naturally existing selfish or myopically strategic behaviour at the level of individual units (see, Acharya and Richardson (2010)), regulation which homogenizes regulatee behaviour (Brunnermeir *et. al.* 2009) or provides perverse incentives (Jones (2000), Hellwig (2000)) - all of which contribute to system instability, there has been few attempts to give an unified and quantifiable framework on system fragility that can incorporate requisite complexity. Systemic risk in financial systems like environmental externalities which lead to over use and degradation of resources arises from well known design problems that are required to attenuate individual behaviour based on local incentives to prevent system collapse. This paper uses an empirically calibrated financial network of the US CDS market developed in Markose *et. al.* (2010) to investigate the extent to which ICT based multi-agent financial network models can be

[5] ECB 5 October 2009 Workshop on *Recent Advances in Modelling Systemic Risk Using Network Analysis"* *http://www.ecb.europa.eu/pub/pdf/other/modellingsystemicrisk012010en.pdf?d216f976f3587224bcc087cc8149ed49*, and also the IMF Workshop *On Operationalizing Systemic Risk Monitoring* 26-28 May 2010 http://www.imf.org/external/np/seminars/eng/2010/MCM/index.htm .

[6] Brunnemier *et. al*(2009, p15)have cited the domino effects triggered by deleveraging that follows when creditors seize the assets given as collateral of stricken FIs. This has been a response from time immemorial and enshrined in common law to mitigate moral hazard from debtors being profligate. While deleveraging is a painful process by which the bubble bursts and more normal conditions are restored – this *per se* it is not a major design flaw of Basel II. They also cite the deleveraging by fire sales that is triggered by losses on assets due to the capital adequacy ratio being breached when assets are impaired due to default or fall in asset markets.

useful in monitoring and analysing extant systems and can be used as computational test beds for the design of robust policy reforms given the legacy of the 2007 crisis.

While boom and bust have generic features with excessive leverage at the heart of the problem, specific institutional propagators are involved every time a crisis occurs and there is no alternative to having fine grained structural knowledge of the system. The specific propagator of the 2007 crisis that will be highlighted is the one to do with the growing concentration in the market structure with a few large FIs in the credit derivatives market that is central to the credit risk transfer (CRT) scheme in Basel II and III. In particular, network stability analyses indicate how socio-economic networks can be driven to so called supercritical states of instability by a combination of individual and institutional incentives in force. In a nut shell, Basel II CRT scheme for assets on bank balance sheets and its precursor in the US, the Federal Reserve Board Rule No. 99.32 which was in force since 2002, stand implicated in turbo charging a process of leverage that increased connectivity between depository institutions and as yet unregulated non-depository FIs. As part of the Basel II scheme on synthetic securitization and due to the Federal Reserve Board Rule No. 99.32, unfunded [7]guarantees inherent to CDS from a triple AAA rated guarantor was deemed a permissible credit risk mitigant for bank balance sheet MBS which also secured banks capital reductions from 8 % to 1.6% using the maximum risk weight of 20%. This strongly incentivized the use of CDS by banks which began to hold MBS on bank balance sheet rather than remotely and also brought AAA players such as AIG, hedge funds and erstwhile municipal bond insurers called Monolines into the CDS market as protection sellers. [8] Highest rated banks and non-depository FIs competed to raise both 5 times more leverage (that the 1.6% capital charge allowed compared to the 8% one) and generate quantities of AAA rated MBS commensurate with this. The CDS protection sellers took on large exposures both in notional value of bank balance sheet MBS and in terms of increased procyclical risk to house price down turns. Indeed, the too *interconnected* to fail epithet (as opposed to being too *big*) has arisen in the context of having to retain AIG in a non-failed state to prevent its failure from triggering failure of its counterparties via the channel of its CDS obligations.

Apart from work reported here on the CDS market there has been to date very little empirical work done[9] on mapping of the network structures of markets involved in propagating the 2007 crisis. I discuss the empirical mapping of the financial network based on firm level FDIC Call Report data (2008 Q4) for US FIs involved in the CDS market in terms of the all too manifest *too interconnected to fail* characteristics. The premise behind Basel II CRT scheme that credit derivatives spread the risk from banks to those who can bear it better appears not to be borne out as failure of dominant CDS protection sellers required and will continue to need substantial tax payer backstops to prevent dominos effects. Further, we find evidence using our US bank simulation platform that Basel II incentives created the bonanza in bank balance sheet MBS which peaked in 2007 at $0.5 trillion for the 26 FDIC banks involved. Technical details on the tenets of complexity, network modelling and on more powerful tools such as *hypergraphs* that are needed so that systemic risk from financial derivatives with FIs operating in multiple markets can be studied, will be collected in four specially designated boxes.

The rest of the paper will contain the following components. I will start with a brief overview of the complexity and multi-agent networks approach for systemic risk management and contrast it with extant approaches in mainstream economics. Mainstream macro- economic or monetary models for policy show an absence of the endemic arms race of strategic gaming by regulatees which includes innovation, race to the bottom and maladaptive compliance when regulation yields perverse incentives. Further, econometric models cannot handle structural interconnections and interactions between economic units. The paradigm shift and skills gap involved in implementing and utilizing such large scale data base driven computational simulators to analyse financial networks stability and to conduct 'what if' analysis will be highlighted. There is an obvious need to reverse a very lax attitude toward the design of robust regulatory policy framework and the need for stress testing policy both *prior* to implementation and to monitor it on an on-going basis for its capacity to generate perverse incentives. In the words of Kane (2010), we must avoid "official definitions of systemic risk that have left out the role of government officials in generating it." I will also draw on a remarkable study by Axelrod (2003) in which he provides a check list of all manner of threats to a networked system. The point of Axelrod's study to those involved in policy and regulatory supervision is not that the check list is pragmatic but that it is premised on obtaining a fine grained knowledge of the networked system itself and to be wary about beliefs and assumptions being made about network structures and regulatee responses when managing systemic stability in a highly combative and interconnected environment. Like-wise, the work of May (1972,1974) which first alerted us of instability from large complex networked systems will feature in the experiments to do with quantifying the role of so called highly interconnected *super spreaders*.

Having provided an original insight into the conundrum on the lack of inflationary overheating in countries with shrinking cash base, the issues on management of a sustainable monetary and financial environment will be seen to pertain to an ever growing complex web of financialized private debt instruments where electronically speeded misallocation of funds responding to technological or regulatory distortions, if left unchecked, can engineer asset market bubbles and systemic collapses. The stumbling block to harnessing technology, resources and new thinking needed to tackle this lies with the long standing dichotomy

---

[7] Funded credit risk transfer secures the funds for the losses on the full notional value of the underlying *before* the credit event. Unfunded schemes that are represented by CDS, require the protection seller to deliver the funds at the time of the credit event. This exposes the protection buyer to counterparty risk.

[8] The 2004 Q 4 BIS Report on CDS protection buyers and sellers showed that 49% of protection selling in the CDS market was done by non-bank entities. At the end of 2007, the capital base of Monolines was approximately $20 bn and their insurance guarantees are to the tune of $2.3 tn implying leverage of 115.

[9] Rama Cont *et. al.* (2009) have illustrated important aspects of systemic risk in financial networks involving credit default swaps. Their work simulates the CDS network connectivity and exposure sizes on the basis of the empirical properties of the Brazilian and Austrian interbank markets. As the CDS market has considerably more concentration and clustering than interbank markets, the latter may be far off the mark for purposes of assessing the impact of CDS network structure for solvency of large US FIs.

between money and finance in central banking policy circles.

Clearly, network analysis and fine grained firm level data based multi-agent simulators can help address stability concerns for any financial market. This methodology can be adopted, for example, to study and monitor small regional banks called *cajas* in Spain which fuelled the real estate bubble and subsequent crash, the ongoing sovereign debt crisis in Europe and in view of an unfolding banking crisis in the micro-finance sector in India which threatens a rural liquidity squeeze and bank failures, regulators will feel some urgency in having a detailed data based contagion model for the sector. However, the specifics of developing systemic risk management tools following in the wake of the 2007 crisis are of relevance to BRICs as they are en route to similar monetary and financial transformations as those experienced by developed countries at heart of the crisis. These involve reductions in inflation and cashlessness in payments due to electronic or mobile phone fund transfers at point of sale, securitization of bank loans and the proliferation of financial derivatives, especially credit default swaps. Russia suffered a 7.9% fall in GDP and Brazil a fall of 0.1%, India and China only experienced a small slow down in GDP growth post the 2007 crisis.[10] The original contagion factors were countered well. For example in the Indian case, the Reserve Bank of India managed to avoid the fall outs from 2007 financial crisis by a judicious exclusion of bank activity in India that involved investments in MBS and structured products. The excesses of a real estate boom were mitigated by moral suasion of banks to limit lending to that sector. In view of an imminent inclusion of CDS in India and China,[11] it must be noted that the distortionary incentive for capital reduction for banks present in the CRT scheme of Basel II based on risk weights and CDS guarantees that entails a potential for a 5- fold increase in leverage is retained in its entirety in Basel III. This business as usual regulatory stance which has also been challenged by Martin Hellwig (2010) and Pablo Tianna (2010) should alert BRICs to be on guard against cognitive capture that afflicted key elites in the recent crisis. While there is evidence that BRICs, especially India is steering clear of the CRT use of CDS (see,footnote 13) the issues concerning inflation reduction from cashless developments which are progressing quickly in Indian and Brazil remain relevant.

2. Financial Networks and Complexity Approach for Systemic Risk Modelling

Network models are increasingly being used to obtain a better understanding of stability of systems in biology, eco-systems, road transport, infra-structure and cities, engineering, power networks, information systems such as the www and others. Typically in a financial network, the nodes are financial institutions and there are links called *in-degrees* which represent obligations from others and *out-degrees* represent a financial entity's obligations to others. Network models are structural models that aim at depicting causal chains between nodes rather than rely solely on statistical correlations which still remain the basis of most extant contagion models. The study of causal chains of network interconnections with nodes taken to be 'agents' with capacity for rule based behaviour or fully fledged autonomous behaviour that represents financial intermediaries (FIs for short) and also regulatory authorities, constitutes the new framework of financial network modelling. It involves multi-agent based tools capable of building computer simulated environments, see Markose *et al* (2010, 2007). The contractual obligations between FIs, FIs and end users that determine bilateral flows of payoffs constitute pre-existing network structures while an actual crisis with default of counterparties can trigger further contingent claims such as on derivatives obligations and also large losses at default due to collapse in asset markets. Thus, interactions of agents produce system wide feed-back loops. In agent based models these need not be restricted to pre-specified equations which have to be estimated using past data in econometric or time series approaches. The main drawback of equation oriented analyses is that structure changes from strategic behaviour and tracing of causal links and influences of feedback loops on individual decisions are almost impossible to do. Hence, it is argued that agent-based ICT technology embedded in fine grained data based driven digital maps of the structural interconnections of financial markets should be developed as the starting point of stress tests and scenario analysis especially in the context of the policy design.

By data base driven multi-agent models is meant that disaggregated data at the level of individual financial entities will have to be accessed electronically to provide 'as is' quantitative characteristics. For example, large-scale databases on US banks provided by FDIC will be accessed to characterize the quarter by quarter bank balance sheet and off balance sheet activities of FDIC banks. This is important to identify those FIs involved in specific derivatives markets and the market shares in these activities and exposures sector -wise. Such information is useful to help calibrate network structures and financial obligations between FIs. Each FI is a vector of financial activities operating in a multi-scale system in markets, each of which has its own constraints and incentives. Without such powerful integrative tools for system wide visualization of firm level data pertaining to all sectors of the financial system, in an increasingly complex environment where size of nodes or parts of networks alter and new subnets form as new financial instruments come on stream, it will be hard to 'see' or quantify systemic risk impacts of units such as key broker-dealers, a sector such as a centralized clearing platform or even of a market such as credit derivatives. As in the Buchanan's excerpt above, orange alerts can be assigned to threat factors such as overleveraged positions and the pro-cyclicality of underlying assets to the same macro-variable that include house prices or debt of a specific sovereign.

---

[10] Many will argue that the BRICS and other emerging market economies are only beginning to endure the biggest threat from the 2007 crisis with large capital inflows especially since quantitative easing in US. The pressure on currency appreciation and potential loss of domestic manufacturing industry can only be countered by asset price bubbles or inflation.

[11] Note Reserve Bank of India only introducing standardized CDS on single name corporate bonds, traders have to have exposure to the underlying and only physical settlement is possible. http://www.rbi.org.in/scripts/BS_PressReleaseDisplay.aspx?prid=22932

So the excesses of Basel III with regard to bank capital reduction are being avoided in India for the foreseeable future and the recommendations for a 100% capital relief for CDS protection set out in an earlier RBI consultation document (see page 13, http://rbidocs.rbi.org.in/rdocs/PublicationReport/Pdfs/35293.pdf) has been rejected. The news on the Chinese introduction of onshore renminbi denominated CDS on corporate bonds can be found here, http://www.risk.net/asia-risk/news/1635804/china-readies-launch-onshore-cds

2.1 Some Network Structures

Financial networks are far from random and are most likely to have small world network properties (see Box 1) like other real world socio-economic, communication and information networks such as the www. These manifest what is regarded to be a statistical signature of complex systems, namely, a top tier multi-hub of few agents who are highly connected among themselves (often called rich club dynamics) and to other nodes who show few if any connections to others in the periphery (Figure B1). Skewed or power law degree distribution and high clustering coefficients[12] are observed with the latter brought about by many nodes being connected via a few hubs with high interconnectivity between the hubs. To generate power law statistics for nodes either in terms of their size or the numbers of links to/from them, Barabási and Albert (1999) proposed a process called preferential attachment, whereby nodes acquire size or numbers of links in proportion to their existing size or connectivity. The consequence of the clustered structure of a network is short path lengths between a node and any other node in the system. This is efficient in terms of liquidity and informational flows in good times but equally pose fragility in bad times when so called hub banks fail or suffer illiquidity. In other words, the hub banks certainly accelerate the speed of financial contagion among themselves. Failure of the 'big' units increases the probability of failure other big units, an aspect of the *too interconnected to fail* phenomena. But structurally, as will be seen, the interconnected hubs can contain the liquidity shocks and prevent them from going to the extremities, but only if there are adequate buffers. Haldane (2009) calls such hub banks 'super-spreaders' and we will retain this epithet in the financial network modelling that follows. Haldane (2009) recommends that super-spreaders should have larger buffers. He notes that the current system does the reverse. In section 4, I will give brief demonstrations of these concepts in the context of the CDS market.

The presence of highly connected and contagion causing players typical of a complex system network perspective is to be contrasted with what economists regard to be an equilibrium network. Recently, Babus (2009) states that in "an equilibrium network the degree of systemic risk, defined as the probability that a contagion occurs conditional on one bank failing, is significantly reduced". Indeed, the premise of *too interconnected to fail* which we find to be the empirical characteristic of the network topology of the CDS market involving US banks indicates that the drivers of network formation in the real world are different from those assumed in economic equilibrium models. Axelrod (2003) in his study of threats to network stability states : " Dealing with risks in a networked information system must take into account the fact that the system is always far from equilibrium: the system is always changing, growing, and innovating." The latter we will find involves a competitive arms race between participants which often involve disruptive technologies that are different from static efficiency of neo-classical economics.

In terms of propagation of failure, however, it will be shown that it is not true that financial systems where no node is too interconnected (as in a random network) are necessarily easier to manage in terms of structural coherence and stability. I will report on the stability analysis of the empirically calibrated US CDS network and also of a random graph of the same size and functionality in terms of the gross notional CDS sold and bought (see, Box 2). The instability propagation in the highly clustered empirically based CDS network and the equivalent random graph is radically different and the less interconnected system is in some respects more dangerous. This suggests the need for caution in espousing an ideal network topology for financial networks. As little work has been done to date on network structures of the specific markets (CDS and repo) responsible for triggering and propagating the 2007 crisis, it must be noted that the bulk of the financial network approach has been confined to interbank markets for their role in the spread of financial contagion (see, Furfine (2003), Upper (2007)) and Nier et.al. (2007)). However, some of the earlier work remained cursory exercises on abstract models of financial networks often assuming them to be random graphs. Further, the use of the entropy method[13] for the construction of the matrix of bilateral obligations of banks which results in a complete network structure for the system as a whole, greatly vitiates the potential for network instability or contagion. In a complete graph, every node is linked to every other node. This underscores the importance of calibrations for networks in contagion analysis to be based on actual financial flows for the market or some close proxies for network connectivity. Recent work by Craig and von Peter (2010) using bilateral interbank data from German banks have identified the tier–periphery structure and find that bilateral flow matrices are sparse rather than complete or as in random networks.

[12] Clustering in networks measures how interconnected each agent's neighbours are and is considered to be the hallmark of social and species oriented networks. For each agent with k_i neighbours the total number of all possible directed links between them is given by $k_i (k_i-1)$. Let Q_i denote the actual number of links between agent i's k_i neighbours, viz. those of i's k_i neighbours who are also neighbours. It is useful to The clustering coefficient C_i for agent i is given by $C_i = \frac{Q_i}{k_i(k_i-1)}$. The clustering coefficient of the network as a whole is the average of all C_i's and is given by $C = \frac{\sum_{i=1}^{N} C_i}{N}$. Note, the clustering coefficient for a random graph is $C^{random} = p$. In a random graph, p, the probability of node pairs being connected by edges is by definition independent, so there is no increase in the probability for two agents to be connected if they were neighbours of another agent from if they were not. See footnote 42.

[13] For a recent criticism of the entropy method in the construction of networks, see, the 2010 ECB Report on *Recent Advances in Recent Advances in Modeling Systemic Risk Using Network Analysis*.

Box 1 Statistical Properties of *Small World* Networks (Watts 1999, Watts and Strogatz, 1998)

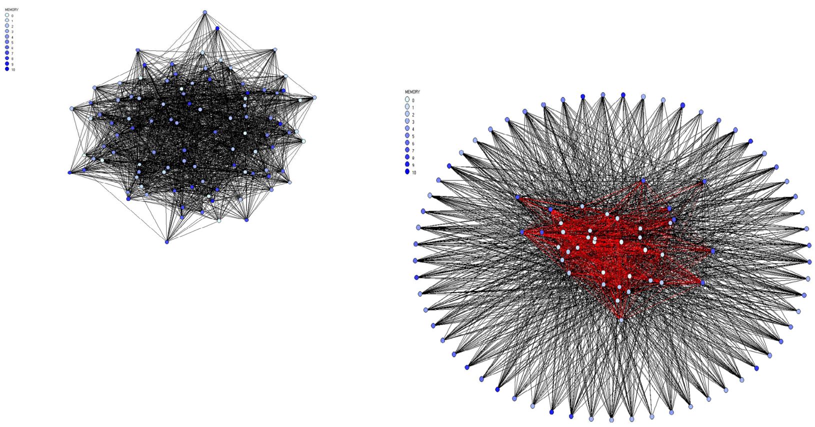
Networks are mainly characterized by the following network statistics - (a) measure of local interconnectivity between nodes called clustering coefficient; (b) number of links between nodes yielding path lengths; *and* (c) degree distribution which can be differentiated for directed graphs as distribution of links to a node (in degrees) and links from a node (out degrees). Text book prototypes of random, regular and scale free networks have properties given in Table B1. Random networks (Figure B1) show no highly interconnected nodes nor any local interconnectivity or clustering. They have short path lengths such that average shortest path between any two arbitrarily chosen nodes is found to be "small" and bounded by the logarithm of the total number of nodes in the system. In regular networks, all nodes have the same number of links to and from them, and they show high and local clustering but do not have short path lengths. Scale free networks have highly skewed distributions of links that follows a power law in the tails of the distribution. Hence, there are some nodes which are very highly connected, but the network does not display local clustering among these highly connected nodes. An important discovery that was made with regard to socio-economic networks is that they do not satisfy these pure text book network types but have only one property common to each of them as shown in Table B1. Socio-economic networks have been called *small world networks.* [14] Socio-economic connections are far from random and their key aspect is high clustering which shows that when an agent is connected to two others, referred to as his neighbours, then there is a higher than average probability that the two neighbours will also be connected. While small world networks like scale free networks have in-egalitarian distribution with some very highly connected nodes, the central tiering of highly clustered nodes which work as hubs for the peripheral nodes (who have few direct connections to others in the periphery) is a signature feature of small worlds (see, Fig B1). The hubs also facilitate short path lengths between two peripheral nodes. We will indicate how such a tiered structure arise in broker-dealer structures as the hub members minimize liquidity and collateral costs by implementing bilateral offsets.

It is useful to estimate so called centrality measures for individual nodes rather than focus on network statistics alone.
A popular measure is the eigenvalue centrality which is for instance used to find the dominance of sites being visiting in Google.

Table B1: Networks Statistics: Diagonal Elements Characterize *Small World* Networks

Properties / Networks	Clustering Coefficient	Average Path Length	Degree Distribution
Regular	*High*	High	Equal and fixed In/Out degrees to each node
Random	Low	*Low*	Exponential
Scale Free / Power Law	Low	Variable	*Fat Tail Distribution*

Figure B.1Graphical representation:Random network (left),Small world network with a multi-hub centre (right)



Source: Markose et. al. (2004)

[14] This is named after the work of the sociologist Stanley Milgram (1967) on the six degrees of separation in that on average everybody is linked to everybody else in a communication type network by no more than six indirect links.

2.2Network Dynamics and Instability: Incentives and Technology

It is important to consider network formation to be a complex adaptive process in that nodes interact strategically and respond to institutional incentives. A key aspect of complex adaptive systems is the capacity of interacting agents to show über intelligence with strong proclivities for contrarian (rule breaking behaviour) and the production of structure changing novelty and 'surprises', Markose (2005). This takes the co-evolutionary form of a Red Queen[15] type arms race in innovation. Regulator-regulatee arms race (no different from a parasite host dynamics) involves monitoring and production of countervailing new measures (comparable to the production of anti-bodies) by authorities in response to regulatee deviations from rules due to perverse incentives or loopholes in place. When competitive co-evolution is present, the system retains status quo in terms of some *relative* performance measure and structures will manifest persistence, especially in market shares. Run away growth in some sectors or of some agents are indications of removal of constraints or countervailing forces which if they are not reintroduced could result in systemic collapse. Failure to monitor and co-evolve the regulatory framework by authorities could result in system collapse. Axelrod (2003) cites system failure in networks to arise from a situation in which "c*oevolution is not anticipated*".
He states: "A networked information system not only evolves, its parts coevolve in response to each other's changes. The evolution of a networked information system is driven by a constant process of change in response to new opportunities (especially technical advances in hardware and software), and new lessons learned (both from experience within the system and from the experiences of other networked systems)." While Axelrod has in mind the arms race between hackers and network developers, a fatal oversight in system design is not to take on board the need to constantly address this factor of competitive co-evolution of potential participants which may threaten system stability. Section 3.1 will give more details on why extant policy design to date abstracts from these considerations on system stability.

Instability of large networks was first studied by May (1972, 1974). May showed that growth in the number of nodes in the networks along with connectivity in the system that was also accompanied by a growing variation measured by standard deviation in the strength of connectivity between nodes[16], contributed to instability. In the more recent literature, network theorists identify supercritical and subcritical states in relation to connectivity and concentration of links in networks. Recent studies (see, Leonard and Howitt, 2010) refer to a combination of individually rational behaviour and policy incentives which reinforce local efficiency but cause an increase in concentration and interconnectedness in the form of closer coupling with reduced buffers of nodes to a point of supercriticality or instability. Leonard and Howitt (2010) claim: "the pressure to conserve scarce resources tends to push system designers, participants and engineers to see buffers as costly and superfluous, leading to tighter coupling within the system. Thus, in human systems driven by economic considerations– which are a very large class of human systems indeed – systematic economic forces drive both designed and self-organising systems towards being balanced on the point of supercriticality." At supercritical states extreme system failure can follow.

Reserves, capital, collateral and margin requirements are all stock in trade of banking and financial risk management but in the Basel II framework these were mostly viewed on a stand alone basis of a single unit. Within an integrative system failure approach, not only the different ways by which FIs in the system implement avoidance or reduction of these key buffers, but also the numbers of those doing this, will have implications for the size of the hub nodes (in terms of total exposures or market shares), the inter-connectivity between them and smaller nodes, and also contingent feedback loops of the system. All these factors can move the system to a supercritical state.

I will outline some technology driven processes that can pose particular challenges for systemic risk management and why policy makers need to understand these drivers behind extant industrial/market organisation to make useful interventions.
The objective of limiting both the size and the number of links to a single FI ie. its global reach, is known to run into what is called Metcalfe's Law (see, Shapiro and Varian, 1999). Metcalf's Law operates in information technology like telephony or in broker dealer platforms where bilateral connections feature. The law states that the benefits to any individual who subscribes to the infrastructure provider are proportionate to the square of the number of users[17] in it while the costs to the provider grows linearly. Hence, very large profits accrue from becoming a large global intermediary or provider. The fact that success of such large operators has not always followed has led Odlyzko and Tilly (2005) to propose a new formula to evaluate the value of the network in terms of Nlog(N) so that benefits to any individual user grows much more modestly at the rate of log(N) rather than as N^2. However, the technology giving rise to Metcalf law can be superseded by a more versatile technology which enables not just pairwise interconnections but also the formation of groups of any size. This is called Reed's Law where the benefits can grow exponentially at the rate 2^N as this denotes the number all subsets of a given set of N users. While Metcalf's law suggests run-away gigantism of FIs in a market, the modified log(N) rule suggests that the FIs in a network will be more numerous and can be given an 'impact' measure (size, connectivity etc) proportionate to their ranking. So the second ranked will have ½ the impact, the third 1/3 etc.

In over the counter derivatives markets and other settlement based systems, concentration[18] with bilateral netting leading to high interconnectivity within the top tier players is recognized as a means by which dealers off set counterparty exposure and minimize

[15] The Red Queen, the character in Lewis Carol's *Alice Through the Looking Glass*, who signifies the need 'to run faster and faster to stay in the square' has become the emblematic of the outcome of competitive co-evolution for evolutionary biologists in that no competitor gains absolute ground, see Markose (2005).
[16] Note May's work predated discovery of Small World networks and the growth of this variation measure can be seen as a proxy for fat tails in degree distribution. The May stability condition is defined in terms of 3 network parameters N, the number of nodes, D, the density of connections and σ, the standard deviation of the links of each node. A network is estimated to be unstable if $\sqrt{ND}\,\sigma > 1$.
[17] The number of potential pairs that can be formed from N users is N(N-1)/2. As N becomes large this approximates N^2.
[18] The 2009 Fitch survey of dealers end users of OTC financial derivatives stated: "dependence on a limited number of counterparties looks to be a permanent feature of the market; this is underscored by the fact that the top 12 counterparties[18] comprised 78% of total exposure in terms of the number of times cited, up

liquidity and collateral needs (see, Bliss and Kaufman, 2004, Galbiati *et. al.* 2010). Network structures that minimize liquidity by multilateral netting can further intensify concentration of links to a single hub (as in a centralized clearing platform, CCP) indicating that the CCP solution is only as good as how well capitalized it is. Reforms in the large value payment systems, LVPS, in the late 1980's from end of day netting to a real time gross settlement system (RTGS) is fully cognizant of the fact that the large size of gross payment positions in a banking system with big asymmetries in the relative size and timing of participants' payments can pose systemic risks from insolvency of a large player. Further, the electronic payment systems can increase the speed of contagion. Computational simulation framework based on the real time LVPS flow networks was pioneered by the Bank of Finland. The trade-off between liquidity savings from netting and the threat to the stability of the payments network from counterparty failure and its contagion effects is at the heart of RTGS reforms. RTGS moves in the direction of a fully funded system. RTGS though high in liquidity requirements was specifically adopted to remove the risk of counterparty failure leading to costly outages in the end of day netting. In simulations done by Alentorn *et. al.* (2005) failed payments from the unwinding due to a large bank failure for a UK Chaps type LVPS is $94.2 bn as compared to a much smaller amount of $21.1bn for a relatively symmetric complete network of bilateral obligations.

2.2 Regulatory Sins of Omission and Commission: Basel II

In terms of regulatory framework, sins of omission and sins of commission can both have bad consequences for system stability. Failure by authorities to monitor evasions of capital requirement via remote off balance sheet vehicles allowed banks to follow an aggressive strategy of loan portfolio expansion by overcoming restrictions placed by the size of a bank's deposit base by reissuing the capital released from securitization into new mortgages/loans. This regulatory arbitrage which placed securitized assets off balance sheet to reduce the minimum 8% capital requirement of the Basel I Accord has been found by many (see, Goderis et. al. (2007))[19] to enable banks to achieve 50% higher loan target levels and reduce equity capital to asset ratio to about 5.3% as opposed to the 9.8% for those that did not.

In the situation permitted by Basel II and Basel III credit risk transfer scheme, the MBS assets remain on the bank balance sheet and CDS protection enables them to leverage the production of more pro-cyclically sensitive MBS. In what is called *wrong way risk* which is unique to CDS derivatives, dominant CDS guarantors suffer an increase in CDS spreads when the underlying assets they provide protection for deteriorate in value. Counterparties that have exposure to the net CDS guarantors and also those who take naked long positions on them in concerted 'bear raids' can accelerate the demise of CDS guarantors. Such phenomena called reflexivity is a key property of complex adaptive systems (see Box 2) which can exacerbate non-linear dynamics and extreme outcomes. A double default can be precipitated ie. both the underlying asset and also the CDS guarantor on it can fall together or in close succession. Increased CDS spreads on CDS sellers can result in a fall in their ratings, increase their costs of financing in the money markets and even their margin/collateral requirements. In other words, the very functionality of protection providers in CDS markets is endogenously threatened in this phenomenon called wrong way risk. In view of the recent events and our stress tests on empirically calibrated CDS financial networks, the reliance in Basel II on extant AAA ratings of CDS guarantors to replace capital requirements within the context of a highly clustered, concentrated and inherently fragile network structure in the CDS market (that I report in section 4) is fundamentally flawed due to lack robustness of extant network structures. The newly leveraged assets that the banks acquire at the time of high ratings of its CDS guarantors will far exceed the capabilities of the guarantors to bear when the credit event looms as ratings downgrades on them trigger wrong way risk. In principle, as we will see in Section 4 network, analysis of the CDS market will indicate how the problem of network concentration and the issue of *too interconnected to fail* can be tackled. However, in the next section I will discuss how the fallacy of composition inherent to Basel II and III which use a seemingly laudable objective at the level of the individual bank, viz. remove credit risk from its own balance sheets via unfunded CDS guarantees goes beyond the immediate problems cited above about the unsustainability of CDS market networks, and to the very heart of the dynamics of fractional banking and private credit creation.

3. Challenges for Systemic Risk Policy Design

In proposing a methodological shift in the way to model and monitor systemic risk in monetary and financial systems, it is imperative to address what the Queen asked luminaries at the London School of Economics "*why did nobody see it coming ?*" This is a subject that will be visited and revisited by both academics and regulators due to the catastrophic consequences of having wrong models that were universally in vogue.

3.1Policy Design and Strategic Behaviour: Markets As Complex Adaptive Systems

While after the event, Haldane and others (see, also Sheng, 2010) have upheld the significance of having a network perspective on financial stability- it is important to understand why economists in the last two decades did not pursue a systemic perspective nor develop any integrative quantitative tool that includes interconnections among component entities for macro-economic modelling and policy design. Reductionism in mainstream economics with the conflation of the so called representative agent with a sector or a system as whole has rendered it useless for analysis of stability of systems that arise from interactions between a multiplicity of *heterogeneous* agents (see, Kirman, 1992, 1997, for a longstanding critique of this). In traditional macro-economics, private claims are netted out and hence interconnections of FIs in terms of their obligations that can trigger cascades of insolvencies do

---

from the 67% reported last year. The top five institutions that provided volume figures accounted for 95% of total notional amount bought and sold. This concentration is a reflection of the dominant role of banks and dealers as counterparties, particularly after the collapse of a limited number of financial institutions who were important intermediaries in this market."
http://www.scribd.com/doc/37557210/Fitch-Market-Research-Global-Credit-Derivatives-Survey-09162010

[19] HBOS, for example, used securitization to double its mortgage book from £125 bn to £237 bn in the period 2001-2007.

not feature in any models on macro-stabilization policy design. However, the main problem with policy design to date is the limited incorporation of strategic behaviour in terms of concrete institutional developments.

Though popular with academic economists, due to the inadequacies of the Theil-Tinbergen theory of policy design based on the so called Linear- Quadratic- Gaussian model of optimal control where the policy maker's targets are only buffeted by random noise rather than by regulatees who game the system, the framework is of little practical use for policy implementation. The Lucas thesis on policy design which implied that policy analysis must not be conducted as if it is a game against nature effectively overturned the traditional Theil-Tinbergen approach. Policy as it was traditionally done. A new dawn was promised along the lines of the Axelrod (2003) dictum on system failure due to oversight of co-evolution. The Lucas view on policy is associated with the three following well known postulates (Lucas, 1972,1976).The *first* Lucas postulate says that policy objectives may be rendered ineffective by the strategic behaviour of regulatees if they can anticipate (viz. have rational expectations) or know the outcomes of policy when policy is effectively transparent. I have called this contrarian, rule breaking behaviour or the *Liar strategy* in that a contra position cannot be implemented from what cannot be computed or known without ambiguity. Lucas's second postulate said that when faced by a private sector with rational expectations, it is deemed necessary for authorities to use 'surprise' strategies to achieve policy objectives. *Third*, the computation of equilibrium outcomes or the econometric estimation of models to evaluate policy may be difficult or impossible as behaviourial changes to anticipated policy lead to a lack of structural invariance of the models concerned. Strictly speaking, it is the third postulate above in Lucas(1976) that is referred to as the Lucas Critique. Subsequently, the Lucas Critique correctly put a nail in the coffin of equation based econometric models which cannot model the capacity of a rule breaking private sector which can anticipate policy and negate policy or jeopardize the system by a process of regulatory arbitrage. Such strategic behaviour results in a lack of structural invariance of the equations being estimated, highlighting the restrictiveness of econometric modelling for policy analysis.

However, a longstanding misunderstanding by macro and monetary economists of the notion of a 'surprise' policy strategy [20]in the Lucas thesis on policy design resulted in the dominant view that good monetary policy is one where authorities are engaged in a pre-commitment strategy of fulfilling a fixed quantitative rule (see, Markose, 2005 Sections 3 and 4) rather than set up a macro-prudential framework that will enable them to co-evolve with regulatees and produce countervailing measures to keep regulatory arbitrage in check. Though Binmore (1987) had indicated that any strategist who upholds deterministic strategies as being optimal must answer the question "what of the Liar ?" or what of the agent who is contrarian and can negate or falsify a rule, few if any recognized the Lucas postulates are analogues of the formal conditions in mathematical logic of complex adaptive systems , Markose (2004,a). 'Surprises' or novelty production that brings about strategic indeterminism is the logical outcome of agents placed in oppositional or hostile positions as predictable outcomes of any player will bring about its demise. Quite simply deterministic strategies cannot be played unless the rule breaker qua Liar can be kept in check and if not, co-evolution is the name of the game to avoid system collapse. An arms race of surprises or innovations can also be proven to arise from this logic of opposition.[21] As for the failure of econometric models to identify undecidable structure changing dynamics from strategic innovations, mathematical logic indicates though the meta model will fully deduce the necessity to surprise or innovate in an arms race structure, there no ex ante way of identifying these emergent outcomes. In other words, the trio of Lucas postulates characterize the famous incompleteness of mathematical logic which underpin the Godel-Turing- Post framework of complexity, Markose (2005).

In the 1990's there has been a bandwagon effect of a class of models called monetary game theory models[22] that set aside the postulates of the Lucas Critique and advocates its exact opposite for the conduct of monetary policy. The dichotomous application of the Lucas Critique to policy objectives pertaining to real and nominal sides of the economy is the prominent feature of monetary game theory models that dominated discussions on policy design, see, Goodhart (1994) [23]. For real side objectives the famous Lucasian categories of 'dust, ambiguity and uncertainty' (*ibid.* p.110) are deemed necessary to achieve policy outcomes. For nominal variables such as the price level and the rate of inflation, these models hold that commitment to transparent monetary rules such as that of currency pegs or preannounced inflation targets involving interest rate adjustment will lead to greater credibility and success in inflation control.

---

[20] The notion of a surprise strategy in the macro-economics literature appears in the so called Lucas surprise supply function often defined as follows: $y = y^* + b(\pi - \pi^e) + \varepsilon$. This says that output, y, will not increase beyond the natural rate, y*, unless there is 'surprise' inflation, $(\pi - \pi^e)$ which is the prediction error from expected inflation, π^e. The idea here is that the private sector contravenes the effects of anticipated inflation, viz. the neutrality result. Hence, it is intuitively asserted that authorities who seek to expand output beyond the natural rate need to use surprise inflation. As surprise inflation sounds like a 'bad' thing to do – the objective of mainstream monetary policy became one of pre-committing authorities to a fixed rule for inflation control. See Box 2 on how surprises or novelty production of objects not previously there is not permissible in extant game theory and hence the role of co-evolutionary arms race between regulator and regulatee is not part of the mainstream macro-economic policy setting framework.

[21] Smullyan (1961) in his monograph on *Formal Systems* and the characterization of the limits of deduction provides a proof of an ever extendable set of such 'surprises' using productive sets and functions that underpin the mathematics of incompleteness. See also Cutland (1980). Box 2 uses this framework.

[22] The number of papers espousing the main tenets of this class of models is so large that it is best to refer to Fischer (1994) for a balanced survey of the macro-policy framework that has dominated in the last two decades. See, also Cukierman (1994).

[23] Goodhart(1994), in the format of an open letter to the Governor of the Bank of England, reviews Cukierman (1992). Though, Goodhart suggests that it may be "*silly"* (italics in original, *ibid*.p144) that these models have diametrically opposite policy recommendations for policy objectives on real and nominal variables, he is unable to explain in strategic terms why people behave differently to real and nominal policy variables.

Box 2 Complexity Perspective For Policy Design

The epithet *complex adaptive system (CAS)* following in the lineage of Gödel-Turing- Post is attributed only to so called Type 4 dynamics of the Wolfram- Chomsky schema where agents with the highest level of computational intelligence interact and produce new objects not previously there and also bring about undecidable structure changing dynamics[24], Markose (2004a, 2005). The mathematical logic that underpins CAS has three key components : (i)Meta representational systems and self referential or reflexive mappings that necessitates ' über' computational intelligence of a Universal Turing machine (ii) Contrarian or self-negating structures like the Liar (as in *'this is false'*), and (iii) The consequences of (i) and (ii) can be represented by so called creative and productive sets with the latter depicting an arms race in novelty production or 'surprises'.

It has been argued that policy design needs to take on board strategic interaction involving hostile or contrarian rule breaking agents and how this implies an arms race with new objects and 'surprises'. However, as partly indicated by Binmore (1987) extant mathematics of game theory is closed and complete. It can only provide strategy mappings to a *fixed* action set and indeterminism extends only to randomizations between given actions. Regarding contrarian behaviour, the Liar and strategic innovations or surprises to escape from hostile agents, as pointed out by Crawford (2003) –to date , economic "theory lags behind the public's intuition"... and "we are left with no systematic way to think about such ubiquitous phenomena". The Gödel-Turing- Post theory of computation provides the best known formalism of meta-representation of an underlying system in terms of encoding using integers, $n \in \aleph$, (also known as Gödel numbers) to represent the instructions utilizing strings of symbols to achieve encoded outputs from inputs in a finite number of steps in terms of an algorithm or program. The execution of this encoded information which one can regard as a *simulation* can be done on 'mechanisms' involving any substrata ranging from in intra- cellular biology to silicon chips. This capacity of meta-representation without which CAS properties do not emerge yields the notion of a universal Turing machine (UTM)which can take encoded information of other machines and replicate them. Remarkably, UTMs can run codes involving themselves, which is the basis of self-reference. If codes of functions are not already given, then successful simulations require discovering fixed points of executable functions. The typical notation for mappings involving encoded information is given as $f(x) \cong \phi_a(x) = q$. That is, function f(.) on input x when computed using the program *a* is denoted as $\phi_a(x)$. If $\phi_a(x)$ is defined or halts it yields output q and if the function f(x) is undefined (~) then $\phi_a(x)$ does not halt.

The function that always yields outputs on any encoded input is called a *total* computable function and can be regarded as all potential technologies. This set denoted by $\mathfrak{R}$ is uncountably infinite and there is no systematic way of 'searching' or listing this set. Some finite subset of this set entails known technologies and can represent a given action set A of traditional game theory. A novelty or a surprise is an encoded object in the set $(\mathfrak{R} - A)$, ie. out- side of set A that is already known to exist. The remarkable achievement of Gödel-Turing- Post mathematical logic is that there is only one way, viz. incorporation of the Liar or contrarian function, we denote by $f^{\neg}$, by which fully deducible meta-computations on fixed point of $f^{\neg}$ determines the logical necessity for surprise mappings into the set $(\mathfrak{R} - A)$. This functional mapping is called the productive function in logic and as it involves novelty and surprise, we will denote it as $f^{!}$. We say that a total computable function *g(m)* has a fixed point m such that $\phi_{g(m)} = \phi_m$. Note, $g(m) \neq m$, but they identify the same function ϕ and if programs *g(m)* and *m* for both sides of equation halt they must yield an identical output *q*, then *m* is the computable fixed point of *g*.

In a simple two person oppositional game involving for example private sector and government authorities (or parasite-host relationship, indexed by *p* and *a*) , the generic statement of the Liar or contrarian strategy is the following :

$$\begin{cases} \phi_{f_p^{\neg}\sigma(b_a, b_a)}(s) = q^{\sim} \text{ if and only if } \phi_{\sigma(b_a, b_a)}(s) = q \\ f_p^{\neg} = 0 \quad : \text{Do Nothing, otherwise.} \end{cases}$$

The first line states that output q will be negated to $q^{\sim}$ by the contrarian $f_p^{\neg}$ strategy if and only if the policy with code b_a is applied and output q is produced in state *s*. If not, as noted in the second line above, the Liar does nothing. The fixed point of $f_p^{\neg}$ is denoted as $\sigma(b_a^{\neg}, b_a^{\neg})$, is *not computable* as in $\phi_{f_p^{\neg}\sigma(b_a^{\neg}, b_a^{\neg})}(s) = \phi_{\sigma(b_a^{\neg}, b_a^{\neg})}(s)$. For if it is, the two sides of the equation will produce contradictory outputs. Remarkably, two place encoding $\sigma(b_a^{\neg}, b_a^{\neg})$ (analogous to Gödel substitution function) says that *p* knows that *a* knows that *p* is the Liar. From here on total computable strategy functions starting with that of the authorities, $f_a^{!}$, can only map into a set such as $(\mathfrak{R} - A)$and will mark an arms race in surprises. If this is not feasible, preannounced policy rule *a* has to be abandoned or the Liar eliminated to avoid policy failure. This framework signifies that recognition of hostile agents requires the highest level of computational intelligence (which Steven Wolfram claims is already ubiquitous even in the humble virus) and further in the absence of contrarian or oppositional structures there is no logical need to innovate or surprise.

[24] In the Wolfram-Chomsky schema of dynamical systems, CAS is shown to be different from chaotic dynamics. The popular view is to conflate either chaos or all manner of complicated situations with CAS. Further, it is only with the discovery of so called mirror neurons in the neuro-physiology of the brain and the work of Ramachandran (2006), Oberman *et. al.* (2005) that it is being understood why the capacity of meta-representation with self as an actor in the mapping (leading to the recognition of hostile oppositional structures) is a key ingredient of strategic behaviour. The significance of the mathematical logic of Gödel-Turing- Post is that any system incorporating such elements will imply incompleteness or capacity to produce new objects with algorithms or encoded information as inputs.

The best known example of reflexivity, often written about in the popular press, is that of stock market prices: $P_{t+1} = g(\sum_{i=1,..N} \beta_{it}(\hat{m}_{it}(P_{t+1})))$. That is, *the price at t+1* is determined by the strategies β_{it} (to buy or sell)of investors (i= 1,2,.N) agents, based on their respective beliefs, $\hat{m}_{it}$, *of the price at t+1* and the market price determination function g(.) is increasing in excess demand (aggregate buy order less sell orders) at t. Spear (1989) was the first to show that rational expectations involving the belief or forecast function $\hat{m}_{it}$ corresponds to inductive identification by trial and error of the fixed point for the market price function g(.), as in $\phi_{q(m)}(s)= \phi_m(s)$ where *s* is an encoding of past historical data. Further, pointing out the inherent contrarian or minority nature of the stock market game here payoffs to pure speculative investors are at their maximum if they sell when majority are buying and vice versa, Arthur (1994) over turned traditional ideas of rationality and showed that it is logically impossible for all investors to have an identical/homogenous rational expectations.[25] The role of contrarians in bringing down financial systems should not be underestimated. The prominent contrarian strategies that have netted vast profits in the context of institutionalized free lunches of the ERM currency peg and the CDS carry trade have been, respectively, that of George Soros in 1992 and Paolo Pelligrini and John Paulson in the 2007 crisis. Good institution design should vitiate such opportunities.

The contents in this Box is to underscore how failure of policy can arise from insufficient understanding of the logic behind co-evolutionary pressures that arise from strategic interaction between intelligent and potentially hostile agents. This is to be contrasted with science behind yet another complexity perspective, which is important in describing a large class of spectacular phenomena which can only emerge or self-organize such as pattern formation in shoals of fish or flock of birds and even racial segregation as in the Schelling model. It is important to understand tipping points and sudden phase transitions that such models can throw light on. These are brought about by simple local interactions or rule following by agents but lack the strategic elements arising from reflexivity or fixed point mappings that lead to arms races in innovation in CAS.

Despite the dramatic demise of the £-Sterling tethered to the European Exchange Rate currency peg brought about by George Soros in 1992 who has openly claimed that fundamental insights from mathematical logic relating to the Cretan Liar (see Box 2)have been served as an inchoate, though powerful, guide to his successful career as a currency speculator (see, Soros ,1995, p. 69, p.213), the development of quantitative integrative modelling tools in a strategic setting for macro-economic policy or financial product design as a replacement of macro-econometric models were all but abandoned. After the serial collapse of currency pegs globally with every one of them defended at large cost to tax payers[26], Stiglitz (1999, 2000) critiqued the tendency for macro-policy makers to prescribe 'optimal' policy rules with little concern of their strategic implementation in circumstances that must realistically prevail. Eichengreen(1999) went on to break ranks with the IMF credo and with hindsight called into question what was considered *de rigueur* on the basis of the very large and influential literature on the conduct of monetary policy which advocated precommitment to a transparent formalistic institution such as the currency peg. In contrast to the prescribed resoluteness by central banks to expend extensive foreign currency reserves in the maintenance of a preannounced parity for the currency at a prespecified discrete point in time, Eichengreen (1999) recommended flexible bands at the first whiff of trouble 'before the crunch' comes. However, no suggestions were made about stress testing policy in terms of the efficacy of the proposed fixed rule before implementation and no questions were asked about the wisdom of authorities relying solely on a fixed rule for inflation for stability of the monetary and economic environment with an almost complete neglect of the fast changing monetary and financial systems or scientific advances. Box 2 summarizes the key tenets of complex adaptive systems perspective for policy design.

There is ofcourse a long line of literature as in the classic work of Albert Hirschman (1991), where Lucas type critiques have aptly been called 'futility, perversity and jeopardy' arguments against institutional building which deliberately aim to bring about specific and predetermined outcomes in society. Such objectives when pursued at a collective level, according to this thesis, will result in unintended consequences for society that may nullify the original intent of public action (the futility argument); it may bring about consequences, that are opposite from those being proposed (the perversity argument); and finally it may 'destabilize' the system as a whole (the jeopardy argument). Despite, Hirschman's original intent to pillory the above as the rhetoric of reaction, he redresses his position and advices policy makers to minimize "the vulnerability of policy proposals on perversity, futility or jeopardy grounds" (Hirschman, 1995, p.61). Needless, to say the dominance of the view that macro-stability lay in maintaining a fixed inflation rule forestalled any scientific advances in the study of the stability of the economic system as a highly interconnected co-evolving one in which policy rules have to be carefully designed to avoid unintended perverse consequences. Interestingly, Eichengreen (2010) now concludes : "fundamentally, the (2007) crisis is the result of flawed regulations and perverse incentives in financial markets ".

---

[25] Assume that there is an unique homogenous forecast function $\forall i$, $\hat{m}_{it} = \phi_a(s) = P_{t+1}\uparrow$, ie. a price rise is predicted. Then the contrarian strategy $\beta_{it}^{\neg}$ kicks in for all investors leading them to sell hence result in the market price function to output a price fall $\phi_{g(a)}(s) = P_{t+1}\downarrow$. Rationality, in the presence of minority pay off structures generates endemic heterogeneity in strategies.

[26] Pegged currency regimes, instituted on grounds of providing an inflation anchor, that have suffered systematic speculative attacks leading to currency crisis and/or economic collapse are the following. Jamaica,1990, 1992 ERM crises involving the £-sterling, lira, franc, krona, punt and others, the 1994 peso crisis, the Thai baht (the second wave of attacks on it), the Malaysian ringit and the Indonesain rupiah, 1997. In January 1999, the IMF package of $41bn. was lost in the defence of the dollar peg with the Brazilian real.

In the context of the events leading to the 2007 crisis, David Jones (2000) noted a lack of interest in the study of regulatory capital arbitrage entailed in securitization and other financial innovations regarding which he said "absent measures to reduce incentives or opportunities for regulatory capital arbitrage over time such developments could undermine the usefulness of formal capital requirement as prudential policy tools". In the context of FIs which operate as short sighted profit centres, arbitrage profits are agnostically garnered using the most advanced ICT tools irrespective of the source of the misalignments in the markets. Jones (2000) concluded that it was a lack of data for econometric modelling that prevented academic or regulators from keeping track of activities that undermined stated policy objectives in Basel II.

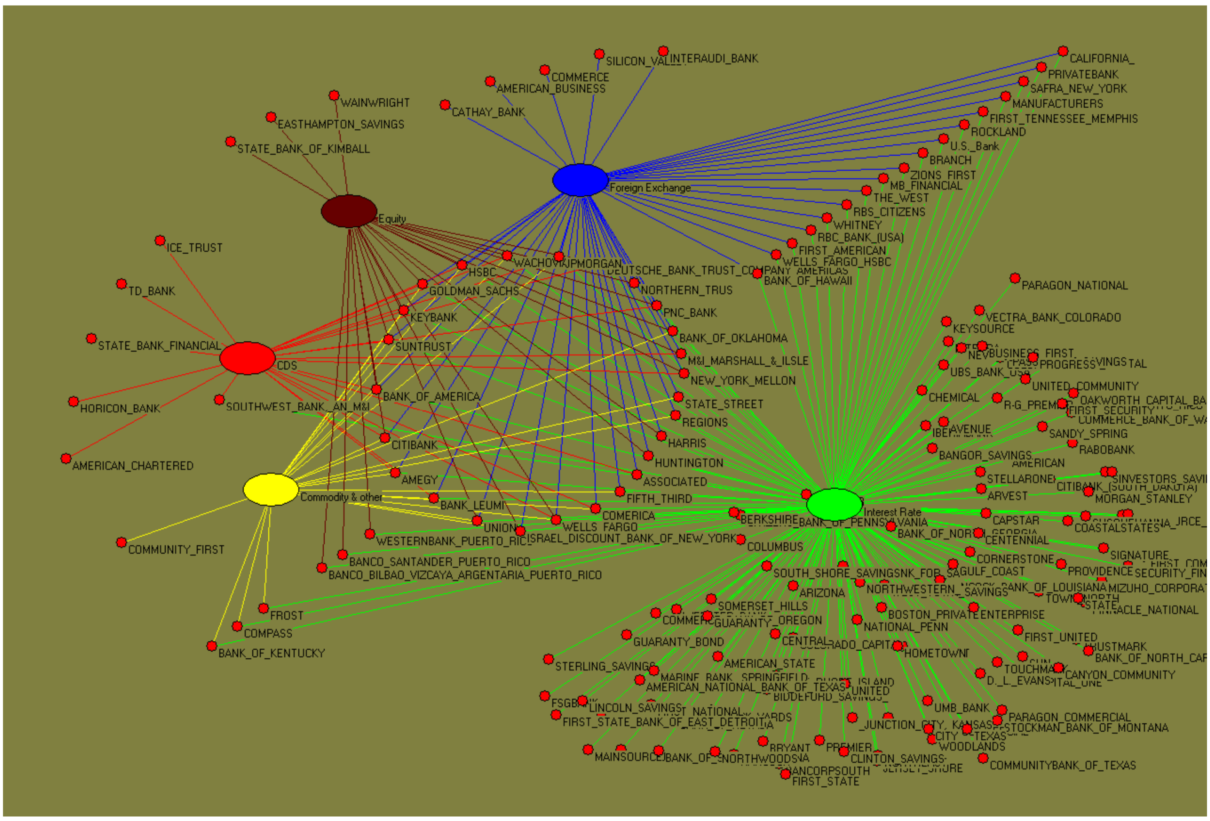
3.2Financial Systemic Risk as Negative Externality: Fallacy of Composition and Holisitic Visualization

Fallacy of composition (see Brunnermeir et. al. 2009) is what has been noted to be one of the fatal flaws of the Basel 1 and 2 regulatory framework. This fallacy arises from the mistaken view that what is efficient or rational at the level of an individual firm also produces systemically stable outcomes. As will be shown below, only a holistic visualization of the topological structure of the system can demonstrate concentration of risk bearing activity and increased interconnectedness in the system, as more and more firms outsource insurance or diversification activities to a few. Risk sharing is only as good as those involved as risk guarantors in terms of numbers and quality of capital. Adverse selection can arise inadvertently (due to problems of mispricing of risk) if risk guarantors in unfunded contingent claims markets undertake obligations which they cannot fulfil when the crisis occurs. The generation of tail risk or extreme outcomes become more probable with 'excessive' outsourcing of risk from balance sheets of firms.

Tiering and concentration of banking activity with some banks assuming specialist broker dealer roles often arises from the objective to economize on liquidity and to minimize on final settlement. For example, bilateral offsetting is undertaken in OTC derivatives to maximize returns from spreads and to minimize final settlement to end users. It must be noted that of the $700 Trillion gross notional value of global derivatives only 5% is for purposes of hedging.

Figure 1 gives the bipartite graph which shows the participants of the global OTC derivatives markets (trading only) in the four markets, Interest Rates, forex, credit, equity and commodities. The graph plots which of the participants operate in only one, two, three, four and all markets. What is significant that the 16 universal banks in a circular grouping in Figure 1 are present in all 5 markets. These are the broker dealers in all these markets while the majority of participants are mostly in the interest rate derivatives only and a smaller number in both interest rate and forex.

Figure 1 : Structure of Financial Derivatives Market: (2009, Q4): Green(Interest Rate), Blue (Forex), Maroon (Equity); Red (Credit/CDS); Yellow (Commodity); Circle layout : Broker Dealers in all markets (Bi-partite Graph) (*Source: Markose, 2011, Report for IMF*[27]*)*



---

27 The final report is to be submitted on 30 June 2010.

The **Figures 2 (a,b)** below from Blake et al. (2010a) give another example of how what appears like a rational strategy to follow in pension fund management at the level of the individual fund sponsor can contribute to growing systemic risk from concentration. They study key shifts in the structure of the UK pension fund industry from 1984 to 2004. From the 1980s to the mid 1990s, pension funds were primarily managed in house and if they were outsourced, fund sponsors used balanced fund managers. Increasingly, pension fund management is both outsourced and the balanced fund manager has been superseded by specialist fund managers that are often specialized according to asset class. At the individual fund level outsourcing to a number of special fund managers rather than putting the bulk of funds in balanced fund management appears to fulfil objectives of diversification. However, as more and more pension fund sponsors follow this route, at a system wide level, there is increasing concentration of fund management in very large specialist funds. In other words, at the system level there is growing evidence of suboptimal diversification. Note that the individual red nodes at the top of the figures depicting individual pension funds following in-house portfolio management have fallen off by 2004 when compared to 1984.

Figure 2a UK Pension Fund Management Network in 1984:

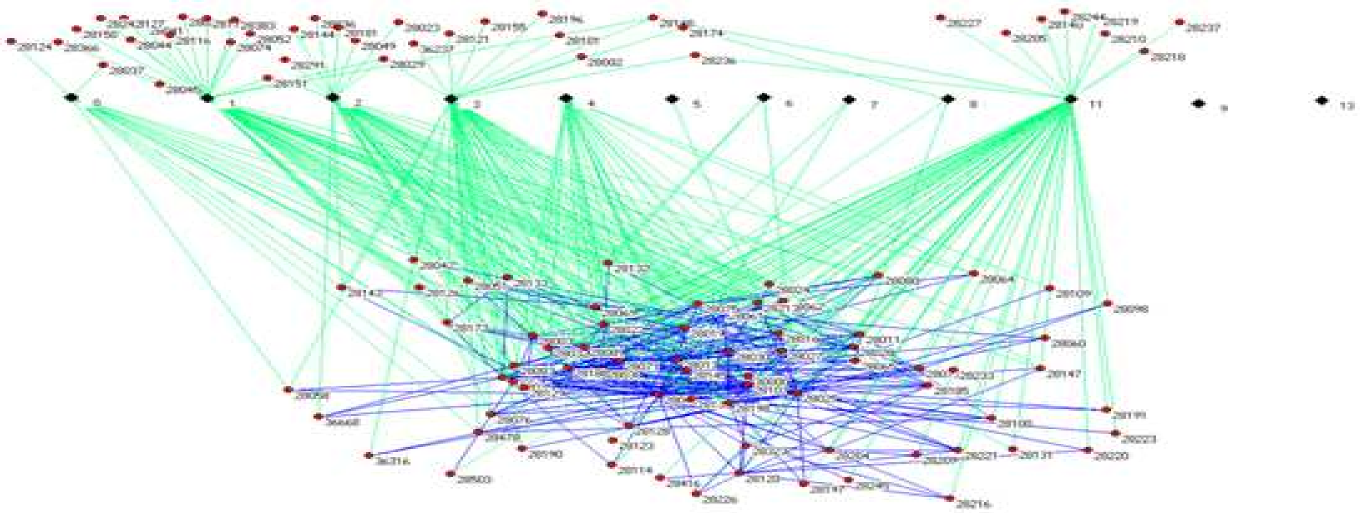
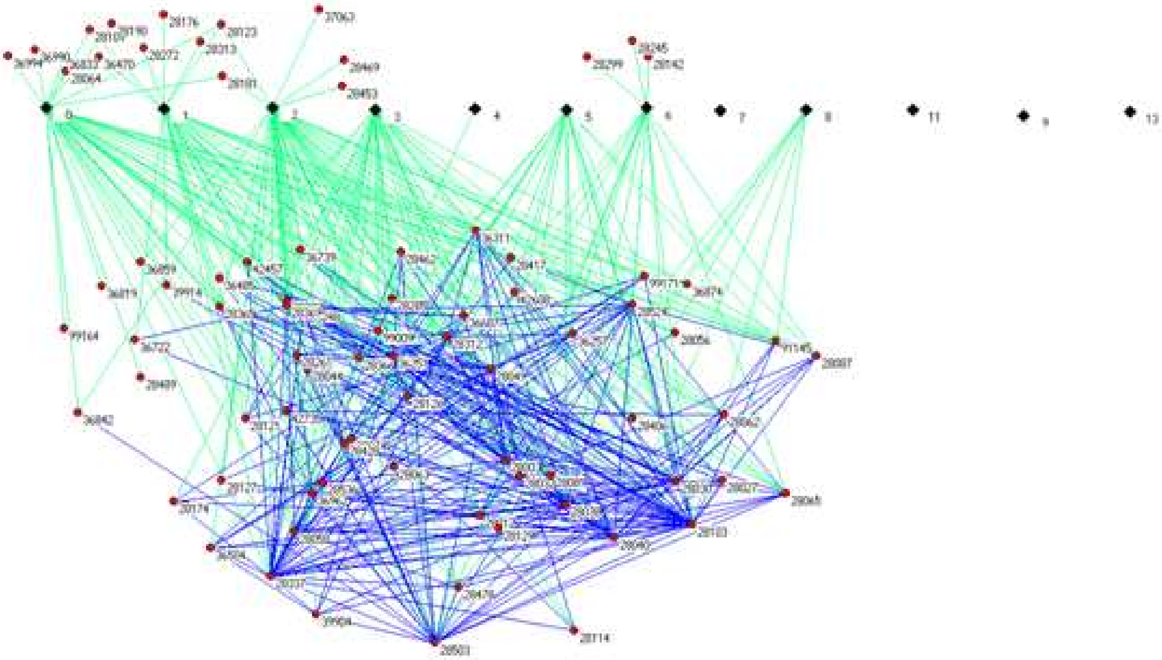


Figure 2b UK Pension Fund Management Network 2004



By 2004, not only are there fewer consultants (black diamonds) channeling funds, the blue lines showing multiple mandates from the same pension funds to specialist managers show greater density implying more and more individual fund sponsors are routing their funds to the same set of specialist fund managers. Growing concentration of funds in specialist fund managers in asset classes can precipitate herding in these markets when compared to funds managed in balanced funds.

No doubt, overcoming the fallacy of composition and designing systemically stable systems while strategic interactions among economic agents dynamically change the stability of network connections is no mean task. As it has become prominent with environmental pollution and congestion issues for society, striking an appropriate trade off between growth versus stability or sustainability requires integrative modelling tools capable of yielding visualizations of systemic instability emanating from individual behaviour. Individual activity is directly observable and collective outcomes from unobservable interactions are hard to 'see'. Hence, it is easy to succumb to fallacy of composition in policy design. Composite scenario analysis is needed to help design satisfactory institutional solutions for sustainable growth where endemic problems of individual behaviour with local incentives may not coincide with stable system wide outcomes.[28] Thus, systemic risk from financial activity and the pricing of it is no different from overuse and degradation of resources as in environmental negative externalities (eg. CO_2 emissions). These arise from economic activities where the 'clean up' costs are not fully priced at point of use by the individual and hence intra and intergenerational problems of fairness follow when costs are passed on. At least since Pigou (1950) it has been known that regulatory intervention is needed to 'cap' the aggregate quantity of the negative externality/economic bad and hence of the original economic activity at sustainable levels. Outright prohibition, taxing the activity or pricing the negative externality by novel 'cap' and trade methods are ways of controlling these potentially unsustainable trends. In financial and monetary instability, what ever the finer details, there is always an inherent 'cap' to the quantity of credit or fiat money that the system can absorb safely and traditionally it is the role of the head of the central bank 'to take the punch bowl away as the party gets going'.

Hence, compared to controls on carbon emissions and other measures that aim to align individual actions with environmental sustainability which are relatively new, institutional controls on privately issued credit or leverage and fiat money supply by governments have had a rich history. With regard to the first, there has always and only been one unique way in determining sustainability of financial intermediation: Privately issued commercial paper and securitized bank assets have to rely on fiat money or government securities as reserves when issues of convertibility are at stake under conditions when the underlying assets suffer loss of value due to increased threat of default of primary debtor, counterparty or collapse of asset markets. The restraints over the years on the fractional system of private credit creation are too numerous to list here. As for the second, state engineered inflation in the consumer price index (CPI) due to the monopoly in its supply of fiat money on which payments for goods and services rely on has been the main threat to monetary and economic stability.

3.3 Conundrum on Inflation

Up until 2007, the lack of incentives for academic or economists in central banks to keep up with the recent advances in the monetary and financial sectors or to build simulation platforms for the assessment of policy within a strategic and system setting is tied up with the major conundrum surrounding the run up to the recent crisis. Since 1994 traditional overheating of economies with inflation in the CPI index despite long standing consumer credit fuelled spending sprees was virtually non-existent in developed countries. Threats to financial and economic instability from inflation have been in abeyance. Subsequent to double digit inflation in the 1970's in some advanced OECD economies, concerted efforts especially in the UK to restrict central banks by statute to focus entirely on fulfilling a fixed rule on inflation, led many to conclude that though interest rate policy was unabashedly loose as in the US in the early part of this decade, the so called 'great moderation' was attributed to good helmsmanship. Hence, few threats were perceived either in the spectacular growth of US shadow banking sector or as in the case of UK bank assets grew by as much as 200% of GDP to about 600% by 2006 in only 2 years, Alessandri and Haldane (2009). To my mind, two key structural developments that occurred in the Anglo-Saxon monetary and financial system were largely ignored. Both of these have a bearing on future developments in BRICs.

Firstly, state supplied notes and coins (also known as M0 in the US) are increasingly being phased out of monetary transactions in so called advanced cashless economies due to the increased use of electronic methods of fund transfer at point of sale (EFTPOS) in physical markets and with electronic payments being the only option in e-markets. The latter have de facto undermined legal tender of state monies. With EFPTOS effectuating fund transfer between payee and payor with direct electronic debit and credits on respective bank balances, M0 circulating outside the banking system is drastically reduced, Markose and Loke (2003a,b). In Finland which is on the vanguard of cashlessness, in this decade M0 is under 1% of GDP, in UK it is about 2% and USA 5%. In economies where e-cashlessness has not yet taken off typically have about 16% -25% of GDP as cash in circulation. There are studies that acknowledge that technology led change in payment habits in the direction of cashlessness has eroded seigniorage. However, few have advanced a theory first propounded by Hayek (1974) that the only *permanent*[29] brake on the capacity of governments to engineer inflation via the monopoly on the supply of payments media is to find private substitutes to economize on this.[30] Marimon *et. al* (1997) admirably stated the following key issues : "Most developed countries have experienced a drastic

[28] In a recent project on a market design for pricing road congestion externalities that was involved in (Markose *et al , 2007*) the build up of congestion Central Gateshead during peak times was artificially reproduced in a computer environment. For this according to the principles of model verité, the entire road system of an urban congestion hot spot is digitally mapped and commuter agents were incrementally added to the road network based on actual origin and destination data for habitual commuters who traverse that city centre area. The 'cap' was then determined as the total distance travelled function peaked and started to fall.

[29] It is well known that productivity growth can be a direct cause of the fall in the price level. However, as shown in Pilat (2002) Figure 1 on multifactor productivity (MFP)for OECD countries, Netherlands, Austria, Belgium, Italy, Japan, France, Germany UK and Spain had lower MFP in 1990-2000 than in the previous decade. In contrast, 1994 has been noted in Markose and Loke (2002) as the watershed when inflation fell to 2% on average in selected G10 countries and remained low thereafter. Cheap goods from China (see, Bean (2006)) have been given as another explanation for the drastic fall in core inflation in developing countries. The lack of upward pressure of factor prices such as wages is another reason why inflation remains low, once it has fallen.

[30]However, though Hayek (1974) conceived of the evolution of private currencies that circulated as a means of substituting away from fiat money for payments, he did not presage the electronic developments such as the debit card of the late 20 th century. Debit cards are successful because they permit direct verification of bank balances and therefore obviate the need for any reputational inputs for payment guarantees that had held up other cashless payment methods. While, Hayek

reduction of inflation rates in the last quarter of this century, from the double digit numbers of the mid seventies to the very low – say, below 2.5% , numbers at the end of the nineties. High inflation episodes seem to be problems of the past, as if society had become immune to the disease. This success in curbing inflation has been usually attributed to a better monetary policy management to achieve price stability. But, maybe the right incentives have been created by the widespread development and use of cash substitutes. Who deserves most credit? An implication of the paper will be that the role of electronic money in curbing inflation has been undervalued." To my best knowledge the only governor of a central bank of a developing country in recent times who sought to eliminate cash from transactions with electronic payment methods as a means to control inflation is that of Ghana. [31]

Theoretical papers that acknowledge the feature of diminishing or zero transactions demand for currency are unable to throw light on what happens to inflation due to what is called indeterminacy of the price level. This is, ofcourse, an artefact of their models rather than a fact of the real world. In contrast, Woodford (1998, p.217) reinstated the price level determinacy but concludes that "… the project of modelling the fine details of the payments system and the sources of money demand is not essential… to the analysis of the effects of alternative monetary policy". This effectively marked an end to any serious academic investigations into one of the most important developments in monetary history, viz. the erosion of governments' role in the supply of the means of payment and its implications for state engineered inflation.

In a highly cash based payments system for goods and services, as were the periods when double digit and hyper inflation crisis occurred, quantity of cash mediating transactions influence the nominal prices of goods. In many variants of monetary theory, this is called the monetary veil. As noted in Humphrey *et. al.* (1996) in fourteen developing countries (barring US) between1987-1993, 34% of retail expenditures involved electronic payments. With increased cashless payments, the role of fiat money in transactions is increasingly being reduced to that of a numeraire or as a unit of account. With the monetary veil being lifted from transactions in goods and services, inflation on CPI index has come down *permanently* in OECD countries. The bulk of fiat money is mostly in the form of bank reserves which underpin the large edifice of 'inside money' or broad money which constitute bank deposit creation, securitized forms of the loan book of banks (example, asset backed commercial paper) and other private credit instruments held as bank liabilities. As private credit is self-liquidating once loans are repaid, inside money (via the proportion channelled to consumer credit) is not capable of bringing about permanent inflation in the CPI index. But unrestricted growth of private credit channelled to assets can produce asset (real estate, equities and commodities) price bubbles.

In view of the recent increase in the US monetary base to the tune of 142% as the Federal Reserve expanded bank reserves to about $1.2 with quantitative easing[32], many have forecast the threat to inflation as the economy picks up. There is in fact an unique social experiment in the making from which we may able to learn what consequences there are for inflation from the technology instilled force of habit of using debit card in payments which leads consumers to desist from withdrawing cash for purchases. It is an intriguing thought that despite high inflationary expectations among consumers and the large monetary base being supplied with quantitative easing, a Weimar Republic scenario of inflation growth can be curtailed by non-cash based payment habits. In 1923 cash withdrawals accelerated to keep up with the upward repricing of goods as real output decreased; cash in circulation grew 15-20 times as prices rose 40-50 times in the Weimar Republic. Despite, some resurgence of cash use due to low interest rates (see, Markose and Loke, 2003), there appears to be an absolute brake placed on the CPI index by cashless payments which warrants the construction of a new cashless consumer price index.

3.3Managing Fractional Private Credit Creation Systems And Leverage From Derivatives

The consequence of a lack of understanding of the role of interest rate management in an advanced cashless economy where interest rates can influence credit generation (subject to the Keynesian liquidity trap) but not inflation in CPI, has not only led to a series of major oversights but allows US and UK authorities to apply quantitative easing via injecting bank reserves with impunity. The process that Minski (1982) called Ponzi finance, when existing financial obligations can only be met by issuing new liabilities became endemic in the banking sector which increased leverage through securitization is now dubbed the shadow banking system. Securitized bank assets which in forms like asset backed commercial paper (ABCP) are bank liabilities in that it enables the bank to leverage its loan book via the short term repo markets. Reserves and the leverage multiplier in the creation of private sector claims ultimately govern issues of convertibility at times of crisis. As presaged by Hayek(1936) and is a well known idea since at least Henry Thornton, private monies will ultimately balloon into problems of systemic collapse when convertibility to more liquid forms of regulated funds or fiat money are at stake. This is the fundamental problem of non fiat monies and fractional banking with less than100% reserves. The run on the repo market (where funds are borrowed and lent against collateral

---

(1976) decried the state monopoly of the mint due to the forced reliance of citizens on national currencies for transactions and the capacity of governments to engineer inflation via this channel, he is clear that "neither higher wages nor higher prices of oil or perhaps inputs can drive up prices of all goods unless purchasers are given more money to buy them" (*ibid* p. 95).

[31] Speaking on the theme "Banking in the next millennium, expectations, opportunities and challenges" at the 28th anniversary of Ghana's Chartered Institute of Bankers in Accra, the Governor, Dr Kwabena Duffour noted that Ghana's payment system is highly cash-based and underdeveloped, saying: "there is still over-reliance on cash as a means of payment despite the few electronic modes of payment currently adopted by the banks". He said the situation allows for increase in the cash flow outside the banking system, with its resultant increase in inflation, foreign exchange and interest rates and severe constraints on commercial activities. In a drive to reduce inflation from 20.8 per cent in December 1997 to 17.4 per cent in May 1999 by reducing money in the economy to further reduce the inflation level to a single digit, Dr. Duffour said that "our current cash-based payment systems are impeding the Bank's effort." http://www.ghanaweb.com/GhanaHomePage/NewsArchive/artikel.php?ID=4351

[32] US cash in circulation is about $900billion in 2009.

that included private debt instruments such as MBS) in the recent crisis is such a manifestation of the convertibility problem of private monies.

In this context, the proposal in Basel II and III that enable banks to replace bank capital by CDS derivatives must be viewed within a fractional monetary system. The regulatory boundary can be extended so that reserve and leverage ratios apply to *all* participants involved in credit creation irrespective of whether they are depository institutions or not. But on the question of whether credit derivatives can be included as a substitute for capital for bank assets, the answer is that they pose a violation of the principle behind capital and reserve requirements. These aim to decrease the multiplier effect on further securitization of debt whereas guarantors of credit derivatives will naturally seek to offset the risk by finding another guarantor and so on. While it is not even clear that banks will adopt CDS for risk mitigation without the capital reduction incentives , there appears to be little understanding that the use of unfunded CDS insurance cover to replace bank equity capital can only produce a potentially explosive Ponzi type fractional system in credit derivatives as 'derivatives beget derivatives'.[33]That is obligations from one level of credit derivatives will be dynamically 'hedged' by further unfunded CDS protection. Note here unlike vanilla type derivatives where dynamic hedging is vis -à-vis an underlying variable whose returns are not (by and large) influenced by derivatives written on it, in credit derivatives on securitized bank loans which themselves become underlying securities can leverage the system further. What appears like an individually rational activity can be systemically lethal. Further bundling up of these credit derivatives can itself become an underlying -all of which can magnify the risk that the original guarantee will not be met when a major macro event occurs which reduces the value of the pro-cyclically correlated underlying. It was the failure to meet CDS obligations by key CDS protection sellers on subprime related MBS and CDOs that led to implicit or explicit tax payer bail-outs on the premise that these financial entities were *too interconnected to fail.* Further, in repo markets that use these assets as collateral suffer higher haircuts – all of which will trigger a run on private debt creation.

4. Empirically Calibrated Financial Networks for the US CDS Obligations: Stability Analysis

In this section I will report on the empirical reconstruction of the US CDS network based on the FDIC Call Report Q4 2008 data which was undertaken by Markose *et. al.* (2010) to investigate the consequences of the fact that top 5 US banks account for 92% of the US bank activity in the $34 tn global gross notional value of CDS for Q4 2008 (see, BIS and DTCC). Issues relating to *too interconnected to fail* will also be discussed.

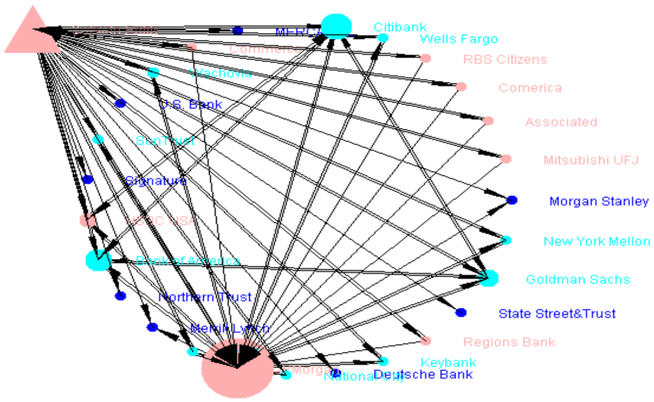
4.1Data
Given the increased use of securitization in bank lending and as failures of institutions with such risk characteristics had cost the FDIC more than $1bn by 2001, it had become mandatory for FDIC banks to report credit risk exposures from securitization and CDS. FDIC data for the latter started in 2006 Q1. In view of advances in BRICs in the direction of securitization and derivatives, it is important that it is made mandatory for FIs to submit data on securitization and off balance sheet activities at least to the level of details given in the FDIC Call Reports. An important aspect of the FDIC Call Report data is that for each FI buy and sell values in terms of gross notional (aggregated over all counterparties for a given product) and appropriately netted derivatives payables (gross positive fair value (GPFV)) and derivatives receivables gross negative fair value (GNFV)are given for each main derivatives product. Firm level data on both sides of the market is essential to identify liquidity providers and liquidity demanders in the market. In a CDS market, failure of net protection sellers will have more contagion spreading consequences than net buyers. Obviously, FDIC data does not give firm level data on non FDIC FIs (such as hedge funds and Monolines and other non-US participants) even if FDIC banks are involved with them. This is a draw back from a regulatory monitoring perspective which BRICs should address when collecting data on new financial markets. As actual bilateral flows for all FIs involved in a given market is not publicly available, we device an algorithm to generate an empirical calibration of a small world network along the lines discussed earlier on the proportionality between size and connectivity. Our algorithm assigns in degrees and out degrees for a bank in terms of its respective market shares for CDS purchases and sales. Thus, JP Morgan with a 53% market share will approximately have direct links (in and out) with 14 banks (out of a total of 26 FDIC banks involved in the CDS market) and these are arranged assortatively, i.e. 14 banks are chosen from the largest to the smallest in terms of their CDS activity. Other data based constraints are imposed on the network algorithm in order to approximate more closely to the extant system.

[33] I'm grateful to Steve Spear of Carnegie Mellon University for the discussion on whether the growth of new financial derivatives markets (with derivatives on derivatives)can succeed in completing markets and provide risk free hedges. As in the well known mathematical logic of incomplete systems, with derivatives on assets that reflect system wide information (and pro-cyclicality), these instruments are inherently incapable of completing markets. Ironically, as these instruments endogenously generate extreme volatility, using them to hedge volatility may seem indispensible at an individual level!

Box 2 Network Stability Analysis for the Empirically Constructed CDS Network for 26 US Banks [34] **(FDIC Call Report Q4 08)**

The figures and statistics in this Box illustrate a point about so called '*too interconnected to fail networks'* that may not be immediately obvious. The algorithm that assigns network links on the basis of market shares can be seen to reflect the very high concentration of network connections among the top 5 banks in terms of bilateral interrelationships and triangular clustering which marks small world network structures, see *Figure* B2.1. This is also underscored by the large cluster coefficient of 0.92 for the empirically calibrated CDS network. In contrast with the equivalent random network of the same connectivity, the clustering coefficient is close to the connectivity parameter of 0.12. The highly asymmetric nature of the empirical CDS network is manifested in the large kurtosis or fat tails in degree distribution which is characterized by a few (two banks in this case) which have a relatively large number of in degrees (up to 14) while many have only a few (as little as 1). In Figure B 2.1, we have colour coded the net sellers (pink), the net buyers (light blue) and sole buyers (dark blue).

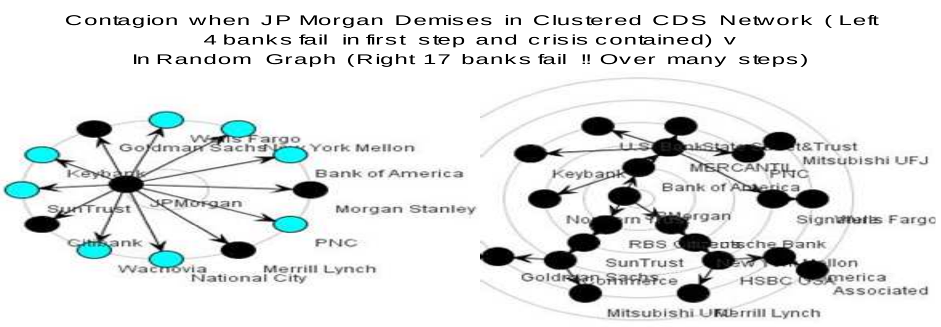
Figure B2.1 **Empirically Constructed CDS Network for US Banks and Outside Entity (Triangle): Empirical Small World initial network (FDIC Call Report Data of 2008 Q4)**



Source: Markose *et. al.* (2010)

The nature of contagion propagation is given in ***Figure B2.2*** for the empirical CDS network with small world properties (right) and the equivalent random graph. The highly interconnected network reveals a top tier of large banks which directly take a hit when a major trigger bank collapses. The contagion stops at this point but in the spirit of being *too interconnected to fail*, 4 top banks are brought down. In contrast the random network with no tiered structure, suffers as many as 17 (out of the 26) bank failures in a series of cascades. In the context of controlling epidemics, the clustered network allows easy solutions in terms of inoculating the few *super-spreaders*, while in the random network the whole population has to be inoculated. Hence, as suggested by Haldane (2009) steps should be taken to reverse the current practice where large broker dealers are given lenient terms in terms of reserves and collateral requirements.

Figure B2.2 : Instability propagation in Clustered CDS Network and in Equivalent Random Network



NB: Black nodes denote failed banks with successive concentric circles denoting the q-steps of the knock on effects
Source: Markose *et. al.* (2010)

4.2Stability of 'Too Interconnected to Fail Networks' and Less Structured Ones

In a network model for financial obligations, data has to be organized in bilateral matrices with each entry a_{ij} denoting row wise,

[34] I'm grateful for discussion with Robert May on these issues.

the ith FI's allocation of gross fair value negative liabilities to the jth one and column wise the jth FI makes payment to the ith FI who is the beneficiary. The matrix produced by the network algorithm is a sparse matrix with a very high concentration of activity. This is graphed below in Figure B2.1. Network statistics such as clustering and eigenvalue centrality are estimated. Box 2 below reports the key findings from the stability analysis where the performance of the empirically clustered CDS network is contrasted with that of an equivalent random network with the same functionalities in terms of aggregate CDS buy and sell. As found in Sinha (2005) and Sinha and Sinha (2006), the random graph shows worse outcomes in terms of stability and capacity of propagation of the contagion. Recall the marked difference in structure is the clustering coefficient of the two networks. The high clustering of the small world CDS network appears to show that there are only direct failures in a closed sector rather than higher order failures spreading to the whole system. It is, ofcourse, cold comfort that the first order shock wipes out the top 4 banks. In contrast, in the random graph, while no node is either too big or too interconnected, the whole system unravels in a series of multiple knock on effects. This is shown in Figure B2.2.

It is known from the work of Sinha (2005) that a clustered small world network structure has some capacity for containment of shocks and in complex system terms these highly interconnected multi-hub based systems can have some stabilizing effects compared to the unstructured random graphs. However, it is clear that the increased capacity to bear the first order shocks by the hub entities in the CDS network can only be achieved by installing 'super-spreader reserves' overturning the current practice of leniency in this direction. We estimate 'super-spreader' reserves by conducting stress tests on the CDS financial network and the systemic risk consequences of failure is quantified in terms of a Systemic Risk Ratio which indicates how much core capital is lost collectively due to failure of the trigger entity. What is remarkable is that local *ex ante* injections of super-spreader reserves to key players, similar to the idea behind inoculations, can avoid costly systemic risk consequences.

It is interesting to see how the CDS network structure alters with the introduction of the centralized clearing platform Intercontinental Clearing Exchange (ICE). The data for ICE Trust is reported in the FDIC Call Reports from 2009Q2. The network produced for the hybrid OTC and CCP clearing for the CDS market is found to be no more stable than the pre ICE network reported in Box 2.[35]We use this computational simulator based on FDIC balance sheet data for the US banks involved in the CDS market and implement precise conditions of the Basel II incentives for capital reduction for each bank. We conduct experiments to see to what extent the acquisition of large balance sheet MBS holdings which peaked in 2007 at $0.5 trillion involving only 26 US FDIC banks was fuelled by the capital reduction incentives and by CDS carry trade. The agent based model approach enables each bank to implement rules of the CDS carry trade discussed in Markose *et. al.* (2010) for the period 2005Q4 – 2007 Q3 when there was the greatest growth of the bank balance sheet RMBS assets and also a chronic underpricing of CDS spreads on subprime RMBS. We find that if the Basel II and Federal Reserve Board Rule No. 99.32 incentives for capital reduction with CDS guarantees were removed in that period, balance sheet RMBS would have grown at only a modest rate.

4.3Generalization of Network Analysis for Multiple Markets: Hypergraphs

While the CDS market has played a unique and pernicious role in the recent 2007 crisis due to CDS guarantees being key to the reduction of bank capital in the credit risk transfer regulatory framework, going forward it is important to quantitatively assess the systemic risk consequences of other financial derivatives markets such as foreign exchange and interest rate swaps. The size of notional amounts outstanding on OTC derivatives markets globally is estimated by BIS Statistics at over $614 tn[36] in Dec 2009, of this interest rate derivatives account for $449.79 trillion[37], followed by foreign exchange derivatives and then the credit derivatives. Interestingly, the Euro dominates the currency denomination for amounts outstanding on OTC interest rate derivatives at $175.7 tn in Dec 2009[38]. The US dollar denominated interest rate swaps come second at $153.3 tn followed by Yen currency ones at $53.8 tn and the Sterling currency ones at $34.256 tn These currency denominations are of significance in terms of locationality of potential financial crisis. When compared to the size of world GDP at $70 tn and size of the global bond market (total debt outstanding) at about $82 tn, there is a major threat from the size of off balance sheet activities of FIs which have grown to many multiples of their assets and especially the concentration of 95% of financial derivatives obligations with a few as five large FIs (see footnote 20). Market wide adverse movements on the underlying such as interest rates, house prices, sovereign debt and most of all the weakness of key CDS protection sellers due to wrong way risk could bring about correlated losses that can overwhelm the equity and assets of FIs involved in financial derivatives. Apart from single name non financial corporate CDS and single name equity derivatives, almost all financial derivatives represent underlying assets that manifest procyclicality with macro-economic and global factors (such as house prices, GDP, government debt, deficit and sovereign bond yields) and also strong co-movements with one another during down turns. The lack of sustainability of historically low interest rates, especially in the context interest rate swaps and the vulnerability of key FIs as CDS guarantors on sovereign risk, makes the systemic risk from derivatives particularly potent. The only quantitative assessment to date of FIs' overall derivatives exposure and systemic risk impact is that of Segoviano and Singh (2010). The paper is based on the FDIC/OCC data on fair value derivatives liabilities for FIs aggregated over all derivatives products and the CDS spreads for these FIs as reference entities. The latter determines the conditional default probabilities and the so called distress dependence between FIs determines which FIs will fail conditional on failure of others. Segoviano-Singh find that the expected cumulative derivatives losses when cascaded in a series of insolvencies

---

[35] The network analysis can be found at the IMF website for the 2010 Workshop on *Operationalizing Systemic Risk Monitoring* and currently more experiments are being run to see if ICE is adequately capitalized within the network structures and CDS obligations based on the FDIC Call Reports.

[36] BIS Quarterly Review , June 2010, Table 19, (*Amounts outstanding of over-the-counter (OTC) derivatives by risk category and instrument*).

[37] Of this Euro dominates the currency denomination.

[38] Table 21 B (Amounts outstanding OTC single currency interest rate derivatives.

of top broker dealers are even beyond the capabilities of the Fed Reserve to provide backstops. This adds urgency for the need to conduct an in-depth structural analysis of the financial derivatives markets and the role of FIs.

Remarkably, FDIC Call Reports yield FI level data broken down across the main financial derivatives in terms of both gross notionals on the buy and sell sides and derivatives payables and receivables after legally binding netting. The aggregated amounts across all financial derivatives products are also given. The sectoral exposures of FDIC FIs to entities that do not report to FDIC are also indicated.

To roll out the network analysis across multiple financial derivatives markets in which a relatively small number of large financial intermediaries are involved as broker dealers, the bilateral relationships that are graphed by simple networks has to be generalized to incorporate *hypergraphs.* Using hypergraphs the activities of FIs in a number of different markets can be characterized by hyper edges while the intersecting graphs can display the FIs which are common to some or all the markets. Thus, the bilateral networks for each of the financial derivatives markets, interest rates, forex and credit will have their own topological structures, but the FIs common to some or all three markets will mesh the separate networks into a hypergraph which may have different systemic properties from any of the individual networks. Box 3 sets out some technical details entailed here. The reasons why the hypergraph structure needs to be investigated are hypothesized as follows: We now have contiguous networks with each network displaying some generic and specific topological features. Are some market networks and market micro-structure rules more destabilizing than others? An agent prominent in only one of the markets (but not in others) can trigger a chain reaction that can spread across markets etc. The aggregated model (aggregated over all derivatives products)cannot highlight which of the derivatives markets/products are more prone to default from a specific macro-economic factor that becomes increasingly prominent and also the sequence of chain reactions.

There is as yet no empirical work on how the concentration of broker-dealers in financial derivatives markets results in systemic risk consequences under conditions of one way markets.[39] Tools to conduct system wide stress tests for globally interconnected derivatives broker-dealers when their portfolios of derivatives become highly correlated with the underlying assets of the end users of derivatives need to be developed. Under conditions of one way markets during downturns when end user demand for hedging is in one direction, broker dealers who remain for the most part identical across all financial derivatives face a positively correlated portfolio in all procyclically aligned underlying assets. There are other fundamental questions, about the gross notional size of derivatives markets and the very small end user benefits, for which we do not have answers yet. There is a growing view that when the underlying of financial derivatives have procyclicality to macro-economic factors or self-reflexivity (from processes that generate more derivatives purchases such as CDS to reduce counterparty risk) which promote the excessive growth of these derivatives to a point at which far from maintaining volatility at the status quo level will bring about extreme tail events that they will be unable to provide protection for in terms of settlement liquidity. It appears that smaller and smaller end user hedge benefits are supported by larger and larger offsetting activities done by broker dealers of derivatives with large payoffs at settlement going to speculative 'naked' buyers of derivatives.[40] The dislocation here is that financial derivatives begin to provide higher profitability to large FIs from chasing spread maximizing trades rather than returns from real side investment.

To achieve the objectives to do with the correlated and macro cyclical aspects of financial derivatives products and the role of key agents dominant in the different derivatives markets – I have discussed how the single network analysis needs to be generalized to involve *hypergraph* theory. For purposes of contagion and systemic risk analysis, we need to investigate whether threats from systemically important entities , especially in the context of financial derivatives, is best done on the basis of derivatives payables and receivable aggregated over all products for each FI or whether the disaggregation across markets can throw better light. It is my conjecture that as it was specific products like CDS on MBS that upended the markets in the 2007 crisis, it is important to understand threats arising from specific derivatives products.

Box 3 Hypergraphs for Systemic Risk Analysis of Financial Derivatives Markets

In order to assess the systemic risk consequences of financial derivatives which involve the two key aspects of financial derivatives markets, viz, the impact of procyclicality with macro-economic variables of the underlying assets for derivatives and their co-movements between themselves and the concentration and clustered network structure of dominant FIs – it is important to disaggregate the activities of FIs in the procyclically sensitive components of the 3 main derivatives markets (forex, interest rates,CDS specifically on FIs and sovereigns and bank balance sheet items). It has long been noted (see, Berge (1973, 1989), Johnson (2006)) that networks only characterize relationships (edges/links) between pairs of entities (nodes) while many relationships (hyper edges) include multiple members and these same individuals can be members of more than one hyper edge. Formally H(E,V) denotes the hypergraph which involves the set of hyper edges $E= \{ E_1, E_2, E_3, ... E_K)$ and the set of individuals or vertices/nodes, $V= \{V_1, V_2, V_3 ... V_N\}$. Note $E \neq \emptyset$ and $\cup_k E_k = V$. In our proposed model for financial derivatives markets, the set E of hyper-edges contains the 3 main markets and all the different FIs and other entities that belong to each of these markets, constitutes the set V. Taking all participants in all the 3 markets, the hyper-graph incidence matrix denoted as E(H) is a Boolean 3xN matrix which yields entries $e_{ij} \in (0,1)$ where the indicator function $e_{ij} = 1$ if vertex $v_i \in E_i$ and $e_{ij} = 0$ if vertex $v_j \notin E_i$.

[39] Financial Times (18 Nov, 2010) reports "hedge funds have begun to hoover up credit protection against Spanish bonds expecting a crisis in the first quarter of next year... the short positions are quite crowded so they are not performing well".

[40] See for example the faster growth in so called *netting benefits* relative to the growth in gross notional value of derivatives contracts in Graph 5B of OCC Quarterly Report on Bank Trading and Derivatives Q4 2009.

B**3.1 Hyper-graph Incidence Matrix (Transpose E$^{/}$) and Example of Hyper-Triangle (Red Arrows)**

	$\mathbf{v_1}$(JP M)	$\mathbf{v_2}$ (CG)	$\mathbf{v_3}$ (BoA)	.....	$\mathbf{v_N}$
$\mathbf{E_1}$(CDS)	**1**	**1**	**0**	**...**	**1**
$\mathbf{E_2}$ (Forex)	**1**	**0**	**1**	**...**	**1**
$\mathbf{E_3}$ (Interest Rate Swaps)	**1**	**1**	**1**	**...**	**0**

Clearly, the vertices can belong to at most 3 (all) hyper edges or markets or at least 1 of them. The degree of the vertex is the number of hyper edges it belongs to. The Adjacency matrix of the hypergraph denoted by A(H) is a VxV matrix with entries A_{ij} denoting the total number of hyper edges to which each pair of vertices belong to:$A_{ij}(H) = |\{\ \forall\ E_k \in E: (v_i, v_j) \in E_k\}|$. Hence , in this case these entries are non-negative integers that range from {0,3} and these denote the number of markets the pair operate in. The complication for financial markets is that in each market, a pair of vertices will have a simple adjacency matrix relating pair wise counterparty relationships.[41] Hence, it is necessary to combine the bilateral information in each of the hyper-edges with the information in the A(H) matrix which only tells us the total number of markets the pair operate in.[42] This adjusted A(H) matrix which is denoted as A*(H) is then used to implement the generalizations for clustering and centrality that applies to hypergraphs. Turning to the clustering coefficient which was prominent in small world networks where triangles emerge (see Figure B21) viz. two neighbours of a node are also linked, in a hypergraph, we consider hyper triangles.

Define a path as sequence of vertices of length l with each vertex , v_1, v_2, ... v_l and hyper edges being distinct. We take paths with lengths of l=3 for hyper-triangles we have closed paths as the path starts and begins with the same vertex but must traverse through distinct hyper- edges as in v_i, E_p, v_j, E_q, v_r, E_z, v_i. An example of this is to take JP Morgan in the CDS market to relate to Bank of America in the Forex market and Citigroup in Interest Rate Swap market, see Table B3.1. The question is if the latter two also connect up. If so, we have a hyper- triangle as shown in Table B3.1. The formula for clustering in the hypergraph[43] is given by

$$C(H) = \frac{6\ x\ Number\ of\ hyper-triangles}{number\ of\ paths\ of\ length\ 2}\ .$$

As A*(H) is a symmetric matrix, Estrada and Rodriquez-Velazquez (2010) show that it is straight forward to apply eigenvalue centrality to hypergraphs. In the analysis that has been done where data on agents can be represented pairwise in a simple network(for example pairs that co-author a paper) and also as a hypergraph , central agents in one may not be so in the other. The distinction here is the role of agents who are dominant in operations across markets as opposed to within the same markets.

5. Concluding Remarks:

This review of monetary and financial systemic risk management has been undertaken in the aftermath of the legacy of the 2007 financial crisis and Basel II regulatory framework. An inescapable conclusion regarding the comprehensive market and regulatory failure of 2007 which has led to the global economic crisis, is that it can only have arisen from deep doctrinal flaws of the dominant economic and financial theories, deficits in the knowledge base and also a lack of appropriate quantitative modelling tools to map and monitor system stability. The relevance of the analysis and recommendations for the BRICs follow not only because they may have suffered from fallouts from the crisis but because they will in due course be subjected to similar structural changes in their financial and monetary institutions as those experienced in advanced cashless economies. I close the review with five main conclusions if there is to be progress in developing new perspectives and tools in the management of systemic risk in of advanced monetary and financial systems.

• **Policy Design and Systemic Risk from Complexity and Networks Perspective:** It may not be far off the mark to say that socio-economic system failures arise from a disparity between the pursuit of local interest and those needed for overall stability of the system. Fallacies of composition easily arise due to a lack of visualization tools that can give a holistic picture of the system not just in terms of disparate individuals or in a simplistic aggregation of them to one agent (the preferred method of extant macro-economics) but where the system is shown in terms of structural interconnections between units. I have indicated how a networks and complexity perspective gives a unified picture of system stability in terms of well known monetary and financial tools to do

[41] Note in a simple graph the adjacency matrix is a VxV Boolean matrix with entries denoted by a_{ij} with non-zero entries which indicate that the pair of vertices are linked and further as the flows are directed, i is the guarantor and j is the beneficiary. In contrast, the notation A_{ij} (H) refers to the entries of the adjacency matrix of the hypergraph.

[42] Further say the pair (v_1, v_2) have an entry 2 in the A(H) matrix and another pair v_3, v_4 also have 2, it is not possible to know whether these two pairs operate in the same 2 markets without referring to E(H) hypergraph incidence matrix.

[43] The equivalent clustering coefficient for the simple network is $C = \frac{3\ \times number\ of\ triangles}{2\ xall\ possible\ connected\ pairs}$. As each triangle implies 3 such triples, we include 3 in the numerator and likewise have 2 in the denominator.

with capital, reserves, collateral, margins and find these get eroded by the pursuit of regulatory arbitrage or perverse incentives from policy. As competitive co-evolution in the form of strategic innovative behaviour between firms and between firms as regulatees and the regulator is the *sine qua non* of complexity in adaptive economic systems, policy design should make this the centre piece of robust design frameworks. In other words, vigilance is mandatory by regulator to detect regulatory arbitrage or for perverse incentives from policy. Network structures of complex systems due to local efficiency drives will typically display supercriticality often manifest in a small world networks structure (see, Box1) with tiered central hubs which are *too interconnected to fail*. Interestingly, managing systemic risk from such clustered structures is easier than in a more diffused random one where as the direction of the epidemic is not easy to predict, all of the population has to be inoculated. Considerable scientific research needs to be done based on empirical mapping of financial network structures especially those involving financial derivatives to design effective interventions. The proposed ICT framework for analysing, monitoring systemic risk in advanced monetary and financial systems is far removed from mainstream optimal policy or regulatory design approach which is mostly wedded to precommitment to a fixed rule within a framework that is devoid of institutional details, and most of all little recognition that certain policy rules can have perverse destabilizing consequences. This will indeed be a missed opportunity if as Edward Kane (2010) notes: "Official definitions of systemic risk leave out the role of government officials in generating it ... and officials adopt definitions of systemic risk that lead to the self-serving hypothesis that systemic risk is caused by defective risk management at "systemically important firms"".

•**Threats from Inflation Misconceived**: In advanced cashless economies, the structural changes in monetary aggregates have meant that that the payments component of money has shrunk drastically leaving 'inside' private credit creation to dominate. This appears to imply that monetary policy influencing interest rates and bank reserves can only contract or expand private credit creation (subject to Keynesian liquidity trap conditions when banks hoard money rather than lend it) and generate asset prices bubbles with little or no impact on inflation on the CPI index. As Marimon *et. al.* (1997) have pointed out, central banking elites in developed countries appear to have a vested interest in not finding out to what extent changes in payment habits which have substituted away from cash have curbed inflation. Misdirected focus of central bankers on a much vitiated inflationary threat which they attribute to their policies, has and continue to be a stumbling block for the research and development in dealing with the threats from a burgeoning private credit creation machine. The latter in all its forms remains a fractional system for which the central bank remains the lender of last resort. This responsibility was overlooked in the recent zeal for adherence to fixed rules of monetary policy on inflation rather than one which encourages co-evolution of policy tools for one more suited to a cashless system and low inflation and interest rates.

In BRICs, the large cash based payments systems still harbour old style inflationary pressures well captured by crude quantity theory of model which revolves around transactions demand for money and the proportionality between inflation rate, cash in circulation and growth in monetary base. Large cash withdrawals from depository institutions for payments due to fractional banking pressures leaves depository institutions with reduced liquidity resulting in upward pressure on deposit rates. Hence, loose monetary conditions by reducing the opportunity cost for money for transactions can create increased transactions demand for it and drive up prices. In cashless economies with loose monetary conditions, all of the increases in bank reserves which do not exit the banking system for transactions can only stoke up asset price bubbles and further leverage. In the BRICs, especially India, mobile phone banking is taking off to both enhance banking inclusion for large parts of the population and also for payments. While these are early days, the rate of penetration promises to be faster than the rate of adoption of plastic card based EFTPOS in the West as the mobile phone itself is already a well established technology in India. Amongst the BRICs, Brazil leads the league in cashless payments. After the 1999-2003 crisis, Banco Central do Brasil has been acting in order to promote the development of the retail payment systems, mainly to take advantage of gains of efficiency relating to, for example, larger use of electronic payment instruments, better use of ATM and POS networks, and higher level of integration among the related clearing and settlement systems. In 2009, according to the Brazilian Credit Card and Services Association (Abecs), there were 565 million cards on the market, including credit, debit, and private label cards. That year around 667 million transactions were performed, 15% more than in the previous year with cash help by public to GDP in 2008 to be about 3%.[44] This review highlights the potential for inflation reduction by this avenue and alerts authorities not to be lulled into a sense of complacency when the inflationary threat has receded.

•**Credit Default Swaps as Credit Risk Mitigant in Fractional Systems of Credit Creation**: The role of credit default swaps to substitute bank capital in the Basel II and III framework adds to the instability of fractional systems of credit generation. The role of capital is to mitigate the leverage impact while the use of credit derivatives will have an endemic tendency, fully justifiable at an individual level as a hedge, to multiply it in a pyramid of derivatives on derivatives. I recommend that the Basel II and III provision for capital reduction on bank assets from the use of CDS guarantees cover should be discontinued. Banks should be left free to seek unfunded CDS cover for bank assets *without* the incentive of capital reduction and leverage. Indeed, this may enhance price discovery role of the CDS market relating to the probability of default of reference assets or entities and reduce the current concentration risks that make the hub banks in the CDS network structure *too interconnected to fail* and necessitating tax payer backstops.

•**Checks and Balances on Negative Externalities from Leverage:** Monetary and financial infrastructure is a public good which is ultimately underpinned by fiat money backed by tax revenues of a government. The need to control negative externalities that

[44] http://www.bcb.gov.br/Pom/Spb/Ing/statistics.pdf

leads to over use/supply by individual entities whether they are private or governmental agencies is the only legitimate economic argument against self-regulation. There is at the heart of the negative externalities problem the need to 'cap' the production of an economic activity. The design of institutional constraints on fiat money and private debt based fractional systems are not different from managing environmental negative externalities where the balance between growth and sustainability has to be designed artificially or evolved by trial and error. Extant pricing models for credit risk are unable to price in the 'clean up' costs entailed in systemic risk leading to chronic underpricing. Privately designed institutions will not voluntarily curtail activity by internalizing the costs relating to either immediate failure of counterparties or wider social 'clean up' costs. I have noted why internal drives toward minimizing liquidity,capital or collateral by financial intermediaries can explain typical *too interconnected to fail* financial network structures. An example of mapping such networks and targeting dominant broker dealers in CDS markets specifically for their capacity to contribute to system collapse in the form of a 'super-spreader' tax was given as an effective way of internalizing this cost of system failure. More work is needed to understand fragilities of a monetary and financial environment which is also increasingly going to be electronically driven.

• **New Governance Structures for Financial Innovations and Regulatory Change:** Consumer protection and public health is well served from workings of food and drugs agencies where innovations are rigorously vetted for their capacity to harm. It is increasingly accepted that a similar agency to authorize financial innovations before commercial use will well serve public interest. The same accountability should be installed for the rule making bodies in banking and finance. Poor rules made with no cognizance of their systemic risk consequences can wreck financial superstructures faster than any terrorist malfeasance. I can only repeat here what Martin Hellwig (2010) has said about the lack of accountability of the Basel Committee on Banking Supervision: "It adheres to the tradition of discussing the rules of capital regulation among the bureaucratic cognoscenti, in some interactions with the industry, without ever providing any theoretical or empirical analysis of the effects that the measures under consideration are deemed to have – and without heeding outsiders who demand that such analysis should be just as much a precondition for the implementation of regulatory rules as for the introduction of new pharmaceutical drugs in the market". BRICs which are en route to similar stages of financial and monetary development will be better served if more accountability is brought into the global rule making body for banking and finance.

Many of the BRICs are well placed in meeting many of these challenges due to the inconsiderable fund of cutting edge IT talent that can be harnessed to help set up holistic models of the financial systems based on fully automated data based driven multi-agent models of all major and emerging credit markets in the country. Digital access of financial and banking data across FIs and markets with visualizations that can highlight leverage, reserves and extraordinary growth rates or transactions sizes should be an attainable goal with advances in ICT. These tools can reveal interconnections and also embed intelligence for agents to respond strategically to rule changes. Hence, these models are a far cry from so called dynamic general equilibrium models or the traditional macro-econometric models that could not incorporate interconnections at micro-level nor strategically driven structure changes that can trigger contagion and system failure. I have made a case for making such computational platforms as the basis of computational policy simulations, stress tests and scenario analysis which are to be conducted in a routine fashion rather than as a fire fighting exercise. As an academic economist, I can only add in conclusion that the biggest threat to our capacity to meet the above challenges is the business as usual attitude that permeates many an economics department where little effort has been invested to revolutionize curricula and training in response to recent catastrophic failures of the profession.

References

Acharya, V. and Richardson, M.(2010) "Causes of the Financial Crisis', Critical Review, 21:2, 195 – 210.

Alentorn, A., Markose S., Millard S. and Yang J. (2005) "Designing large value payment systems: An agent-based approach", Centre For Computational Finance and Economic Agents and Economics Department, University of Essex, Mimeo.

Alessandri,P. and Haldane A.(2009) "Banking on the state", Paper based on presentation at the Federal Reserve Bank of Chicago, 12 International Banking Conference.

Arthur, W.B., (1994). "Inductive Behaviour and Bounded Rationality", *American Economic Review*, 84, pp.406-411.

Axelrod , R. (2003) "Risk in Networked Information Systems", Mimeo, Gerald R. Ford School of Public Policy, University of Michigan.

Babus, Ana (2009) "The formation of financial networks", Discussion Paper, 06-093, Tinbergen Institute.

Barabási, A.-L.; R. Albert (1999), "Emergence of scaling in random networks". Science 286: 509–512.s

Berge, C. (1989) *Hypergraphs: The Theory of Finite Sets* (North-Holland, Amsterdam).

Berge, C.(1973), *Graphs and Hypergraphs* (Elsevier, New York).

Binmore, K. (1987), 'Modelling Rational Players: Part 1', *Journal of Economics and Philosophy*, vol. 3, pp. 179-214.

Bliss R., and Kaufman G (2005) "Derivatives and Systemic Risk:Netting, Collateral, and Closeout", Federal Reserve Bank of Chicago.

Brunnermeier, M., A. Crockett, C. Goodhart, A. Persaud and H. Shin, (2009), "The fundamental principles of financial regulation", Geneva Reports on the World Economy 11, International Center for Money and Banking Studies.

Mark Buchanan, "Meltdown Modeling: Could Agent-Based Computer Models Prevent Another Financial Crisis?" **(pdf,1.2K)**, *Nature*, Vol. 460, August 6, 2009, 680-682.

Buiter, W. (2009) "The unfortunate uselessness of most 'state of the art' academic monetary economics " http://www.voxeu.org/index.php?q=node/3210

Cont,R., Minca,A. and Moussa A.(2009), "Measuring systemic risk in financial networks", Power Point Slides, Columbia University.

Crawford, V. (2003) "Lying for Strategic Advantage: Rational and Boundedly Rational Mirepresentation of Intentions", American

Economic Review, pp. 133-149.
Craig, B and von Peter, G., 2010, "Interbank tiering and money center banks", BIS Mimeo.
Cukierman, A.(1992).*Central Bank Strategy, Credibility and Independence:Theory and Evidence*, MIT Press, Cambridge and London.
Cutland, N.,1980, Computability: An introduction to recursive function theory (Cambridge University Press).
Darby, M. (1994) "Over the counter derivatives and systemic risk to the global financial system", NBER WP No. 4801.
European Central Bank Report (2010) Recent Advances in Modelling Systemic Risk Using Network Analysis
http://www.ecb.europa.eu/pub/pdf/other/modellingsystemicrisk012010en.pdf?d216f976f3587224bcc087cc8149ed49
Eichengreen, B., (1999), 'Kicking The Habit: Moving From Pegged Rates To Greater Exchange Rate Flexibility', *Economic Journal*, vol. 109, pp.C1-C15.
Estrada, E. And Rodriquez-Velazquez (2010) "Complex Networks as Hypergraphs", Mimeo ,*Complex Systems Research Group*, University of Santiago De Compostela, Spain.
Fischer, S.(1994). 'Modern Central Banking', in Capie, F. et al. *The Future of Central Banking: the Tercentenary Symposium of the Bank of England*, Cambridge University Press, Cambridge, pp. 262-330.
Furfine, C. H. (2003), "Interbank Exposures: Quantifying the Risk of Contagion", Journal of Money, Credit and Banking, No 35(1), pp.111-28.
Galbiati, M., Giansante, G., Adams, M. (2010) "Emergence of tiering in large value payment systems", *Forthcoming*, Bank of England Working Paper.
Goodhart, C. (1994). 'Game Theory for Central Bankers: A Report to the Governor of the Bank of England', *Journal of Economic Literature*, vol. 32, pp. 101-15.
Goderis, B., Marsh , I., Castello, J. Wagner, W, (2007), "Bank behaviour with access to credit risk transfer markets", Bank of Finland Discussion Paper 4/2007.
Haldane, A. (2010) "The $100 billion question ", Talk given at the Institute of Regulation and Risk, Hong Kong.
Haldane, A.(April 2009) "Rethinking the financial network", Speech delivered at the Financial Student Association, Amsterdam
Hayek, F.A. (1936), Prices and Production, Routledge.
Hayek, F.A., *Denationalization of Money*, First published 1976, now downloadable from Institute of Economic Affairs.
Hellwig, M. (2010)"Capital regulation after the crisis: business as usual ?", CESifo DICE Report , Journal for Institutional Comparisons.Vol 8, No. 2.
Hirschman, A.(1991).*The Rhetoric of Reaction:Perversity, Futility, Jeopardy*,The elknap Press of Harvard University Press, England.
Hirschman, A.(1995).*A Propensity to Self-Subversion*, Cambridge, MA:Harvard University Press.
Humphrey, D., Pulley, L., and Vesala, J. (1996) "Cash, paper and electronic payments: A cross country analysis", Journal of Money, Credit and Banking, 28, 914-939.
Jones, D. (2000): "Emerging Problems with the Basel Capital Accord: Regulatory Capital Arbitrage and Related Issues", No 24, pages 35-58.
Johnson, J. (2006), " Hypernetworks for Reconstructing the Dynamics of Multi-Level Systems", *Paper presented at European Conference on Complex Systems , Oxford University Sept 2006.*
Kane, E. (2010): "Redfining and Containing Systemic Risk ", Mimeo Boston College.
Kirman, A., (1992) "Whom or what does the representative individual represent?", Journal of Economic Perspectives, 6, 117-136.
Kirman, A. (1997) "The Economy as an evolving network", Journal of Evolutionary Economics, 7 (4): 339-353.
Leonard, H. and Howitt, A . (2010)" Understanding and coping with increasing risk of system level accidents", In, Integrative Risk Management: Advanced Disaster Recovery , Swiss Re Centre for Global Dialogue.
Lucas, R. (1972) "Expectations and the Neutrality of Money", Journal of Economic Theory , vol. 4, pp.103-24.
Lucas, R. (1976) "Econometric Policy Evaluation: A Critique", Carnegie-Rochester Conference Series on Public Policy, vol. 1, pp. 19-46.
Markose, S.M, S. Giansante, M. Gatkowski and A. R. Shaghagi, 2010**,** "Too Interconnected To Fail: Financial contagion and systemic risk In network Model of CDS and other credit enhancement obligations of US banks", Economics Department, University of Essex, DP 683, Feb 2010.
Markose S., Alentorn A., Koesrindartoto D., Allen P., Blythe P. and Grosso S., 2007, "A smart market for passenger road transport (SMPRT) congestion: An application of computational mechanism design ", ***Journal of Economic Dynamics and Control*** , Volume 31, Issue 6, June 2007, pp 2001-2032.
Markose, S. M., J. Arifovic and S. Sunder (2007), "Advances in Experimental and Agent-based Modelling: Asset Markets, Economic Networks, Computational Mechanism Design and Evolutionary Game Dynamics", Journal of Economic Dynamics and Control, Volume 31, Issue 6, pp 1801-1807.
Markose, S. M. (2005), "Computability and evolutionary complexity: Markets as complex adaptive systems (CAS)", Economic Journal, Vol. 115, pp. F159-F192.
Markose, S.M (2004a) "Novelty in Complex Adaptive Systems (CAS): A Computational Theory of Actor Innovation", *Physica A: Statistical Mechanics and Its Applications*, vol. 344, pp. 41- 49.
Markose, S., Alentorn A. and Krause A. (2004b) "Dynamic learning, herding and Guru effects in networks", University of Essex, Economics Department Working Paper (No. 582).
Markose, S. M. and Loke,Y.J. (April 2003), "Network Effects of Cash-Card Substitution In Transactions and Low Interest Rate Regimes", *Economic Journal*, vol.113, pp.456-476.
Markose, S. and Loke Y.J (2002) "Innovations In cash-card payments networks: Implications for monetary policy in low interest rate regimes, *in International Correspondent Banking Review , Yearbook, 2001/2002, Euromoney Publication.*

Marimon, R. Nicolini, J.P, Teles, P. (1997) “Electronic money: The end of inflation ?”, Discussion Paper 122, Institute for Empirical Macroeconomics, Federal Reserve Bank of Minneapolis.
May, R.M. (1972) “Will a large complex system be stable?” Nature 238, 413-414.
May, R.M. (1974) “Stability and complexity in model ecosystems”, Princeton University Press.
Minski, H. (1982) "The Financial-Instability hypothesis: Capitalist processes and the behavior of the economy", 1982, in Kindleberger and Laffargue, editors, *Financial Crises*.
Nier, E. , Yang J., Yorulmazer T. and Alentorn, A. (2007) “Network models and financial stability” , Journal of Economics Dynamics and Control, Vol 31, No. 6, 2033-60
Odlyzko, A., and Tilly, B. (2005) “A refutation of Metcalfe's Law and a better estimate for the value of networks and network interconnections”, Digital Technology Center, University of Minnesota, Mimeo.
Oberman LM, Hubbard EM, McCleery JP, Altschuler EL, Ramachandran VS, Pineda JA., *EEG evidence for mirror neuron dysfunction in autism spectral disorders*, Brain Res Cogn Brain Res.; 24(2):190-8, 2005-06
Pilat, D. (2002) “International comparisons of productivity key findings and measurement issues”, Paper presented at National Statistics: Productivity Workshop, 2002.
Ramachandran, V.S, “ Mirror Neurons and imitation learning as the driving force behind "the great leap forward" in human evolution”, Edge Foundation. Retrieved on 2006 November 16.
Schapiro and Varian, H., (1999) *Information rules : A Strategic guide to the network economy.* Cambridge, MA: Harvard University Press.
Sheng, A. (2010) “Financial crisis and global governance: Network analysis”, The Commission on Growth and Development Working Paper Series, No. 67.
Segoviano, Miguel and Manmohan Singh, (2008) “Counterparty Risk in the Over-The-Counter Derivatives Market.” IMF Working Paper 08/258.

Sinha, S. (2005) “Complexity vs. stability in small-world networks”, Physica A (Amsterdam), 346, 147-153.

Sinha, S. and S. Sinha (2006) “Robust emergent activity in dynamical networks”, Physics Review E Stat. Nonlinear Soft Matter Physics, 74, 066177.

Stiglitz, J., 2000,‘Capital Market Liberalization, Economic Growth, and Instability’, *World Development*, Vol.28, No. 6, pp.1075-1086.

Stiglitz, J., 2000, ‘The World Bank AT the Millennium’, *The Economic Journal*, 109, November, F577-F597.

Smullyan, R. (1961) Theory of Formal Systems, Princeton University Press.

Soros, G.(1995). *Soros on Soros: Staying Ahead of the Curve*, John Wiley.

Spear, S.(1989), “Learning Rational Expectations Under Computability Constraints”, Econometrica, 57, 889-910.

Milgram, S., (1967), “The small world problem”, Psychology Today 2, 60-67

Triana, P. (2010) “Basel III still contains seeds of more chaos”, Financial Times 20 September .

Upper, C. (2007) “Using counterfactual simulations to assess the danger of contagion in interbank markets”, BIS Working Paper No. 234, Basel.

Watts, D.J., Strogatz, S. H. (1998):“Collective dynamics of ‘small-world’ networks”, Nature, vol. 393, pp. 440-442.

Watts, D. (1999), “Small Worlds”, Princeton University Press.