NOT YOUR RANDOM WALK DOWN WALL STREET: AN APPLICATION OF COMPLEXITY THEORY TO FINANCIAL INNOVATION

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I. INTRODUCTION

The financial crisis that began in 2007 and continues to the present day has been blamed in part on the widespread use of complex financial products and, in particular, derivatives. The evolution of complex financial products has posed challenges to market participants since their inception, confusing even Aristotle.[1] In the twentieth century, it began with the adaptation of the option in the 1920s and the creation of federal regulators as a result of the Crash of 1929. As indexes were introduced in the 1980s and futures in the 1990s, U.S. financial markets continued to grow and were transformed into some of the most competitive and highly valued markets in the world. The fast rise and widespread use of the credit default swap is one of the latest financial innovations in this series and also at the center of the current financial crisis. While there are countless variations on these financial products, and many other innovative ones, for simplicity's sake, this paper will address only derivatives, and in broad, general terms.

The emergence of derivatives and the increasing frequency of low-probability, catastrophic events that have roiled U.S. and global financial markets raise interesting questions about the role these derivatives play and what, if any, lessons we can learn about how to avoid future crises and economic bubbles. Given the inability of financial modeling and quantitative analysis to predict or mitigate these crises and bubbles, a re-examination of the products and

[1] *See* MICHAEL SINCERE, UNDERSTANDING OPTIONS 9 (2006), *infra* note 9 and associated text.

events through the lens of complexity theory may offer new explanations and solutions for the future.

What caused the current financial crisis? As with many problems that typically receive a "who knows?" answer, complexity theory's framework is useful and perhaps more meaningful in the long run than a typical systemic risk analysis. The widespread use of derivatives across global financial networks is nothing if not "*complex*": "a great many independent agents are interacting with each other in a great many ways."[2] A brief look at the Office of the Comptroller of the Currency's 2008 ranking of derivatives held and issued by large financial institutions bears this out.[3] As in biological or other systems, "the very richness of these interactions allows the system as a whole to undergo *spontaneous self-organization*."[4] In the case of complex financial products, the mere presence of the International Swaps and Derivatives Association (ISDA), a third generation voluntary organization, is evidence of this extra-regulatory, extra-institutional organization. Financial institutions seeking to spread risk, increase returns, or benefit from taxation or regulatory loopholes "organized themselves into an economy through myriad individual acts of buying and selling," in our case, through individually negotiated contracts and a series of ever-expanding counterparties.[5] This "complex, self-organizing" system is also "adaptive": it has "actively tr[ied] to turn whatever happens to [its] advantage."[6] Finally, the global use of derivatives indicates some of the most important aspects of complexity theory: (1) dynamism, the ability to incorporate chaos and spontaneity into some semblance of order, and (2) the ability to thrive at "the edge of chaos."[7] This "shifting battle zone between stagnation and

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[2] M. Mitchell Waldrop, Complexity: The Emerging Science at the Edge of Order and Chaos 11 (1992).
[3] For a chart of these positions, please see the Appendix. Office of the Comptroller of the Currency, Quarterly Report on Bank Trading and Derivatives Activities, Second Quarter 2008, 21.
[4] *Id.*
[5] *Id.*
[6] *Id.*
[7] *Id.* at 12.

anarchy" encapsulates the tensions between the very different competing interests of market participants as well as countervailing market forces.[8]

This paper will re-examine the adaptation of derivatives to the modern financial network, and in so doing, trace the contours of complexity theory, increasing returns, and network effects. Part II will discuss the evolution of the use of derivatives, including its tipping points as bubbles are created and then burst. Part III examines the role of increasing returns by comparing a derivatives trading fund to an internet start-up, a comparison of the two most recent and chaotic financial events in U.S. financial history. Part IV applies the notion of network effects to the current financial crisis, focusing specifically on the impact of derivatives use on liquidity, contagion, and transparency. Part V offers a conclusion and suggestions for further applications of complexity theory, increasing returns, and network effects analysis on pressing financial matters.

II. HISTORICAL PERSPECTIVE: TIPPING POINT

A. THE USE OF DERIVATIVES

Derivatives have been in existence for millennia, most commonly as option contracts. The first recorded derivative was an option contract between Jacob and Laban, described in the Bible.[9] In that option contract, Jacob gave seven years of labor to Laban in exchange for the right to marry one of Laban's daughters, Rachel.[10]

In the time of Ancient Greece, Aristotle describes option speculation by Thales.[11] Thales was apparently able to predict weather patterns using astronomy, and in turn used these weather

[8] WALDROP, *supra* note 2, at 12.
[9] MICHAEL SINCERE, UNDERSTANDING OPTIONS, 8 (2006).
[10] *Id*. (discussing Genesis 29:18)
[11] *Id*. at 9.

forecasts to predict the size of olive crops.[12] Thales approached the olive press owners and paid them a deposit to reserve the use of the olive presses nine months into the future.[13] No one actually believed Thales could predict the harvests that far in advance, so there were no competing bids.[14] When the olive harvest wound up being plentiful, Thales was able to sell his option contracts, the previously purchased rights to use the olive presses, at a steep increase to what he originally paid.[15]

But the question remains: if derivatives have been around for so long, why wasn't it until 1973 that they began their meteoric rise to prominence? The first major derivatives market in the U.S. was an over the counter (OTC) options market for New York Stock Exchange (NYSE) stocks.[16] There were no computers or telephones, so options traders had to walk around the floor of the NYSE searching for buyers and sellers.[17] As time went on, parties began using newspaper ads to increase liquidity.[18] This allowed more parties to enter the market and eventually a loose organization of OTC stock options dealers was formed, the Put and Call Brokers and Dealers Association.[19]

Nevertheless, it was still quite some time before the first organized options exchange.[20] This meant that negotiating an option contract was difficult, because each contract was idiosyncratic, with its own unique terms. Additionally, transaction costs were high, and there

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[12] *Id*.
[13] *Id*.
[14] *Id*.
[15] SINCERE, supra *note 9*, at 9.
[16] *Id*.
[17] *Id*.
[18] *Id*.
[19] *Id*.
[20] *Id*. at 10.

was significant time required to execute a trade. Also, this meant no one guaranteed options contracts.[21] If a party defaulted on their obligation to the bilateral option contract, the counterparty would have little recourse.[22]

In 1973, the first options exchange was created by the Chicago Board of Trade.[23] The exchange allowed for standardized option contracts, reducing the need for negotiation. The time and expense of trading those standardized contracts were also significantly reduced (and would further be reduced with the advent of computer trading). Finally, the exchange served as a large, individual counterparty for options, creating one massive, centralized guarantor to protect trading parties. At that point, many more parties began options trading, but there was one last problem left: no one knew how to properly price an option.[24] Without a fair price, it was "very easy for either party to make bad deal and lose money."[25] The watershed moment for derivatives trading was May of 1973, when Fisher Black and Myron Scholes published their eponymous option pricing formula.[26] Now parties were able to confidently agree on the fair price of an option, starting a massive flood of options trading. Moreover, the Black Sholes pricing method was quickly adapted to apply to other derivatives, allowing confident price estimates across OTC derivative markets.[27]

Because of the great financial successes with options, many new derivatives were created and legalized to follow in their footsteps. Index futures began trading in the 1980s, allowing cheap diversification across exchanges, indicators, and sectors.[28] Non-financial companies, such as

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[21] SINCERE, supra *note 9*, at 10.
[22] *Id*.
[23] PETER BERNSTEIN, AGAINST THE GODS: THE REMARKABLE STORY OF RISK, 315 (1998)
[24] SINCERE, supra *note 9*, at 9.
[25] *Id*.
[26] BERNSTEIN, *supra* note *23*, at 315; *see also* Fischer Black & Myron Scholes, *The Pricing of Options and Corporate Liabilities*, 81 J. POL. ECON. 637 (1973).
[27] *See* BERNSTEIN, supra *note 23*, at 315
[28] JERRY W. MARKHAM, A FINANCIAL HISTORY OF THE UNITED STATES, 86 (2002).

Ford Motor Company and General Motors, began *originating* derivatives to diversify their holding, acquire a share of the financial profits and become more competitive within their own industries.[29] While the regulatory bodies devoted their resources to policing these new exchange traded derivatives, new OTC derivatives sprang up mostly unnoticed.[30] By the time regulators were able to discover certain financial innovations, large lobbying groups had already stepped in to prevent regulatory interference.[31]

This sudden increase in derivatives trading and new product origination was the chaotic event which has led shattered the previous financial order. By 1992, the total notional amount of derivatives was at least $12.1 trillion, spread out among more than 1,200 different financial derivatives products.[32] As Figure 1 shows, this trend has accelerated among OTC derivatives.

[29] *Id*. at 193-95.
[30] *Id*. at 191.
[31] *Id*. at 191.
[32] *Id*. at 198.

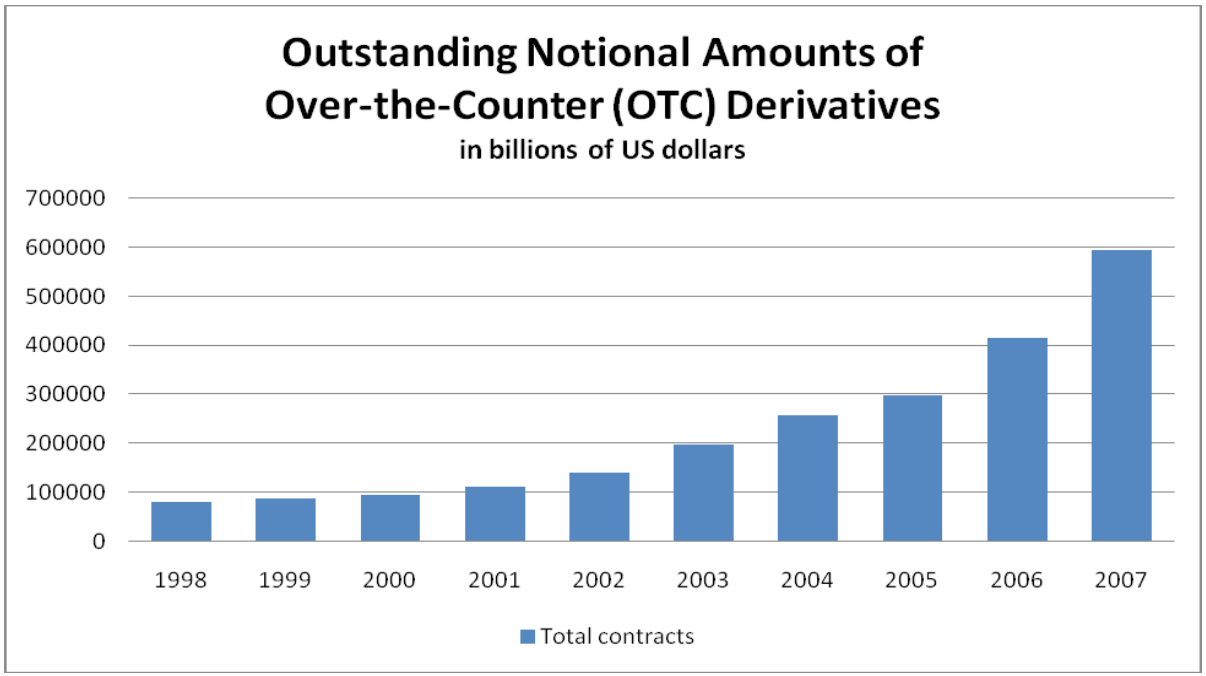

Figure 1 Derivatives Contracts by Product, 1998–2007[33]

B. THE BUBBLE BURST

The relationship between bubbles and financial crises is central to our analysis. At some point, a tipping point was reached and insufficient liquidity triggered the U.S. sub-prime mortgage asset bubble to burst in during 2007 and 2008. Bubbles are created by mispriced assets, yet when these assets are securitized—when serious risk is transferred—so are the effects of default and collapse across more market participants.[34] A burst bubble can result in financial crisis when mispriced assets—or their derivatives—are held or issued by enough market participants.

[33] BANK OF INTERNATIONAL SETTLEMENTS, TRIENNIAL CENTRAL BANK SURVEY, FOREIGN EXCHANGE AND DERIVATIVES MARKET ACTIVITY IN 2007, Table 19 (Dec. 2007).
[34] Franklin Allen & Douglas Gale, *Bubbles, Crises & Policy*, 15 OX. REV. ECON. POL. 9, 9 (1999).

Yet in the case of derivatives, which can provide protection or profits on downward market activity, issuers or buyers stood to profit by the bursting bubble, and may have had incentives to inflate and then burst the bubble. Andy Lo has documented two instancing of de-leveraging in August 2007, collectively termed the "Quant Meltdown" or "Quant Quake" of 2007.[35] During these two transactions, one lasting forty-five minutes and the other five hours, empirical data suggest hedge funds unwound a number of positions in financial sector stocks as well as bets on earnings momentum and other "factor-driven" holdings.[36] It is important to note these were not necessarily derivatives, but they indicate large-scale movements which are often tied to offsetting derivatives transactions and involve numerous counterparties. Thus, a sudden, large de-leveraging in August 2007 aligns with the sharp decline in liquidity in August 2007 which burst the subprime, CDO-driven bubble.[37] The reasons for a fund's ability to deleverage quickly and undetected at the time will be explained in Section IV Network Effects.

It may be too early to say for sure what caused the derivatives bubble to burst, but a few factors can be noted. First, as mentioned above, the ability for a relatively unknown actor to issue systemic shocks to counterparties is wholly dependent on the pervasive use of derivatives. It is unclear whether these shocks were predominantly created with the intent to profit on their effects or merely as a defensive reaction. Second, problems with the price stability and monitoring of the derivatives' underlying assets, themselves undergoing a bubble burst at the time, certainly contributed to the sharp decline in derivative values.

Admittedly, other periphery issues are undoubtedly at play. Yet, as with any crisis in the initial stages of fallout, experts can contribute their expertise, but an interdisciplinary solution is lacking. In sum, if you are a hammer, all you see are nails. Accountants cite a lack of

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[35] Amir E. Khandani & Andrew W. Lo, *What Happened to the Quants in August 2007?: Evidence from Factors and Transactions Data* (Oct. 23, 2008), *available at* http://ssrn.com/abstract=1288988.
[36] Khadani & Lo, *supra* note 35, at 1–13.
[37] Khadani & Lo, *supra* note 35, at 19.

accounting standards and corporate boards unwilling or unable to heed warnings.[38] Executives cite a sheer inability to control the vast network of derivatives.[39] Congressmen cite weak regulators, regulators blame informational asymmetries on other regulators or the regulated entities themselves.[40] Yet this back-and-forth obscures what is of central importance to this analysis: that consistent with complexity theory, regardless of the nature of the regulatory or financial structures in place, derivatives not only tipped but that they continued to prove their efficacy to certain market participants through the bursting of the bubble.

III. The Role of Increasing Returns: Lessons from Tech Start-Ups

The widespread growth and reliance upon derivatives largely explains the connection between a bubble and the current financial crisis, just as the role of the tech start-up as an overpriced asset provides the nexus between the tech bubble and resulting market crash. But if we examine the start-up and the derivative fund before they "tip," or fall off the "edge of chaos," we can learn more about the role of increasing returns.

Both the proliferation of high-tech stocks and derivatives are an example of increasing returns. As with the Beta/VHS competition or the entrenchment of the QWERTY row,[41] one could argue that the derivatives in question are not superior to less-used alternatives and, especially in

[38] *See, e.g.*, Hearing on the Causes and Effects of the AIG Bailout, Before the H. Comm. on Oversight and Gov't Reform, 110th Cong. 35–36 (Oct. 7, 2008) (testimony of Mr. Lynn Turner).
[39] *See,e.g.*, Hearing on the Causes and Effects of the Lehman Brothers Bankruptcy, Before the H. Comm. on Oversight and Gov't Reform, 110th Cong. (Oct. 6, 2008) (testimony of Mr. Richard S. Fuld, Jr.).
[40] *See generally*, Hearing on the Causes and Effects of the Lehman Brothers Bankruptcy, Before the H. Comm. on Oversight and Gov't Reform, 110th Cong. (Oct. 6, 2008).
[41] Waldrop, *supra* note 8, at 35–36.

the case of tech stocks, that once the NASDAQ took hold, "them that has gets…there was no turning back."[42] Likewise, once large financial institutions and non-financial companies began making use of derivatives, it was only natural that a web of counterparties would develop and spread across market participants. Because funds could write any contract they wished, so long as they could find a willing buyer, the opportunities for the dissemination and diffusion of these derivatives was limited only by counterparties' tolerance for finding additional counterparties. In sum, the participants drove the expansion, or unfolding, of the system at a rapid, highly leveraged pace.

Successful start-ups often times are credited with the following characteristics: first mover advantage if it has the requisite expertise; ability to capitalize quickly in a limited market; requiring limited up-front capital. All three can be said of a derivatives fund, as well. Increasingly, the distinguishing characteristic of a derivative from a start-up in this instance is that with a derivative there is a different notion of an end-product; it is perhaps better characterized as a service. It offers an opportunity for regulatory gaming, risk sharing, and tax benefits, for example.

Yet, the first mover advantage, ability to maximize a limited market—and grow into new ones—as well as the limited need for up-front capital,[43] all promote the pace of increasing returns. Because a firm could issue many derivatives, very quickly, all it needed was willing counterparties to gain first mover advantage. Little wonder, then, that the top derivatives issuers remain in existence, despite the collapse of AIG, Merrill Lynch, and Lehman Brothers.[44] Because regulators kept relaxing net capital standards—and especially because the Federal Reserve has relaxed collateral standards in face of financial collapse—derivatives issuance is limited only by a given firm's appetite for risk and confidence in

[42] Waldrop, *supra* note 8, at 37.
[43] *See, e.g.*, the Net Capital Rule, as revised by the SEC in 2004.
[44] *See* Appendix.

its counterparties' ability to pay. From 2002 to 2007, when U.S. monetary policy created optimal conditions for derivatives, the effects of increasing returns are crystal clear, and by their very nature, inherently complex. Figure 1 illustrates these increasing returns and provides the same data for U.S. options contracts to illustrate that increasing returns are not automatic for complex financial products, particularly those subject to similar monetary and fiscal policies. Thus, there is something special about credit derivatives that created these increasing returns.

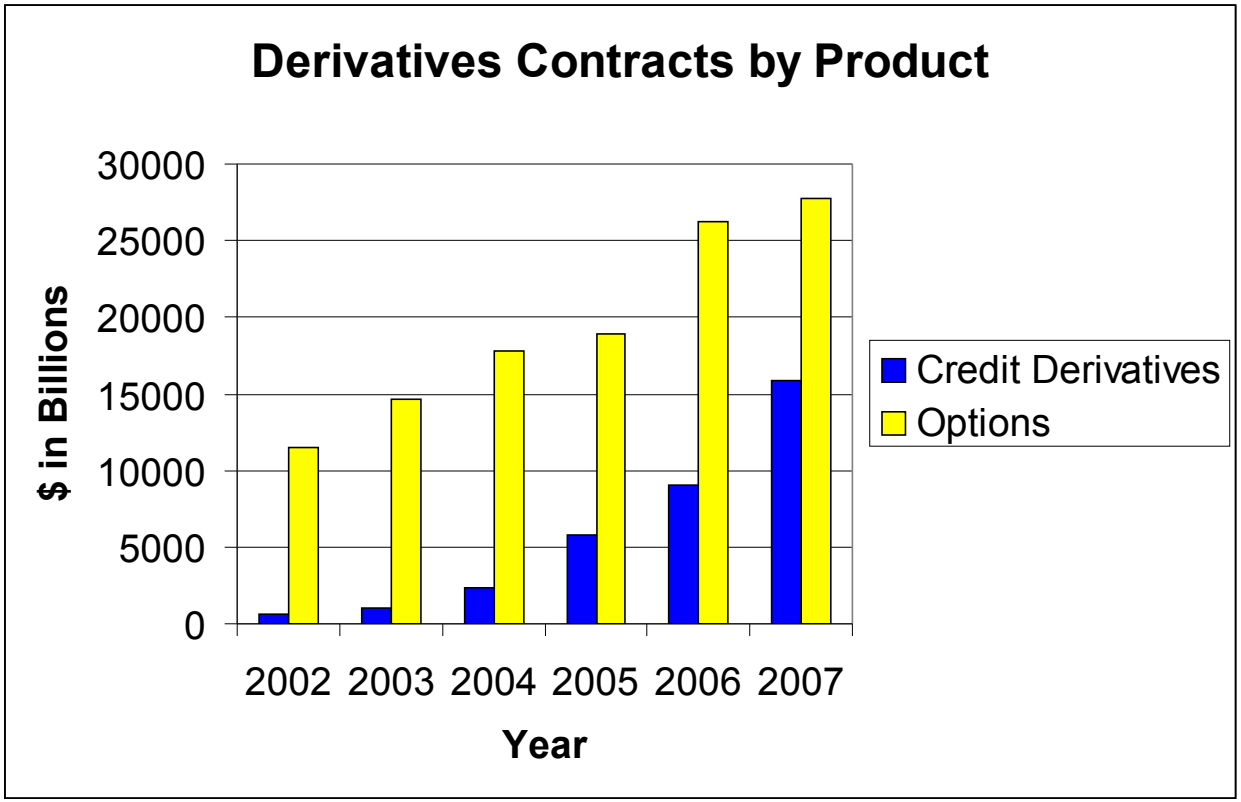

Figure 2 Derivatives Contracts by Product, 2002–2007[45]

[45] Office of the Comptroller of the Currency, Quarterly Report on Bank Trading and Derivatives Activities, Second Quarter 2008, 9.

When both the tech start-up and the derivatives-dependent entities fell off the "edge of chaos," one key question became: What keeps bubbles aloft? In the start-up, it was stock options—holders could only benefit by increased stock prices, yet arguably lost nothing if prices sank since they were only "rich on paper." In the current crisis, the same lopsided incentives existed for banks that could sell overvalued financial products with "little downside risk."[46] In both cases, one would think that investors who were able to synthetically short both tech stocks and bank stocks would have been able to escape the bubble. Yet, in the tech bubble—unlike in the current crisis—this was not the case.[47] Battalio and Schultz propose that the lack of effective synthetic shorting is a result of the lack of knowledge of the overpricing.[48] Unlike in the current crisis, market participants in a position to short were not aware of the overpricing. By contrast, say what you will about the current crisis, but this was not a mistake that Goldman Sachs and others repeated, and the increasing returns effects of derivatives issuance was part of the reason for this.

IV. Network Effects:

By increasing derivatives use throughout the market, new participants (and their capital) are able to access new or previously unavailable capital allocation and risk management techniques.[49] In other words, new participants and old participants are able to share risk and capital. The more participants are engaged in the market, the more types and larger amounts of capital and risk are available.

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[46] Julia Homer, *Op-ed: It Takes a Bubble*, CFO Magazine (March 2008).
[47] Robert Battalio & Paul Schultz, *Options and the Bubble*, 61 J. of Fin. 2071, 2073 (2006).
[48] *Id*.
[49] Rob Hamilton et al., *Innovation and Integration in Financial Markets and the Implication for Financial Stability*, *in* The Structure and Resilience of the Financial System, 226, 232, 237 (2007) [hereinafter Hamilton et al. (2007)].

Diffusion may come at a cost, though. First, information premiums may be introduced, such as by new market participants who are not sufficiently financially literate may introduce costs into the system.[50] Third, where the influx of new participants results from price changes, there may be other participants who are forced out due to price pressures.[51] Second, diffusion leads to increased interconnection of risk, contagion and complexity, discussed in Part B, Social Welfare Losses.[52]

A. Liquidity

Network effects are most evident in terms of liquidity. The more common a particular derivative is, the more easily it can be traded. The more participants are involved in derivatives markets, the more easily derivatives can be traded. On an individual level, retail investors may be able to manage risk associated with retirement investing, home ownership, and other concerns to allow for financial smoothing and access not previously possible.[53] Larger parties with greater risk burdens or capital requirements are able to spread those needs out across a much larger market.

Some derivatives seem to be created with little other purpose than to directly increase market participation, such as synthetic hedge funds marketed specifically to retail investors.[54] Other derivatives leave the realm of normal finance as they are adopted outside of the capital markets,

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[50] *See id.* at 230-236.
[51] Laurent Calvet et al., *Financial Innovation, Market Participation, and Asset Prices*, 39 J. Fin. & Quant. Analysis 431 (2004) [hereinafter *Calvet et al. (2004)*].
[52] *Id*.
[53] *See id.* at 230, 232, 236.
[54] Steven M. Davidoff, *Paradigm Shift: Fed. Securities Regulation in the New Millennium*, 2 Brook. J. Corp. Fin. & Com. L. 339, 342 (2008) [hereinafter *Davidoff (2008)*].

such as options on sports tickets.[55] This democratization of finance allows for greater allocation efficiency and integration throughout all structures of capital and risk.

A more liquid market allows for more accurate pricing of an asset. The monitoring costs of a particular reference asset can be spread out among multiple derivatives holders. This allows information to be more quickly and efficiently incorporated into the price of both the derivative and the underlying asset.

Indeed, at a certain point, a derivative becomes so common that it can be traded as near money, a kind of pseudo currency. Recall that paper money developed originally into a reference note freely exchangeable with an underlying asset: gold. Similarly, the majority of derivatives were originally exchangeable, physically settled, for their underlying assets. Today, the more common form of derivatives, so-called "cash settlement" derivatives, are priced based on a particular reference asset but paid out in cash, without the requirement of any party possessing the underlying asset. These derivatives may be more akin to the common notion of currency, now that the dollar has left the gold standard.

At the other end of the spectrum, there are negative network effects associated with liquidity. Limited market participation can amplify the effect of liquidity trading, such that a small liquidity shock can cause significant price volatility.[56] In a market with few parties, it may be difficult to determine what the fair price for an option is. More noticeable though, may be the network effects of contagion.

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[55] Arun Muralidhar et al., *Options on Competitive Events: A New Application of the Theory of Options to Consumption of Goods by Individuals*, 9 DERIVATIVES USE, TRADING & REGULATION 246, 246-47 (2003) [hereinafter *Muralidhar et al. (2003)*].

[56] Franklin Allen & Douglas Gale, *Limited Market Participation and Volatility of Asset Prices*, 84 AM. ECON. REV. 933, 933 (1994) [hereinafter *Allen and Gale (1994)*]

B. Contagion

At a certain point, too much market exposure to a particular derivative may have adverse consequences. Derivatives are linked to contagion, the likelihood of a financial crisis in one market to spread to other markets.[57] Contagion, also considered a situation where numerous parties' become exposed to each other's risks, may lead to decreased liquidity and the risk of crises.

As derivatives increase in popularity and use, more parties are exposed to derivatives—and thus the balance sheets of their counterparties—and each party pools more and more exposure upon itself. At some point, the parties may fear an event of default in one party would result in the insolvency of its counterparties. This may make parties less likely to trade, decreasing market liquidity. Liquidity problems of individual banks can lead to systemic risk if the central bank is unable to prevent systemic repercussions[58] One small bank in Asia may collapse, affecting another party and then another. At some point it reaches a tipping point, and the entire market collapses.[59]

Consider also an example where parties use derivatives to hedge their individual risk. Each party then becomes contractually linked to their counterparty, until all parties equally share in all risks. This may be detrimental to welfare.[60] Because of the effects of contagion, although all risks are shared equally, the event of particular low-chance risks may bring down all parties simultaneously, instead of sinking one party individually. Thus, contagion is known to increase the risk of crises.[61]

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[57] Donald Lien & Mei Zhang, *A Survey of Emerging Derivatives Markets*, 44 Emerging Markets Fin. & Trade 39, 39 (2008).
[58] Xavier Freixas et al., *Systemic Risk, Interbank Relations and Liquidity Provision by the Central Bank*, 32 J. Money, Credit & Banking 611, 611 (2000) [hereinafter *Freixas et al. (2000)*].
[59] Alex Blumberg, *Unregulated Credit Default Swaps Led to Weakness*, NPR, All Things Considered (Oct. 31, 2008) *available at* http://www.npr.org/templates/story/story.php?storyId=96395271.
[60] Franklin Allen & Elena Carletti, *Credit Risk Transfer and Contagion*, 53 J. Monetary Econ. 89, 89 (2006) [hereinafter *Allen and Carletti (2006)*].
[61] *Id*.

Homogeneity may also lead to contagion. As parties become more similar, they may jointly become more susceptible to certain risks. Even without creating extensive contractual linkages between parties, the mere fact that the parties are engaged in the same activity, derivatives trading, makes them more homogenous.[62] While the act of derivatives trading may allow a firm to diversity its holdings, systemically it lowers the diversity of the market.[63]

If only a few parties are trading derivatives, then the direct effects of those derivatives are contained to the involved parties. The less complete the market's banking structure is, the less vulnerable to contagion it is.[64] Nevertheless, banks may choose to accept the risk of contagion if that risk appears to be manageable.[65]

C. Transparency

The lack of transparency in the derivatives markets can lead to several problems. Calculating investment strategies without having all necessary information may make the use of derivatives prohibitively risky. This is particularly true concerning a lack of information regarding counterparty risk, such as not knowing who the derivative's counterparties are and not knowing a potential counterparty's total derivatives exposure.

First, a derivative may be sold and shuffled among several parties. After several transactions and sales of the contract, and due to poor regulatory oversight and lax recordkeeping, the ultimate payor in the event of default being long forgotten. This creates significant problems in

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[62] Wolf Wagner, *The Homogenization of the Financial System and Financial Crises*, 17 J. Fin. Intermediation 330 (2008) [hereinafter *Wagner (2008)*].
[63] *See id.*
[64] Augusto Hasman & Margarita Samartin, *Information Acquisition and Financial Contagion*, 32 J. Banking & Fin. 2136, 2146 (2008) [hereainfter *Hasman and Samartin (2008)*].
[65] *Id*.

the event payment is required. Furthermore, this may result in contracts being very difficult to restructure should a counterparty require the terms of the contract to be changed.

Second, a lack of transparency in the OTC derivatives market can make the total exposure of a potential counterparty to derivatives contracts would be difficult (if not impossible) to determine. Not only will a party not know the total value of exposure of a potential counterparty, the various firms and derivatives to which the potential counterparty is exposed may be unknown. Not knowing the total exposure of a potential counterparty can lead to significant problems.

In order to prevent loss on an individual derivatives transaction, parties may require more assurance that their counterparties are not overburdened and overexposed to the derivatives market. As more and more parties are exposed to derivatives, and each party pools more and more exposure upon itself, parties will require some form of insurance against the event of counterparty default. In the beginning of the current financial crisis, this manifested itself through counterparties' insistence on heightened collateral standards for collateralized debt, loan, or mortgages obligations (CDOs, CLOs and CMOs, respectively)—at least until the Federal Reserve relaxed the standards for what types of collateral satisfied these standards in September 2008. Yet a form of insurance also may manifest itself in terms of increased transaction costs, such as increased premium within the cost of the derivative itself.[66] As transaction costs increase, parties will be less willing to trade in derivatives, decreasing liquidity. Consider such a scenario as a tipping point of fear, where at some point all parties refuse to engage in transactions with each other.

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[66] *See* Jefferson Duarte & Christopher S. Jones, *The Price of Market Volatility Risk*, 32-33 (Oct. 28, 2007) [hereinafter *Duarte and Jones (2007)*] available at http://ssrn.com/abstract_id= (suggesting a volatility premium in prices).

Other external costs may be manifested from opacity of derivatives transactions. In the lead up to the current crisis, because banks were unaware of the optimal level of credit hedging, they were incentivized to fully hedge their lending exposures.[67] When lenders are fully covered for any losses on lending, they no longer have any important incentives to monitor borrowers.[68] Without incentives to monitor, banks began loaning money to parties who were incapable of paying back the loans, increasing the risk of default across the market.

Furthermore, parties may actually fear engaging in any transactions with other parties.[69] For example, Party A may fear that Party B has a significant exposure to derivatives which reference the default of Party A as a payment event.[70] At some point, Party B may actually have enough exposure to such derivatives that Party B would be incentivized to ensure Party A defaults. Party A may avoid contracting with Party B, to avoid giving Party B any legal rights that may allow Party B to induce the default of Party A.

Indeed, some have argued that if all parties had known the exposures of their counterparties in the chain, we would not be in the current financial crisis.[71] Knowing counterparty risk would have allowed banks to protect themselves from the market contagion, preventing both idiosyncratic and systemic failures.[72]

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[67] Alan Morrison, *Credit Derivatives, Disintermediation, and Investment Decisions*, 78 J. Bus. 621 (2005) [hereinafter *Morrison (2005)*].
[68] *Id.*
[69] *See* Alex Blumberg, *Unregulated Credit Default Swaps Led to Weakness*, NPR, All Things Considered (Oct. 31, 2008) *available at* http://www.npr.org/templates/story/story.php?storyId=96395271.
[70] *See id*.
[71] *Id*.
[72] *Id*.

D. Regulatory Challenges

One of the major challenges presented by derivatives is their regulation and control. Issues arise not only from regulation by the government, its authorized self-regulatory organizations like the Financial Industry Regulatory Authority (FINRA), but also by customs and standards set by non-governmental industry organizations, such as the International Swaps and Derivatives Association (ISDA), and the counterparties enforcing the contracts. These problems arise because of the size of the derivatives markets, the number of derivative types available, and the pace of innovation.

First, the derivatives market is, and has for a long time been, too large and too private to effectively regulate and control.[73] The resources necessary to merely observe all derivatives transactions may be prohibitive at this point. The daily notional volume of derivatives transactions is currently in the tens of billions, and many banks fiercely protect the privacy of such transactions from outside scrutiny. Regulators simply have not had sufficient resources to monitor the entire market of derivatives transactions. To expect full enforcement on top of monitoring would be impossible at this point.

Second, derivatives markets are comprised of a wide variety of contracts. Aside from the plain-vanilla futures and options, derivatives have been developed to reference more sophisticated assets and events, such as weather and catastrophe.[74] Regulators may not have sufficient expertise to understand the underlying references of the financial instruments.[75] Moreover, regulators may be incapable of understanding the intricate financial models and payout rules required for the derivatives to function properly. Finally, even if regulators were capable of

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[73] *See* Davidoff (2008), *supra* note 54, at 354 (citation omitted).
[74] *Id*. (citation omitted).
[75] *Id*. at 355.

understanding several derivative types, this would still represent only a fraction of the available derivative contracts, and the regulator may not fully comprehend how the contracts interact. Frankly, the integrated markets of derivatives contracts with their underlying assets may be too complex for anyone to fully comprehend. Thus, the effective regulation of the markets may be impossible

Third, the rate of innovation in the derivatives markets is simply too fast for regulators to keep up.[76] For every new regulation that is created, a new derivative will be constructed to avoid it.[77] Regulators will forever be one step behind financial innovation, particularly to the extent regulation is "rule- rather than principle-based."[78]

This means that a broad base of opportunity is available for financial innovators. On the one hand, without regulatory interference, derivatives traders have free reign to create narrowly tailored investments that help solve financial problems, such as risk management, for their clients. This freedom to contract can allow the entrepreneurial derivatives trader to develop a particular derivatives transaction, sell it, and move on to another future investment opportunity.

On the other hand, this leaves counterparties and their investors very vulnerable. Without regulatory oversight, the derivatives market can exact severe externalities on outside markets, as evidenced in the aftermath of the subprime mortgage defaults. At some point between the development and the adoption of new derivative contracts, regulators must be able to step in and prevent potential systemic market damage.

V. CONCLUSION

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[76] *Id*.
[77] *Id*. (citing Lawrence A. Cunningham, *A Prescription to Retire the Rhetoric of "Principles-Based Systems" in Corporate Law, Securities Regulation, and Accounting*, 60 VAND. L. REV. 1411 (2007)).
[78] *Id*. (citing Cunningham, *supra* note *77*).

We have shown how complexity theory offers a refreshed explanation of the rise of derivatives and its relation to the current financial crisis. By re-examining the distinct use and spread of derivatives in terms of increasing returns, coupled with how derivatives have adapted to traditional notions of bubble economics to permit participants to promote and then ride out the burst bubble's effects, the implications for network effects are significant.

Issues of liquidity, transparency, contagion, and regulatory approaches acquire new urgency for those who seek to regulate and limit the potentially harmful effects of derivatives while still fostering their beneficial ones. Conversely, for those firms who have mastered a first-mover strategy, decreased opacity and limited contagion may signal the need for new derivatives and strategies, providing another opportunity for derivatives to adapt and for their use to self-organize again in different, dynamic forms.

While it remains to be seen whether participants and regulators truly require a transformation of the derivatives markets in the wake of the financial crisis, to date we are unaware of any congressional testimony or public discussion among key decision makers that explicitly consider the effects of complexity theory or Brian Arthur's notions of "new economics." Yet, it is impossible to fully appreciate the pace of innovation and the adaptive capacities of derivatives as they affect global finance without some notion of "the edge of chaos."

APPENDIX: NOTIONAL AMOUNT OF DERIVATIVE CONTRACTS
TOP 25 COMMERCIAL BANKS AND TRUST COMPANIES IN DERIVATIVES
JUNE 30, 2008, $ MILLIONS

Rank	Bank Name	State	Total Assets	Total Derivatives	Total Futures (Exch Tr)	Total Options (Exch Tr)	Total Forwards (OTC)	Total Swaps (OTC)	Total Options (OTC)	Total Credit Derivatives	Spot FX
1	JPMORGAN CHASE BANK NA	OH	$1,378,468	$91,287,215	$1,324,845	$2,577,403	$8,177,168	$58,955,659	$12,401,876	$7,850,264	$342,892
2	BANK OF AMERICA NA	NC	1,327,429	39,671,792	1,934,850	690,507	3,833,388	26,777,854	3,724,655	2,710,538	184,098
3	CITIBANK NATIONAL ASSN	NV	1,228,445	37,132,353	264,052	364,061	4,655,682	21,462,142	7,176,738	3,209,678	385,635
4	WACHOVIA BANK NATIONAL ASSN	NC	670,639	4,447,446	227,045	141,116	162,932	2,982,131	548,606	385,616	25,852
5	HSBC BANK USA NATIONAL ASSN	DE	177,466	4,063,104	76,396	67,438	440,213	1,955,046	283,785	1,240,227	56,836
6	WELLS FARGO BANK NA	SD	503,327	1,515,920	275,709	16,466	470,655	563,095	187,757	2,238	18,278
7	BANK OF NEW YORK	NY	130,062	1,049,529	36,416	13,469	278,978	354,211	364,778	1,677	31,594
8	STATE STREET BANK&TRUST CO	MA	138,859	837,209	1,215	498	758,977	19,815	56,467	238	43,724
9	SUNTRUST BANK	GA	171,501	268,822	53,951	30,246	15,649	130,387	35,485	3,104	520
10	PNC BANK NATIONAL ASSN	PA	128,348	210,693	25,241	13,200	6,573	132,303	28,025	5,352	1,790
11	NORTHERN TRUST CO	IL	65,200	184,177	0	0	172,357	11,007	559	254	36,250
12	MELLON BANK NATIONAL ASSN	PA	39,476	183,003	0	0	151,648	29,659	1,695	0	23,354
13	KEYBANK NATIONAL ASSN	OH	98,048	136,697	22,261	0	13,580	84,291	7,852	8,714	1,468
14	NATIONAL CITY BANK	OH	151,165	110,748	9,058	250	12,944	42,859	43,230	2,408	250
15	U S BANK NATIONAL ASSN	OH	242,308	87,448	945	5,000	21,011	49,943	8,379	2,170	1,017
16	REGIONS BANK	AL	139,354	80,155	13,591	4,000	1,238	59,364	1,678	283	4
17	BRANCH BANKING&TRUST CO	NC	132,884	63,524	4,296	0	7,852	43,764	7,560	52	44
18	MERRILL LYNCH BANK USA	UT	58,042	59,567	34,125	294	749	15,253	0	9,146	0
19	RBS CITIZENS NATIONAL ASSN	RI	132,051	57,625	0	0	4,645	51,931	815	234	61
20	FIFTH THIRD BANK	OH	67,272	55,976	37	0	6,526	37,618	11,483	313	1,296
21	UNION BANK OF CALIFORNIA NA	CA	60,228	35,486	786	0	3,927	19,177	11,596	0	1,204
22	LASALLE BANK NATIONAL ASSN	IL	68,379	34,601	0	0	4	24,271	8,506	1,820	0
23	UBS BANK USA	UT	27,316	34,160	0	0	0	34,160	0	0	0
24	DEUTSCHE BANK TR CO AMERICAS	NY	46,071	33,887	0	0	361	26,646	1,683	5,197	0
25	LEHMAN BROTHERS COML BK	UT	6,418	28,086	10,845	0	0	17,241	0	0	0
	TOP 25 COMMERCIAL BANKS & TCs WITH DERIVATIVES		$7,188,756	$181,669,224	$4,304,818	$3,923,948	$19,207,902	$113,879,825	$24,913,209	$15,439,522	$1,156,168
	OTHER COMMERCIAL BANKS & TCs WITH DERIVATIVES		2,741,623	466,209	8,253	2,754	61,040	290,553	74,328	29,281	1,155
	TOTAL COMMERCIAL BANKS & TCs WITH DERIVATIVES		9,930,380	182,135,432	4,313,071	3,926,702	19,268,942	114,170,378	24,987,537	15,468,802	1,157,324

Note: Before the first quarter of 1995 total derivatives included spot foreign exchange. Beginning in the first quarter, 1995, spot foreign exchange was reported separately.
Note: Numbers may not add due to rounding.
Data source: Call Reports, schedule RC-L.
Note: Credit derivatives have been included in the sum of total derivatives. Credit derivatives have been included as an "over the counter" category, although the Call Report does not differentiate by market currently.
Source: Office of the Comptroller of the Currency, Quarterly Report on Bank Trading and Derivatives Activities, Second Quarter 2008, 21.