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The real estate crash of 2007-8 as a systemic failure

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Abstract. This article considers the 2007-8 real estate market as a complex adaptive system. The article begins with a discussion of its perception of a system. Given that definition, system elements are reviewed. Agents include mortgage holders, lending institutions of a variety of forms, insurers, and regulatory agencies. The focus is on the US with some comparison to the UK and Canada. This system was affected by economics with heavy governmental influence. A market that had been highly stable for decades reacted very negatively to the influences of financial engineering seeking to take advantage of expedient opportunities. The complex interactions of financial and governmental actors led to the apparent (and most likely temporary) disappearance of many paper fortunes, as well as leading to the demise of some established banking institutions and foreclosure of many homes in certain areas. Conversely, Canadian real estate markets had less relaxation of regulation, and experienced fewer risky mortgages. The evolution of the real estate system from a systems perspective is described, with analysis of interactions among actors.

Keywords: Complex adaptive systems, financial systems, real estate, bubbles

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1. Introduction

The current population of the United States has grown up with what seemed to be a steady and reliable increase in value of homes. Owning one's own home is one of those signs of success in a prosperous culture. The governmental/banking system in the United States evolved to allow residents to hold mortgages on homes, giving the perception that they owned their own home. This ownership state depended upon their keeping tax payments and mortgage payments current, as the mortgage holders actually owned a portion of the home, and taxing entities had the right to seize homes for which taxes weren't current. But the perception of home ownership provided a sense of responsibility and hope of financial gain with rising real estate price.

This wasn't always common. In the 1930s many people lost title to their homes during one of the greatest failures of human economic systems known. In response, banks and mortgage lending were regulated, bank deposits insured up to a level covering what most people had, and stock-trading practices ostensibly controlled. While very old people could remember a time when the price of housing would drop, with the inevitable passage of life, this group was smaller and smaller and older and older and less relevant. There were anomalies in local areas where, for whatever reason, home prices might negatively fluctuate. Reinhart and Rogoff described five such

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anomalies, all associated with banking crises (Spain in 1977, Norway in 1987, Finland and Sweden in 1991, and Japan in 1992) [1]. But house price decline occurred very rarely, and nobody really noticed.

There also was a strong feeling that less regulation was always better. Ronald Reagan became the champion of the conservative class. He rode this popularity to the presidency with a conservative preference for less government interference. Even when Bill Clinton became president, his economic regulation did not vary that much from that of conservatives. Many of the regulations imposed during the 1930s were overturned in an effort to let the market run free, which was expected to lead to a golden age of prosperity.

The Efficient Market Hypothesis (EMT) held that asset prices are always and everywhere at the correct price, a view that fits well with the concept that that economy is regulated best that is regulated least [2]. Financial service companies developed many tools that became popular during this period. Investors prospered during the 1990s, none more than Long Term Capital Management (LTCM). LTCM was built on the financial models of Black, Scholes, and Merton, providing tools to price derivatives. Billionaires who could afford to buy into LTCM made billions [3, 4].

But human economic activity consists of a complex interaction of many actors, some more exuberant about prospects than others. On average, for every buyer there is a seller, and the idea of a stable equilibrium seems reasonable, human history is full of periods where a market will go crazy and drive prices beyond reason. These periods are known as bubbles. Consider the following:

1630 Tulip mania
1720 The Mississippi Company
1720 The South Sea Company
1929 Stock Market Crash

These are only four of many economic crashes, all preceded by excessive rapid growth [5]. There are many studies of these bubbles. Something triggers expansion, followed by rising prices, overtrading, mass participation, followed by some event triggering doubt, a subsequent selling flood, and ultimate collapse. The 1990s saw the crash of LTCM, demonstrating that theoretical models do NOT cover everything, that every model leaves something out, and life is more complex than anyone understands. Trade in technical stocks made the NASDAQ highly popular, but it also demonstrated a bubble, crashing the confidence of the world of computer techs around 2000.

2. Systems

Systems are broadly defined in common usage as a group of elements acting in concert to accomplish some purpose. There are many kinds of systems, to include governmental systems, economic systems, mechanical systems, etc. [6]. There have been different views of systems with varying degrees of popularity over the decades [7]. The hard systems view is represented by a management science perspective (including EMT), avoiding subjective components and seeking to reduce complexity by focusing on decomposable system parts to enable solution to particular problems [8]. This hard systems view focuses on engineering problems, where subjectivity plays little role.

But there is a recognition that human interaction is influential in many systems [9]. This led to soft systems approaches, emphasizing the social and cooperative element in efforts to achieve consensus and continuous improvement [10]. Forrester [11] and colleagues provided feedback modeling systems able to take subjective assumptions of complex societal systems, enabling predictions of long-range system performance, with results limited by the subjective input assumptions [12]. Yet a third strain of systems definition comes from the recognition that rationalistic views overlook the autopoetic aspects of living beings as autonomous systems [13]. Autopoesis was defined as a network of processes of components reproducing through interactions and transformations. Autopoietic systems are capable of creating and maintaining themselves.

In contemporary terms, there is a wider recognition that life is non-linear, involving many complexities involving feedback mechanisms leading to unintended consequences [14]. Nonlinearity is manifested in complex behavior in terrorism, where rationalist efforts at control have resulted in greater spread of the problem, as well as in the subject real estate system in 2007-8 [15]. Ramo concluded that adaptive systems were needed, with greater resilience. The more densely linked a system, the less resilient. Greater security in such systems was to be gained by learning to view systems holistically, with truth identification obtained through study and reflection.

3. Complex adaptive systems

This article looks at the real estate industry as a system. The complex adaptive systems (CAS) view

Table 1
2008 Real estate systemic features

Elements	Components
Agents	Actors – homeowners, mortgage lenders, investment banks, insurers, regulators, policy makers
Interaction	Resources and activities
	Financial, information, marketing, risk management
Autonomy	Relative degree of independence in operation
Learning	Knowledge exchange and development

looks at behaviors and effects of system elements to include system evolution over time in a non-linear fashion, with self-organization when faced with threatening change. The CAS view examines intertwined relationships among system elements, sometimes cooperative, often competitive. CAS system components include the following bubbles:

- Elements – agents, with different degrees of autonomy, interacting and learning.
- Behaviors – co-evolution and self-organization when faced with challenges.
- Effects – adaption that is often non-linear and/or irreversible.

Table 1 shows Holland's [16] characteristics of systems features in the real estate market.

Originally, homes were owned by those who could build them. With wealth accumulation, especially in England, vast estates could be built at the discretion of owners with means. In the more primitive United States, settlers could build their own homes, with land ownership on the frontier encouraged through the Homestead Act of 1864, but in urban areas tenements prevailed over individual homes. In the 20th Century a more inclusive system emerged both in the United States and in England, with a savings and loan system emerging to enable workers to slowly save up to the point that such institutions would cover the cost of home mortgage, and the subsequent mortgage paid off over decades.

As part of the New Deal, the Federal National Mortgage Association (FNMA) was created in 1938 to buy mortgages from lenders, with the intent of allowing lenders to make additional home loans. FNMA was supplemented by the Federal Home Loan Mortgage Corporation (FHLMC) in 1970 to expand the secondary mortgage market. In 1989 both of these agencies were privatized as part of the Reagan Era emphasis on privatization. Similar agencies and encouragement of privatization occurred in England under the leadership of Margaret Thatcher.

Thus home mortgages expanded markedly, and were encouraged during the Clinton administration through making it easier for people to obtain home loans. The second Bush Presidency continued the Clinton encouragement of expanded home mortgages. Michael Lewis [17] has documented numerous cases where individuals with little means took the opportunity to leverage multiple home loans during the first few years of the 21st Century.

This system could have benefited from adaptive system features. There was feedback among agents, but lack of learning (some due to the pace of events). We would argue that the primary culprit was the removal of accountability. The governmental agents (across administrations from both parties) had the noble goal of increasing the prospect of home ownership by making mortgages easier to obtain. The banking system evolved from a very regulated system created in the 1930s through aggressive savings and loan operations in the 1980s to a new era in mortgage banking in the 2000s, utilizing on-line mortgage lenders pushing mortgages regardless of ability to repay, which were then sold on to investment bankers looking for financial instruments that they could push on investors seeking high returns with governmental guarantees. These investment bankers in turn offloaded their risk to insurers. A new environment was created where none of the agents really knew what the relationship between action and outcome was going to be. Thus this wasn't so much a complex adaptive system, as a system out of control. The only ones who learned were those who were able to exploit the system to reap large profits at the expense of others.

3.1. Systems theory and finance

Systems theory is a well-developed field [18], extending ideas arising from biology and other sciences to provide valuable concepts found useful in business [19] as well as social systems [20]. Adaptation is a major element of adaptive systems

theory [21]. Complex adaptive systems are viewed as having a life of their own, labelled autopoeisis [22]. Financial markets consist of many agents that could participate at a number of levels, with new sources entering through market competition.

Complex adaptive systems of this type are thus said to exhibit emergent behavior [23]. The butterfly effect is used to describe emergence within complex systems, implying that the output of a collection of interacting objects in a complex, nonlinear system evade precise modeling [24]. System development is viewed as one-way, or irreversible, following the arrow of time [25]. System elements interact through feedback. We note that feedback by itself is not a sufficient condition to define a truly natural, societal human system that is not simply a deterministic, hard system. But the idea is that understanding object relationships can lead to better understanding at the macro-level, and might lead to better prediction and control (if nonlinearities don't make precise modeling impossible).

4. Real estate in 2007

Financial events were traumatic in the 2007-2008 period, with massive impacts that still linger. This bubble was caused by a complex real estate system with nonlinear features that led to many unintended consequences arising from the interactions of a number of specific agents. Table 2 (graphically displayed in Fig. 1) shows the steep increase in dollar value of US mortgages peaking in 2003, but continuing high until 2007, when they steeply declined.

Table 2
Mortgage Dollar volume in the US in $Millions

Year	Government-backed Single-Family	Conventional Mortgages
1990	$77,929	$380,513
1991	$63,592	$498,482
1992	$64,899	$828,767
1993	$94,853	$925,009
1994	$142,354	$630,767
1995	$71,036	$568,394
1996	$106,915	$678,414
1997	$103,642	$755,478
1998	$148,530	$1,301,470
1999	$175,695	$1,134,304
2000	$118,906	$929,094
2001	$170,814	$2,044,186
2002	$188,061	$2,696,939
2003	$234,301	$3,710,699
2004	$132,564	$2,787,437
2005	$87,120	$3,032,879
2006	$84,622	$2,895,378
2007	$99,028	$2,330,972
2008	$281,369	$1,218,606
2009	$441,165	$1,373,836
2010	$368,070	$1,202,011

Source: www.fhfa.gov/DataTools/Downloads/Pages/Current-Market-Data.aspx.

Conversely, the smaller government backed mortgage volume correspondingly rose in compensation. The role of deregulation seems apparent in comparing US and English real estate results with those

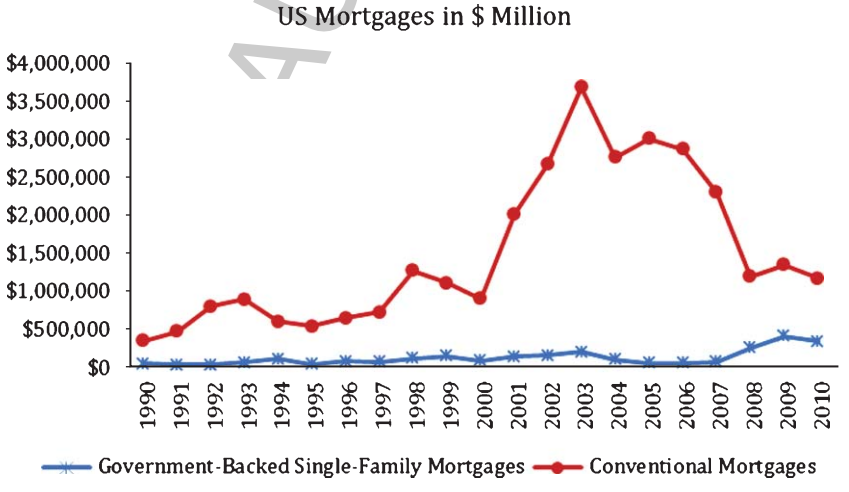

Fig. 1. Graph of US Mortgage Dollar Volume.

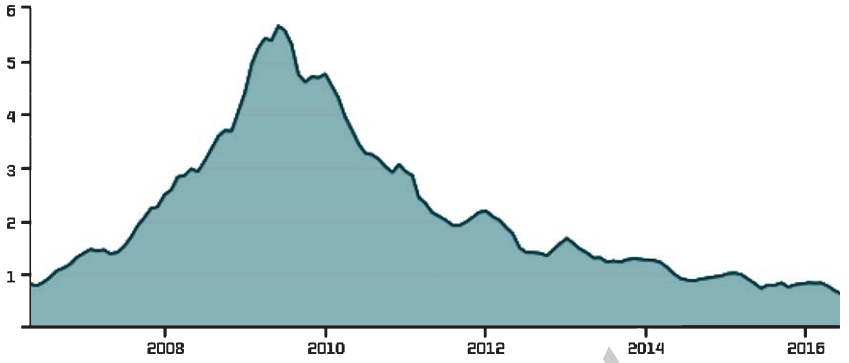

Fig. 2. S&P/Experian First Mortgage Default Index – 2006 through 2015. Source http://us.spindices.com/indices/specialty/sp-experien-first-mortgage-default-index.

of Canada, who retained many of the real estate regulations of eighty years prior [26]. There also were notable differences in the US between the high-population high-growth coasts than in the interior. We will review the US home market, sample a representative real estate case in England, and look at AIG, the insurer at the end of the chain of investment.

Investors still held great confidence in some safe sectors of the economy, such as real estate (as safe as houses). Risk managers created new tools intended to make investment safer. Derivatives are securities or contracts deriving value from an underlying natural security, such as a stock, a bond, or a mortgage [27]. While derivatives provide some security through diversification, their primary attraction is that they enable high degrees of leverage.

4.1. US home market

The crisis is credited with beginning with the collapse of the US subprime residential mortgage market in 2007, which spread throughout the world due to exposure to US real estate assets through financial derivatives [28]. Figure 2 displays the radical change in the market, showing default rates in first mortgages. Causes could be the growth in asset securitization, US government initiatives to expand home mortgages (thus encouraging less loan restrictions), expansionary monetary policy, and weaker regulatory oversight [29]. The real estate price boom was furthered by financial institution exploitation of loopholes in capital regulation, allowing them to significantly increase leverage while remaining within required capitalization. Mortgage derivatives allowed investment in riskier and non-liquid assets funded in wholesale markets without sufficient capital backing. This, along with high dependence on a short-term view, along with lax regulatory oversight, has been credited with inducing the collapse of the bubble in 2008 [30, 31]. Distress first appeared in 2007 with losses by US subprime loan originators and those holding derivatives based upon such mortgages.

There were individual agents who exhibited learning, or at least understanding. John R. Paulson made a fortune shorting CDOs. Goldman Sachs also came out of a period with high profits, in an environment where other investment banking firms like Lehman Brothers went under, and insurance giant AIG (which took the other side of Goldman Sachs's insurance) lost heavily. The banking system internationally faced challenges. In late 2007 losses by Northern Rock [32], a UK mortgage lender, indicated that the bust was going global.

Wiseman [33] outlined four stages in a real estate cycle, with corresponding activities (see Table 3):

This cycle leads to fortunes as well as flops, as players in the real estate market (see agents in Table 1) create paper money out of air, and exchange this paper money for real estate.

4.2. English real estate

England also underwent a conservative, deregulatory movement in the 1980s. One of the more noted real estate cases in England concerns Northern Rock. The Northern Counties Permanent Building Society was established in 1850, serving Newcastle upon Tyne. The Rock Building Society was established in 1865. Both were building societies, merging into Northern Rock. Northern Rock was a mutually owned

Table 3
Real estate cycle (based on [33])

Phase		Characteristics
Peak	Boom	Government raises interest rates to cool economy
		Consumer confidence high
		Higher demand for goods and services
		Aggregate supply near aggregate demand
		Adequate housing inventory, home prices stable
		New home starts and real estate activity stable
		Bank-owned inventory and foreclosures low
		Low vacancies, high rental prices
		Speculators overvalue properties
Contraction	Bust	Restrictive and expensive credit financing
		Decreased consumer confidence, declining consumer demand
		Aggregate supply > aggregate demand
		Housing inventory builds as sales decline
		Home prices start to decline
		New home starts decline
		Banked-owned inventory and foreclosures increase
		Commodity based properties (farmland) decline
		Competition declines, speculators sell off
Trough	Bust	Government lowers interest rates to stimulate
		Consumer confidence low, supply > demand
		Excess housing inventory, low sales level
		Home prices stabilize at low levels
		New home starts low
		Bank-owned inventory and foreclosures high
		Vacancies high, rental prices low
		Speculators tend to undervalue properties
		Buyer's market
Recovery	Boom	Easy, cheap credit
		Increasing consumer confidence
		Increasing consumer demand for goods and services
		Aggregate supply > aggregate demand
		Demand for housing exceeds inventory
		Commodity based business properties peak in value
		Home sales increase
		Home prices increase
		More new home starts
		Bank-owned inventory and foreclosures decrease
		Vacancies decrease, rental prices rise
		Prices rise, speculators buy
		Seller's market

savings and mortgage bank. The Building Societies Act of 1986 allowed building societies to convert to public banks. This allowed access to wholesale money markets. Northern Rock went public in 1997, enabling it to sell shares on the stock market. It borrowed on capital markets, lent this money to customers, turned the loans into bonds, and sold the bonds.

Sampath wrote about the organizational risk in reputation, using Northern Rock as a case in point [34]. Basel II addressed operational risk, credit risk, and market risk. In a Pillar 2, it mentioned strategic risk,

Table 4
Northern rock events extracted from [36]

2007	Event
25 Jul	Northern Rock issues optimistic outlook
9 Aug	BNP Paribas suspends three investment funds with subprime mortgages
13 Aug	Northern Rock informs regulators of funding difficulties
14 Aug	Bank of England alerted of Northern Rock difficulties
4 Sep	Money market problems increase, LIBOR reaches 9 year peak
12 Sep	Bank of England announces it would support banks through short-term loans, but not massive injection of funds
13 Sep	BBC reveals Northern Rock asked for, will receive BOE aid
14 Sep	BOE and others reveal Northern Rock will receive help, lines queue at Northern Rock
17 Sep	After stock market close, British Government announces guarantee of all Northern Rock deposits in turbulent period
19 Sep	BOE announces injection of liquidity into money markets, extension to mortgage debt
20 Sep	Government guarantee extended to unsecured wholesale funding
9 Oct	Government guarantee extended to new retail deposits

Table 5
Key events for AIG (extracted from [37])

Date	Event
11 Feb 2008	AIG announced write down of $4.88 billion in CDSs
15 Sep 2008	AIG reported to be seeking $40 billion in capital to avoid downgrading by credit rating firms
17 Sep 2008	Fed authorized loan of $85 billion to AIG, giving Government 79.9% equity in AIG and veto power over dividends, to be repaid in 24 months
9 Oct 2008	Fed authorized bailout package of another $37.8 billion in securities in exchange for cash collateral

reputation risk, and non-standard risk, but these last three categories of risk have no specific capitalization provisions. This is because there is less data available and this makes it difficult to quantify exposure. Sampath argued that Northern Rock demonstrated failure in management of these less quantifiable risks.

Northern Rock's difficulties in obtaining short-term funds were not due to its lending practices, but rather to the systems inability to provide funds. This in turn was due to the subprime mortgage issues of 2007. Events are outlined in Table 4:

While Northern Rock did not make subprime loans, they were vulnerable in a market where housing values were in decline. Because they were overleveraged, they suffered the first bank run in Great Britain in over a century.

Northern Rock failed strategically. They shifted away from their traditional market of mutual mortgage lending, seeking perceived higher profits in broader lending. Sampath attributes their troubles to underestimation of reputational risk which jeopardized public confidence. Restrictive and sharp practices destroyed their credibility and reputation, and they were hit with a run that was withstood only through Bank of England intervention.

4.3. AIG

AIG is the world's largest insurance company. It began in China. In 1926 it opened operations in the U.S. to write insurance on American risks outside the U.S. AIG started to buy American insurance companies in the 1930s [35]. It became very large, and by the time of the real estate crisis in 2007, this had a bearing on the risk AIG was exposed to. On paper, it could say that it had offloaded some risk to a reinsurer. However, since it owned the reinsurer, the risk was retained [37].

Starting in 1999, AIG and its subsidiaries issued a large number of CDSs. These provided a very strong revenue stream for the firm when market conditions were stable and there were low default rates. A feature of CDSs purchased by AIG from investment banks were credit support annexes, standard contracts attached to swap agreements mandating that the instrument be marked to market price nightly. The investment bank was buying insurance that the CDS

would not fall below a certain value. Checking every night made it more likely that AIG would have to pay off the swap [35]. Events related to the 2008 real estate crisis are shown in Table 5:

While AIG made a lot of money issuing CDSs before 2008, investment banks took the opportunity to purchase many CDSs that paid off in 2008. In fact, they purchased more CDSs than the value of the underlying mortgage assets. By 16 September 2008 AIG was in severe difficulty, its stock down to $3.75 (it had been $63.44 a year earlier) [37]. The failure of AIG has been attributed to high-leverage trading, just as with large banks such as Lehman Brothers and Bear Stearns [38]. Other problems cited were lack of transparency with respect to the risk of CDSs and CDOs, adverse selection in that investment banks knew more about the risks associated with the coverage they purchased from AIG than AIG did, and the high magnitude of unhedged CDOs held by AIG ($562 billion) without hedging. The issue with unhedged CDOs was complicated in that the conventional expectation is that they are naturally diversified, but the mortgage markets upon which they were based turned out to have a highly correlated downward trend.

5. Systems perspective of 2007-8 real estate

5.1. Mortgage system

With deregulation, the mortgage industry became more specialized, with a number of organizations playing a role in the overall system. Lenders such as Green Tree Finance led the charge to issue as many mortgages as possible (mobile homes in the case of Green Tree, Ameriquest, Countrywide, Golden West and others for conventional homes) [39]. These mortgages were sold to banks and other investment agencies, so the mortgage initiators had little concern other than generating lots of mortgages and making a living off of fees. In fact, many home mortgage holders saw the inevitable rise in home value to be an opportunity to make a financial killing by leveraging as many home loans as they could, making purchases for speculation rather than for residence. The purchasers of these mortgages often combined various tranches of different levels of perceived risk, with higher interest rate mortgages associated with higher probability of loan failure. This evolved into the convolution in logic that marginal borrowers, who had no choice but the highest interest rates, were preferred customers. These instruments were sold to investors.

Meanwhile, these banks often covered their risk through CDSs. Collateralized mortgage obligations (CMOs) are certificates built from tranches of mortgage-backed securities. Thus it is a tranched instrument of an instrument that is already tranched. A collateralized debt obligation (CDO) is similar, but can be based on any kind of debt, not just mortgages [40].

5.2. Recapitulation of events

We contend that this system started with the commendable societal desire on the part of politicians of both ends of the spectrum to first, make government less intrusive and possibly more efficient through deregulation. In the mortgage banking field, regulations were loosened, allowing savings and loan institutions to move into conventional banking, and vice versa. Banks were also allowed to trade paper, and mortgage granting companies would contact their borrowers to ask them to refinance when interest rates dropped, something unheard of before the mid-1980s. There also was a desire to expand home ownership to as many people as possible. This was the case both with the Clinton Administration as well as with the subsequent Bush Administration. Similar initiatives were present in England. (Canada had less deregulation.)

On the technical side, e-business took off, with a slight bump around 2000 with the dot-com bubble when over-exuberance reined in excessive rush to go on-line. The financial field saw e-business boom, with on-line mortgage institutions making a living by closing loans quickly, selling them on to other banks (including investment banks). Organizations such as Quicken Loans would saturate advertising media with opportunities for more people to purchase homes. While these lending institutions still did credit checks, changes in regulations biased credit ratings toward growth in riskier loans. There was the intended increase in home mortgages, as well as up-grades in home amenities, but there also were unintended increases in speculation. Investment banks in turn utilized this free market to create new and attractive investment products, such as collateralized debt obligations (CDOs). These products combined a number of securities together with the intent of lowering risk through diversification.

In the housing market, loans offered to marginal borrowers might involve some risk, but while some might default, most were not expected to. CDOs combined securities into tranches, with various levels of a product having different levels of risk.

Furthermore, investors had some confidence that the government would not stand by and see massive evictions of mortgage defaulters, thus providing an added level of protection to investors should the unforeseen worst happen. Since capitalist investors often feel that greed is good, they often sought the greatest expected return which was generally associated with the highest risk. Thus there was a rather strong market for CDO tranches with high risk. Since these investment products could be fungibly traded, risk could further be off-loaded to insurers, such as AIG, who saw insuring CDOs as a source of premiums that were never expected to have claims. This system was further complicated by the role played by rating agencies. Moody's, Fitch, and S&P had once been the clients of purchasers, and were noted conservatives. Deregulation included assigning their payment to the providers of investment products, which could only be expected to induce them to be more liberal in rating investments.

When housing inflation continued, there was no problem. Home mortgage holders had nicer homes, and there were more of them. Speculators made money as real estate prices rose. E-mortgage firms made more loans, and they generated revenue from each closing. Investment bankers had more product packages to offer investors. Investors had a great time, as they could obtain high returns on CDOs that they felt would never fail, partially because real estate values always increased, partially because if they didn't the government would protect them. In effect, risk was perceived to be guaranteed by the government. Insurers such as AIG were happy to collect premiums by insuring as many CDOs as Goldman-Sachs could create (which incidentally grew to exceed the value of the underlying mortgages). Systems evolution in this market is categorized in Table 6:

In Table 6, agents in all seven categories listed experienced failure. As with any turbulent economic period, there were winners and losers. But most lost. Self-organization and emergence was insufficient. Government actions to control the system failed. Depending upon one's political leanings, some argue that the system was saved, while others noted that banks were flooded with capital to loan, but that they didn't loan these funds. Thus while there was system change from bank deregulation, and even autopoesis in the emergence of electronic mortgaging and CDOs, the complexity of the system eluded intelligent control. Had housing prices continued to rise, as they had for decades, possibly this can could have been kicked down the road to the distant future. But economic systems are cyclical by nature, and market prices go up and they go down. The system was not prepared for the drop. The drop itself could be viewed as an outcome of overaggressive mortgage lending to those

Table 6
Real estate market systems evolution

Systems Concept	CAS element	Housing system
Autopoeisis		Bank deregulation
		CDO evolution
Internal mechanism	Agents	Home borrowers
		Mortgage lenders
		Investment banks
		Rating agencies
		Investors
		Insurers
		Regulators
	Self-organization and emergence	Bank deregulation
		E-lending
		Evolution of CDOs
	Connectivity	E-business
		Government bailout
	Complexity	CDOs
		Moral hazard
Environment	Dynamism	Housing prices
Co-evolution	Nonlinear change	Regulatory unexpected consequence
		Rating agency behavior

who had no reasonable means of repayment. History is replete with bubbles in market systems. Whenever there is overinvestment in something, there is a natural systemic control mechanism in the form of bubble bursting [41].

6. Conclusions

Complex system features of the 2008 real estate bubble include *agents*: homeowners, mortgage initiators, banks, investors, insurers, and regulators (to include agencies designed to control this market such as FNMA). *Interaction* occurred in a process, with regulators attempting to provide a market where fairness prevailed, encouraging citizens to own homes. Mortgage holders initiated mortgages from various sources, most through mortgage initiators. The e-business environment includes many e-mortgage operators, such as Quicken Loans, who advertise heavily to encourage people to obtain loans quickly. These mortgage initiators do not have much reason to critically assess applications, as they collect their fees and sell the paper on to banks. Mortgage notes worked their way up to investment bankers, who packaged mortgages with risk ratings into innovative products such as CDOs which they then marketed to investors seeking greater return. Because of the climate where investors perceived government guarantees of the system, higher risk ratings were perceived as reasonably safe higher returns. Some investment bankers also had the foresight to insure their CDOs, creating credit default swaps (CDS) leaving insurers such as AIG holding the risk. But AIG and their fellow insurers perceived this as free premiums without expectation of ever having to pay (whoever heard of housing prices falling!). The process blew up when real estate markets on the coasts of the US (as well as in England) dropped. This system demonstrated lack of systemic control, needed for a successful complex adaptive system.

Autonomy was demonstrated by the mortgage holder pool, which included not only single-family purchasers of mortgages, but also many speculators, some of whom had no reasonable basis for expectation of paying back the mortgage. Mortgage initiators were driven by the desire to collect fees which would be maximized by encouraging as many loans as possible – they didn't worry about risk because they sold the paper. Banks took risky paper and combined them with other safer mortgages into CDOs and other innovative instruments, which they unloaded to investors and insurers. The system was driven by greed that was perceived to involve little risk, because first of all, house prices were expected to rise, and secondly, government agencies were present to bail them out if problems arose. In retrospect, it seems like a system bound to fail. But housing prices really had demonstrated prolonged ability to continue to rise, so it was not really that irrational.

There doesn't seem to have been that much *learning* in this system. Regulators thought that they could correct the system by providing banks lots of money, although there is every evidence that the banks took the money and sat on it (the learning induced behavior with unexpected consequences for government regulators). E-mortgages seem to be every bit as pervasive as they were.

We began with a discussion of systems. Hard systems take a hierarchical, causal view of the world. Government agencies and investment banks may have thought that the real estate mortgage system of the early 2000s was a hierarchical system that they could solve, but clearly they were wrong. There is much about the human interaction in social systems that defy hard system quantification enabling control through known cause-and-effect. Furthermore, due to evolving group behavior in markets, what worked in the past might well not work now. This market clearly was a social (soft) system. Such systems are things that we cope with, not effectively control. Our conclusion is that it is not a complex adaptive system defined to the extent that feedback control is possible.

Thus we must conclude that the 2007-2008 housing bubble and collapse displays systemic features. However, it was a failed system. Whatever learning occurred was on the part of a few, who reaped large profits at the expense of the many. Government again exhibited ineffectual response, with no apparent mastery or understanding of cause and effect. Markets are social systems controlled by crowds, at least occasionally demonstrating their ability to avoid central control. Better understanding of systems may eventually give us the insight to understand such systems (but it is doubtful that they can be mastered by central control).

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