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Dysfunctional markets: A spray of prey perspective

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Dysfunctional markets: A spray of prey perspective

ABSTRACT

We revisit the theory of financial crises using a predator-prey metaphor, highlighting the relationship between greed, risk aversion and debt accumulation and aggregating concepts from economics, finance and psychology. We argue that regulations that are implemented inefficiently, with weak enforcement or at the wrong time can have deleterious effects on the market, worsening the ailment they initially intended to correct and leaving a spray of prey in their wake. To illustrate our hypothesis, we examine the role of regulations in the years leading up to and during the Global Financial Crisis (GFC) in the U.S., when the Federal Reserve tried to restrain the over-heated housing market fuelled by the predatory mortgage frenzy and the increased use of securitization in risk-hiding financial tools such as Collateralized Debt Obligations (CDOs). Our results indicate that deleterious government interventions may act as a chemotherapy of sorts, causing harm followed by a slow recovery. This understanding can help governments draft better regulations to lower market frictions and better protect investors.

Key words: risk aversion; predation; regulations; contagion; debt trap

JEL: G01, G18, G21, G40, H31, H63

1. INTRODUCTION

Deleterious effects of economic policies have long been known (Bordo, 2008). As an example, in 1925 English Prime minister Stanley Baldwin reinstated the gold standard (a decision immediately criticized by Keynes), which caused unemployment, inflation and in the end harmed all of Europe. In its wake and in 1931, panic set in, especially in Austria and Germany, with large bank runs set off by consumers (Kindleberger, 1996).

Since the earliest days of financial markets, there have been examples of market crises around the world. See, for example, the Dutch-based Tulipomania in Holland in the 17th century, the Mississippi Bubble in France in the 18th and the U.S. savings and loans fiasco in the 1980's (Kindleberger, 1996; Rajan, 2010). Certainly, from the 17th to early 20th century, the absence of proper regulatory institutions endangered financial stability, but this vulnerability has since then been alleviated with, for example, the creation of the Federal Reserve in the U.S. in 1913 (Grossman & Meissner, 2010). Yet the dubious management of government-sponsored enterprises (GSEs) such as Fannie Mae and Freddie Mac cannot be ignored (Calomiris & Wallison, 2008)[1]. In the same vein, Samuel (2009) notes that the Great Depression was followed by unprecedented government regulations and the creation of the Securities Exchange Commission in the 1930s, but these measures proved ineffective during the 1980s' savings and loan debacle.

The 2007-2009 Global financial crisis (GFC) crisis offers the most recent example of government failure, one that damaged the confidence of consumers, communities, and businesses (K. J. Brown, 2010; Sama & Shoaf, 2005; P. Wallison, 2009)[2]. The market acted as a pressurized container that sprayed its toxicity over time, covering an ever-increasing

[1] Wallison and Pinto (2010) argue that the Dobb-Frank Act allowed the substitution of the Federal Housing Administration (FHA) by Fannie Mae and Freddie Mac as the main provider of subprime mortgages. By their estimation, the U.S. government sponsored no less than 27 million subprime mortgages.

[2] The U.S. government is not the only one at fault. Authors note that other governments have had failures as well (Glaeser & Shleifer, 2001).

range of victims, hence the name "spray of prey" (Carroll, Otsuka, & Slacalek, 2011). Indeed, the market can be seen for what it was: many sellers acting as predators, using subprime (predatory) mortgages to trap their prey (customers) in order to obtain financial gain. This type of behavior we define as toxic as it potentially leads to market failure (Akerlof & Shiller, 2009).

As opposed to the Market Efficiency Hypothesis (Fama, 1970) and similar economic theories (e.g., Adam Smith's invisible hand) that assume market agents act in good faith and for the benefit of the overall market, we adopt a paradigm by which we assume that some market agents - sellers and buyers included - are motivated by self-interested, hidden agendas, in line with the concept of predation and one that can affect the collective unconscious (see Carl Jung in Roudinesco and Plon (2000)). As such, for the sake of our framework, we focus on predatory behaviors, those framed by moral hazard and deceit, leading to market toxicity. Subprime or "predatory" mortgages and other such financial products were part of a financial arsenal of securitization meant to hide risk, which were by nature toxic and served as a trap to catch non-vigilant/distracted/ill-prepared buyers or prey. A detailed list of such products and behaviors can be found in Appendix 3. The notion of predator-prey dynamics has been used in economic science in the past, although sparingly (Dejuàn & Dejuàn-Bitrià, 2018; Ditzen, 2018; Henry, 2012; Samuelson, 1971; Zhang, 2012).

During the GFC, the U.S. housing market had roughly seven million loans worth USD 1.2 trillion in circulation, out of which subprime or predatory mortgages made up 23.5% at their peak in 2006 (Frame, Lehnert, & Prescott, 2008). Consumer debt accumulated and ballooned, forcing countless delinquencies and foreclosures (of which nearly 50% were predatory loans – Albanesi, De Giorgi, and Nosal (2017)), up to a value of USD 250 billion, or 2% of U.S. GDP[3]. Debt from housing purchases was accompanied by other forms of debt, for example expenses linked to house repairs and furniture, bought on credit cards (Case,

[3] U.S. Census Bureau (https://www.census.gov); World Bank (https://data.worldbank.org). Accessed Feb. 1, 2019.

Quigley, & Shillder, 2005; Elul, Souleles, Chomsisengphet, Glennon, & Hunt, 2010; Guiso, Sapienza, & Zingales, 2009). In addition, many buyers purchased new cars within two years of buying a new home (Mian & Sufi, 2015).

On the corporate side, losses skyrocketed: 43 billion USD for Citigroup, 38 for UBS, 37 for Merrill Lynch, 20 for HSBC, 10 for JP Morgan Chase, 8 for Lehman Brothers and the Deutsche Bank, and 6 for Barclays[4]. All of the largest U.S. market players were affected: Lehman Brothers was forced to close, Bear Stearns and Merrill Lynch sought new owners, and Morgan Stanley and Goldman Sachs transformed into bank-holding companies (BHCs).

The Financial Crisis Inquiry Commission (2011) and the International Monetary Fund (2009b) blame in part the U.S. government's interventions as the source of the crisis through the promotion of risk-free and easy credit (Fostel & Geanakoplos, 2012), low interest rates, weak enforcement, and lax controls.

Root GFC causes that have been identified are many and varied, yet not focused on richer analyses than standard assumptions. (See, for example, Appendix 3, which outlines the fact that hidden, potentially toxic agendas may have been at play in the markets.) They range from policy-driven to agent-driven factors, with the former actually encouraging toxicity in the marketplace and the latter linked to psychological forces such as deceit, biases[5] and greed.

The crisis had long been in the making (Razin & Rosefielde, 2011). The 1977 US Community Reinvestment Act (CRA) permitted banks to grant credits to unqualified clients, a leniency that was reinforced by the Glass-Stegall Act revision of the mid-1990's (White, 2009)[6,7]. From 2005 to 2007, the Fed's discount rate (main lending rate) varied and increased

[4] Bloomberg. Accessed Feb. 1, 2019.
[5] To that effect, Stiglitz (2009) mentions: "Thus, the notion that markets, by themselves, lead to efficient outcomes has, today, no theoretical justification: no one believes that the conditions under which that statement is true are satisfied."
[6] See also: Hellwig (2009), Reinhart and Rogoff (2009), and Priewe (2010).

from roughly 1 to 5 percent, and, in parallel, housing starts (new houses being built) declined from approximately 2 million to 1.5, and then to 500,000 units in 2010[8]. After 2007, the Fed passed a series of cuts to drive the interest rate close to the zero point (Saunders, Cornett, & McGraw, 2014; Veronesi, 2010)[9]. (See also Appendices 1 and 2 for an outline of the events and regulations before and during the GFC. The latter, in particular, provides examples of the many missed opportunities the U.S. government had to protect consumers ahead of the GFC.) In such a financial ecosystem, lax regulations tend to encourage abuse on the part of lenders and sellers of toxic products, with the net effect of leading the market towards collapse, a situation that benefits neither the regulators, nor sellers, nor buyers.

In addition to the above-mentioned policy-driven causes, the following also appear in the literature: (1) the voluntary registration of the U.S.-domiciled hedge funds (S. Brown, Goetzmann, Liang, & Schwarz, 2009); (2) financial liberalization (Kaminsky & Schmukler, 2003); (3) financial imbalances across advanced economies (Acharya & Richardson, 2009; B. S. Bernanke, 2009; Obstfeld & Rogoff, 2009); (4) the absence of protection or affordable legal recourse for victims (Ferguson (2012), Appendix 1); and (5) the compression of long 10-year yields *versus* the short-term yields on 3-month Treasury securities (Merrouche & Nier, 2010).

In summary, events indicate that the choice to avoid regulations is a policy in and of itself. A no-government intervention policy is a policy, and we posit that such policy may have had deleterious effects on the economy as proven by the build-up to the GFC.

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[7] The Glass-Steagall Act meant to separate commercial from investment banking, developed to fight the Great Depression.

[8] Federal Reserve Bank of St. Louis (https://research.stlouisfed.org). Accessed February 1, 2018.

[9] From June 2004 to June 2006 rates rose steadily from 1.00% to 5.25%, and then stood still for a year. The Federal Reserve began lowering its rates in September 2007. While the interest rate was set in large part to target inflation (Saunders, Cornett, & McGraw, 2014; Veronesi, 2010), as a consequence it certainly encouraged borrowing. By December 2015 the target rate was between 0.00-0.25%, the lowest in the Fed's history, at least in part resulting from the aftermaths of the GFC. See https://www.federalreserve.gov/. Accessed June, Sept., Dec. 2019, January 2020.

This paper posits that, albeit little use has been made of multidisciplinarity in the financial theoretical field, resorting to concepts borrowed from biological ecosystems and medicine can rightfully serve to express the dynamics of troubled markets. The name "predatory mortgages", after all, indicates that the thought of such use already exists.

In the second section of this paper, we lay out our key assumptions with respect to modelling the GFC from a predator-prey perspective. We present our conceptual model framework in the third section and indicate the most important links between key variables. In the fourth section, we examine the implications of our proposed model. The final section makes recommendations on how our model can be exploited for drafting economic policies.

2. KEY ASSUMPTIONS

Current models explaining the GFC point to the need for a new approach, one capable of rendering what happened during the crisis in a way that can more effectively explain its mechanics as well as better forecast future market upheavals. However, resorting to such comparisons requires a better grasp of the natural forces behind market movements. We would argue that these forces include predator-prey relationships between sellers and buyers of housing mortgages, which necessarily involves perceived risk and risk aversion, toxicity, traps and utility maximization[10]. In our proposed model framework, we attempt to balance simplicity and complexity and focus on five core variables: sellers of predatory mortgages, buyers of predatory mortgages, regulations (interest rates), toxic products (predatory mortgages), and debt. To achieve this, we make a number of assumptions (Samuel, 2009):

[10] We are using the phrase 'utility maximization' to refer to market agents acting in their own self-interest. Although our framework could be used to analyze traditional utility maximization problems, it includes psychological constructs such as deception, greed, and fear, which often violates assumptions of mainstrain economics (Huck, Mavoori, and Mesly, 2019).

(1) We posit that one of the government's main concerns is to minimize household over indebtedness by controlling interest rates, and we assume that consumers respond to government interventions (Feldstein, 1980). Governments are seen as benevolent entities, which prioritize the welfare of its citizens (Lysandrou, 2013). In industrialized countries, they thus endeavor to stay within sustainable levels of national and personal debt (Fincke & Greiner, 2011). Yet, the context of our model is a buoyant U.S. market where predatory mortgages (and other risk-hiding tools such as Special Purpose Entities, a process generally called securitization) engage greedy buyers and astute sellers, all willing to maximize their profits in the shortest time possible. We focus on interest rates because, unlike other types of government regulations, they are effective, easy to measure, and straightforward to implement.

(2) The market is composed of four market variables: two policy-driven (stock) variables – interest rates and predatory mortgages – and two agent-driven (population) variables – sellers and buyers of predatory mortgages. Regulations act as predators to toxic products; namely, subprime or predatory mortgages. Our research suggests that there existed for the U.S. subprime crisis, Lotka-Volterra predator-prey relationships between these market variables (Brady, 2017; Lotka, 1920; Volterra, 1928), as follows (Table 1, Figure 1):

Table 1 – The four markets variables (agents)

	Predators	Prey
1st pair (agent-driven)	Sellers of predatory mortgages	Buyers of predatory mortgages
Proxy	Ratio of shadow to traditional banking	1- (% of foreclosures)
2nd pair (policy-driven)	Regulations	Predatory mortgages
Proxy	Interest rates set by the Federal Reserve	Ratio of predatory to total mortgages

In ecology, populations of predators (such as foxes) and prey (such as hares) are known to follow Lotka-Volterra equations (Edelstein-Keshet, 2005; Gotelli, 1995). In their simplest form, Lotka-Volterra equations link the populations of predator and prey together via an interaction term to describe how the levels of each population fluctuate with the rise and fall of the other. In our framework, we associate sellers of predatory mortgages as predators and potential buyers of such products as prey, and attempt to show that they in fact follow similar dynamics. As for the predatory mortgages, they are the result of the interaction between predators and prey. They can be thought of as "caught" prey. Similarly, regulations are meant to curve predatory behavior and in their wake the rise and presence of the number of predatory mortgages. As they become effective, they negatively impact the number of predatory mortgages and facilitate the survival and growth of the prey. Hence, patterns in regulations could be thought of as a predatory interaction exerted on sellers of subprime mortgages. We provide a more detailed explanation of Lotka-Volterra equations and their connection to financial markets in Appendix 4.

Market data suggest that the government responded in part via a delayed response to the increase in predatory mortgages (Figure 1). As the number of sold predatory

mortgages increased, the number of sellers of predatory mortgages kept increasing even when the number of sold products diminished, as is typical in Lotka-Volterra (LV) predator-prey dynamics (Appendix 4). As the predatory mortgages' teaser rates came to an end (with a lag effect), buyers in vast numbers realized how much debt they had actually taken on, while the number of sellers of predatory mortgages decreased.

Figure 1 – Market data suggesting Lotka-Volterra trends in the U.S. market

Notes: The curve "predatory mortgages" was calculated using actual predatory mortgages that existed in the U.S. market. We posit they are toxic products. The government responded to these by increasing interest rates to reduce the capacity of buyers to borrow money. However, buyers who had purchased predatory mortgages found themselves unable to pay as their grace period came to an end. Thus, foreclosures followed. All curves were built from market data, adjusted to emphasize their tendencies through exponentiation, and standardized to allow comparisons.

Figure 2 highlights the effects of the government intervention. That is, even though the Federal Reserve increased interest rates and buyers reduced their investment in real estate, surprisingly, debt kept mounting. The nature of the predatory mortgage (adjustable interest rate, higher payments several years after the initial purchase) led to the delayed burst of foreclosures and debt, and decline in owner equity. In other words, even though the number of predatory mortgages was declining by 2006, when the purchasers of the previous years' mortgages were hit with the adjustable interest rate (see the parallel increase in the Fed's interest rate) and higher payments it led to the delayed increase in foreclosures and decline in owner's equity going into 2007-2009. In other words, by controlling the interest rate while aiming to be benevolent, the government actually acted as a super-predator of sorts at the top the financial ecosystem.

(3) The basic nature of sellers and buyers' interaction is predatory (Besanko, Doraszelski, & Kryukov, 2014). In any natural ecosystem, predator and prey populations reach an equilibrium that theoretically guarantees the survival of both agents (Bonsall & Hassell, 2007). The market is prime for manipulations: sellers want to take advantage of naive prey, which are blinded by the appeal of easy money, unknowingly locking themselves in a debt trap (Seyfert, 2016). This is equivalent to neglecting risk, which in turn encourages security issuance (Gennaioli, Shleifer, & Vishny, 2012).

(4) The U.S. government's interventions during the GFC primarily targeted debt accumulation. Past a certain level, the debt-to-disposable income ratio becomes unsustainable as consumers are assumed not to be able to pay off their debt, and the economic system collapses. For the government, too large a household debt means less tax revenues, so that debt is actually a threat to the government;

Figure 2 – Owners' equity and debt

Note: Debt kept mounting despite disinvestment of buyers in the housing market. This is due not only to interest rates but also to the delayed effects of predatory mortgages. Government intervention initially exacerbated the problem, much like chemotherapy initially makes the patient worse off before improvement.

(5) Buyers are motivated by greed but also fear a possible debt trap, assuming they are able or willing to realize that it exists. All buyers of predatory mortgages assess their risks, yet they are vulnerable due to (in)voluntary blindness to risk (Keltner & Gross, 1999; Kunzmann, Kappes, & Wrosch, 2014);

(6) U.S. home buyers during the GFC exhibited little financial product diversification, focusing mostly on houses bought in their local neighborhood and making themselves

more susceptible to market hazards. This tied them down financially and geographically, reducing their opportunities to escape the claws of a predatory market;

(7) The market system exists as a series of spillover effects (feedback loops) between the different variables and agents. For example, sellers of predatory mortgages adjust their behavior based on the level of government intervention (or lack thereof), buyers of mortgages base their decisions to buy mortgages based on interest rates and risk, and the Federal Reserve analyzes market changes and reacts by adjusting interest rates.

(8) A market characterized by excessive frictions that cause debt to accumulate without ceasing except through exceptional government intervention is assumed not to be sustainable.

3. THE GFC USING A PREDATOR-PREY MODEL

There has been a number of economic models trying to explain financial crises and the banking system, including those of B. Bernanke, Gertler, and Gilchrist (1996), Bayoumi and Melander (2008), Gennaioli et al. (2012), Gennaioli, Shleifer, and Vishny (2013), and Brunnermeier and Sannikov (2014). We do not challenge the validity of the various models but complement them with a predator-prey perspective based on dynamical systems analysis. Many of these models emphasize utility maximization; this maximization, however, is implicitly considered in the interaction between predators and prey. In ecology prey attempt to maximize their utility while remaining vigilant against harmful outcomes. The end effect of such scenario is that complete extinction of the market is rare: predators and prey, being mutually dependent, must both survive no matter how toxic the markets are. Crises are one of the many possibilities by which markets can behave. Frictions-free markets imply stable cycles with repeated patterns; frictions-loaded markets imply unstable cycles with stochastic

forces. In either case, the coevolution between predators and prey illustrate this type of market dynamics. Of course, a predator-prey analysis necessarily resorts to populations (or aggregates) whereas other models focus solely on utility maximization, the assumptions of which has been challenged by various authors (Boland, 1981).

We now present our conceptual model, which again, is meant to be a mere simplification of reality. Our core model is as follows (Figure 3).

Figure 3 – The GFC as a predator-prey phenomenon

Notes: Sellers and buyers of predatory mortgages interact in typical predator-prey fashion. Debt is a stock that can accumulate, but a high rate of reimbursement can overcome the influx of indebtedness. Interest rates are stocks of which the accumulation is conditioned by market frictions; however, the more efficient the interest rate is at curbing debt, the less there is a need to adjust interest rates. Innovation in predatory mortgages boosts the opportunity to hide risk in toxic products while high interest rates and tougher regulations discourage the buying (and selling) of these products, making them obsolete.

Governments have many tools at their disposal to steer the economy in a targeted direction[11]. Specifically, interest rates are effective levers, easy to measure, and are straightforward to implement. Increases in interest rates are fuelled by market frictions and by debt, in particular. However, sound regulations drive the market towards more efficiency, and as the market becomes more efficient, fewer regulations are needed. It is worth clarifying that we are not claiming that the Fed's discount or interest rate is meant solely to curb predatory behaviors. Rather, it is one way that the government can regulate inflation, unemployment, and debt, among other objectives. When the market overheats (at times due to excessive

[11] Specifically, these include threats, collusion, resources control inclusion withdrawal, false information, easy credit, incentives, lawsuits, and regulatory agencies (Djankov, Glaeser, La Porta, Lopez-de-Silane, & Shleifer, 2003).

predatory financial behaviors), the Feds may increase the discount rate to discourage consumers and companies from borrowing.

The government wants to minimize the "bathtub" ("aggregate" or "population") of toxic products, including predatory mortgages, by pulling the plug, that is, by accelerating the rate of obsolescence. It therefore enacts tougher regulations to drain the market of toxic products and tricky, risk-hiding financial instruments (Artzrouni & Tramontana, 2014). A deceitful, toxic instrument is one with "terms and conditions that ultimately harm borrowers," as stated by the U.S. Government Accountability Office[12]. Financial product innovation serves the goals of the predatory sellers when they are designed to hide risks and obliviate consumers' vigilance, thus leading them to neglect the danger of a debt trap (DeMarzo, Kaniel, & Kremer, 2007; Gennaioli et al., 2012). We also assume that the government monitors and regulates the household debt-to-disposable income – a point that will be discussed in more detail in the proceeding text.

Sellers of predatory mortgages are motivated by gain, and more precisely, quick profits with minimal risk aversion (Garling, Kirchler, Lewis, & dan van Raaij, 2009). They are considered agent-driven predators. Shiller (2005) describes these agents as follows: "When clever persons become professionals at deceiving people, and devote years to perfect their act, they can put seemingly impossible feats before our eyes and fool us, at least for a while." The "bathtub" of sellers increases when avid sellers enter the market ("rate of sellers' expansion"), and empties as sellers leave the market ("rate of sellers' extinction").

Buyers are prey only if they are deemed in sufficiently good financial health to interest financial predators. Agent-driven predators and prey entertain a Lotka-Volterra relationship. Captured prey are buyers who have purchased a predatory mortgage, which can be approximated by the number of sold predatory mortgages. The "bathtub" of prey increases

[12] Government Accountability Office (https://www.gao.gov/). Accessed June 13, 2017.

when new, potential buyers enter the market ("rate of buyers' expansion"), and empties when eager, highly-motivated and greedy buyers disregard risk and buy toxic products (such as subprime mortgages). We also include the rate at which potential buyers naturally leave the market ("rate of buyers' extinction").

Just like predators, prey are motivated by gain, and more precisely, quick profits. They are characterized by their vulnerability and gullibility, both of which affect the probability of purchasing a predatory mortgage (Frame et al., 2008; Sama & Shoaf, 2005). Researchers have noted that the majority of the buyers were from younger and older age groups (Tongren, 1988)[13,14], with lower levels of education, financial literacy and income (Iacoviello, 2008; Roy & Kemme, 2012), at times suffering psychological impairments (Danis & Pennington-Cross, 2008) and belonging to minorities, including the African American population (Albanesi et al., 2017). For simplicity we consider all sub-populations of people to be within a single group.

The links between the sellers and buyers, as well as the link between regulations and sellers exhibit a Lotka-Volterra dynamics in our framework. Sellers engage in predatory behavior to sell subprime mortgages to potential buyers, with sold predatory mortgages inviting more sellers to join the market. Government regulations (in the form of interest rates) push sellers out of the market, essentially acting as a pseudo-predator on sellers. Interest rates further affect how buyers manage their debt, both in terms of paying off debt but also engaging in new mortgages (rates of "indebtedness" and "reimbursement").

Our model includes two psychological constructs in the prey: greed and the fear of the debt trap. Greed has been expressed in various ways by academics, including the fear of not

[13] Academics have noted that older people are fooled more easily because of cognitive biases (Mather & Carstensen, 2005) or lower capacities (Charles & Piazza, 2009) while younger people are more naïve because they have less experience.

[14] Eighty percent of fraud victims were aged 65 years or more (U.S. Federal Trade Commission, 2001; Yoon *et al.*, 2005).

entering the market on time (Mesly & Racicot, 2018). Greed fuels the rate of indebtedness: consumers borrow more to take advantage of a booming market, ignoring risk. The "bathtub" of debt is emptied when consumers reimburse their debt, providing they have not fallen into a debt trap that leads them towards foreclosure/bankruptcies. The fear (anxiety) related to the latter will motivate buyers to reimburse their debt, of course. As for the fear of the debt trap, this is a more detailed term for the psychological concept of perceived threat, perceived risk or the fear of not exiting the market on time. The equivalent term in finance is risk aversion, which can be high or low: a few bad news are not sufficient to sway the positive outlook of investors (Gennaioli, Shleifer, & Vishny, 2015). In our context, buyers must weigh the fulfillment of their needs against the fear of the debt trap.

The "bathtub" of predatory mortgages changes as a result of the interaction between sellers and potential buyers. It fills in as astute financiers create more sophisticated financial products meant to hide risk and escape regulations ("rate of innovation"), but empties when these products become obsolete ("rate of obsolescence"), because consumers are now guarded against them or government regulations curb their inherent toxicity.

The existence of sold subprime mortgages encourages astute sellers to seek buyers who can afford them while being duped[15]. During the GFC, higher interest rates discouraged sellers because they found it more difficult to make their products attractive to buyers who often must borrow to buy houses. Considering the fact that there was a lag effect during the GFC, the embedded toxicity of predatory mortgages appeared only once the teaser rates were no longer effective, because the grace period (usually one to two years) had expired (Figures 1 and 2). Until this point, though, eager buyers borrowed heavily as motivated by ease of access to credit (Rajan & Ramcharan, 2012) and promptly bought one or multiple houses, the

[15] The toxicity of the GFC ecosystem is exemplified by Razin and Rosefielde (2011): "Richard Bowen, III testified to the Financial Crisis Inquiry Commission that mortgage underwriting standards collapsed in the final years of the U.S. housing bubble (2006-2007). Sixty percent of mortgages purchased by Citicorp from some 1,600 mortgage companies were defective. Clayton Holdings reported in parallel testimony that only 54 percent of mortgage loans met their originators' underwriting standards."

412 sales of which were encouraged by heavy advertising (Ben-David, 2011). Many buyers
413 renovated their houses through credit, hence pushing the selling prices up. As prices
414 increased, more profits were generated, allowing them to keep buying and borrowing by using
415 their assets as collateral (Wachter, 2015).
416
417 House prices rose faster in areas where subprime mortgages prevailed (Pavlov &
418 Wachter, 2011). Greenspan and Kennedy (2008) note that "free cash generated by home
419 equity extraction contributed an average of $136 billion per year in personal consumption
420 expenditures from 2001 to 2006—more than triple the average yearly contribution of $44
421 billion from 1996 to 2000". This phenomenon is not unique to the U.S. or limited to
422 individuals. For example, in Japan, one refers to the "evergreening" or "forbearance lending"
423 practices that precipitated the banking-crisis period of 1996-97 (Okada & Horioka, 2007).
424
425 As for predatory mortgages and a booming housing market, the possibilities of profits
426 increased, as did the household debt-to-disposable income ratio and the eagerness of sellers
427 and buyers to jump on the bandwagon in anticipation of future gains. In this context of self-
428 reinforcing loops, astute financiers developed more sophisticated products aimed at hiding
429 risk, such as Collateralized Debt Obligations (CBOs) and SPEs (Brunnermeier & Sannikov,
430 2014). Of course, the ease of access to credit accelerated the contagion effect (Allen & Gale,
431 2000) and the rising housing prices and in its wake, buyers' indebtedness[16].
432
433 During the GFC, the interaction between the policy-driven and the agent-driven
434 variables created a contagion process (Allen & Gale, 2000; Shiller, 2005). Originally derived
435 in epidemiology to describe the spread of disease, contagion has found its way into general
436 analyses of networks in ecology, sociology, and finance (Albert & Barabasi, 2002; Baggio et
437 al., 2016; Newman, 2003; Rayfield, Fortin, & Fall, 2011). In our context contagion refers to
438 the creation of a positive feedback loop in the selling and purchasing of subprime mortgages

[16] U.S. Financial Crisis Inquiry Commission (http://fcic.gov). Accessed February 1, 2017.

and debt accumulation[17]. This means that only a portion of the financially healthy buyers remained healthy; the remainders were either eliminated from the market (via foreclosures and bankruptcies) or left financially weakened (via arrears and delinquencies). The debt trap links regulators and potential buyers of predatory mortgages. It forms a closed habitat where toxicity can develop exponentially, because the opportunity to escape is non-existent.

In our model, as mentioned, we consider the household debt-to-disposable income as the main motivational force that drives the Federal Reserve's intervention. Indeed, "Financial crises are ultimately related to two problems: insolvency and illiquidity," (Hinds, 2009)[18]. When market agents – whether individuals or institutional – are unable to recover, the government must intervene: during the GFC, this came in the form of the Paulson's plan.

Our framework sheds a different light on concepts such as perceived risk and risk aversion, toxicity, traps and utility maximization. Clearly, as consumers become greedy, they tend to ignore risk just as astute financier are eager to hide risk. Risk aversion is at its minimum in a context where the appearance of financial opportunity is great and ease of credit prevails. This, however, soon leads to a financial debt trap as buyers resort to ongoing borrowing. Maximization of utility implicitly filters through to all market agents. Buyers may choose to ignore or seek risk in order to maximize wealth (even going so far as to present falsified financial reports). Indeed, even though it is to the potential prey's advantage to assess risk and monitor the market, only some chose to search for proper information, being driven by an optimistic profit-making track (Abreu & Brunnermeier, 2003). Obviously, greed is an expression of need, though exaggerated from a normal need (Lewin, 1951). Lenders may deceive buyers or close their eyes on their obvious inability to assume their debt in the near future. Government regulations are put in place specifically to manage the overall

[17] A variety of terms in the literature roughly describe the same phenomenon: herding (Dass, Massa, & Patgiri, 2008), "keeping up with the Joneses" (Dupor & Liu, 2003) or the bandwagon effect (Granovetter & Soong, 1986).

[18] Razin and Rosefielde (2011) cited an erroneous belief that structural deficits promoted accelerated economic growth.

functionality of the entire market. At the same time, our framework extends the notion of utility maximization, relaxing some of the assumptions of neoclassical economics. Psychological constructs such as greed or fear naturally violate assumptions such as stable preferences or rational behavior (Huck, Mavoori, & Mesly, 2019).

4. THE DELETERIOUS EFFECTS OF INADEQUATE REGULATIONS *VERSUS* THE DEBT TRAP

Government policies, when ill-timed, insufficiently robust, or both, can have a deleterious effect on the economy. We showed that the rise in interest rates by the Federal Reserve during the GFC actually harmed a large portion of the population. More particularly, we showed that prior to the GFC government policy encouraged deceptive, predatory (risky) behaviors on the part of sellers (buyers) and that the delayed increase in interest rates during the GFC interacted with the nature of subprime mortgages to propagate foreclosures and nourish debt.

Debt accumulation and servicing have long been at the heart of banking activities and economic systems. The Great Depression and the First and Second World Wars created a series of debt-building and coping mechanisms that influenced the way the entire world evolved. Some argue that the debt incurred by the Germans as part of the First World War reparations set the stage for the Second World War even more decisively than political agendas (Bordo, 2008). With deficits, governments face no other choice but to raise taxes, as did, for example, J.F. Kennedy in 1963 (Bordo, 2008). The deleterious effect of the policy was immediate: instead of stopping the exodus of American dollars, it actually increased the incoming flow of the dollars held outside the U.S., thus aggravating the American deficit. President Johnson would only worsen the situation by inciting voluntary limitations of foreign investments.

In our model, the debt trap results from the problematic interaction between regulators and potential buyers of predatory mortgagees. The debt trap forms a closed habitat where toxicity can develop, because the opportunity to escape is nul. The only way to solve an unsustainable debt problem is through strong government intervention (Cantamutto & Ozarow, 2016). As can be seen from Figure 3, our model mixes monetarist, financial fragility and business cycle approaches, which are traditionally used in analyzing banking crises (Bordo & Meissner, 2012). It takes the position that debt accumulation revels in weaknesses in the financial and banking system (Benmelech & Dvir, 2013). Indeed, academics have noted that, "Overall there is a strong positive relationship between real credit growth and the probability of having a banking crisis" (Bordo & Meissner, 2012). Once individuals or banks cannot reimburse their debt, it becomes a debt trap, which, economically, we consider to be the worst ailment possible.

To make matter worse, studies on consumers' habits show that about 26% of home buyers choose to default on their mortgage, thus increasing their debt load (Guiso et al., 2009). In the same vein, Elul et al. (2010) find that mortgage default risk increases over a percentage point per quarter for homeowners with 80% utilization rate on their credit card. In short, debt invites debt. In the U.S., the household mortgage debt-to-consumption ratio rose from approximately 2.5 to 4.5 between 2000 and 2007, only to decline sharply to 3 by 2015. During that same entire period, the ratio of housing rent to consumption decreased from roughly 0.08 to 0.07. As for the ratio of consumption-to-income, it rose from 0.90 to 0.94 at the peak of 2005, and reached 0.87 in 2015. Mortgage debt grew, and grew nearly twofold for prime mortgages from 2001 to 2008 and by a bit less than twofold for predatory mortgages (Albanesi et al., 2017). The government intervened but, in the process, put countless borrowers against a wall. This resembles chemotherapy treatments; initially, they cause great harm on the body but in the process, allow it to get rid of cancerous cells and recover.

With increases in housing-related debt come increases to other related debts accumulating expenses (Carroll et al., 2011; Case et al., 2005), such as automobile-related

debt – consumers generally buy a new car within two years of buying a new house (Mian & Sufi, 2009). In fact, data suggest that cumulative defaults kept rising between 2005 and 2009 even though the interest rates had started to decrease by 2008 (Foote, Gerardi, & Willen, 2012). Consumers embarked on a house spending spree that increased their household debt substantially (Gelain, Lansing, & Natvik, 2018); a phenomenon that took place across all income levels (Antoinette & Schoar, 2016).

In a debt-accumulating economy, greed far exceeds the fear of the debt trap, a fact that that is thought to have fueled the housing bubble (McCoy, Pavlov, & Wachter, 2009). The fact that the Standard & Poors' risk premium between 2000 and 2010 rose from roughly -1 to 20 speaks to the level of greed that prevailed.

When the fear of not entering the market on time (with the result of not making a quick profit) far outweighs the fear of the debt trap (with the risk of falling into defaults, delinquencies or foreclosures), deceit (framing, subversion and the like[19]) and the use of toxic products are a natural consequence (Hallsworth, List, Metcalfe, & Vlaev, 2015). That is, risk-seeking behavior promotes the use of surprise effects designed to lure the more vulnerable individuals (Caballero & Krishnamurthy, 2008). The surprise effect is emblematic of asymmetry of information: sellers withhold information valuable or essential for proper decision-making by their prey. It is a tool to catch potential buyers by dissimulating facts and data that would prevent them from falling into a debt trap (Mishkin, 2015). But what is particularly interesting is that asymmetric information can and did go in the other direction, with consumers falsifying financial documents in order to obtain loans (Ashcraft & Schuermann, 2008; Bianco, 2008).

[19] See, for example, Glaeser and Shleifer (2001): "Subversion includes such techniques as intimidating judges and regulators, bribing them, and using delay tactics to postpone a trial or a liability payment. By expending sufficient resources on subversion of justice, the potential violator can avoid either regulatory compliance or a liability payment."

In this regard, S. Brown et al. (2009) report strategic, regulatory, and legal misstatements hovering over 25% during the GFC. Certainly, shadow banking falls into the same category of behaviors (Gennaioli et al., 2013; Moreira & Savov, 2014), which also includes the creation of "predatory cells" and dubious partnerships of "politicians, administrators, business persons and activists" and lobbyists (Razin & Rosefielde, 2011).

In short, the U.S. market had traits of a predator-prey ecosystem: it was financially and geographically bounded by the nature of the products (houses); it put at play predators (sellers) and prey (consumers); and it engaged in foraging efforts whereby sellers aggressively sought their prey and prey weakly debated between the opportunity to gain access to wealth and the risk of engaging in a debt trap.

The U.S. policy before the GFC (or lack thereof) and the FED's manipulation of the interest rates, and their consequent interaction with predatory mortgages caused further market frictions in the market. Regulations were ineffective in part due to the U.S. economic system in place, which compared unfavorably with the conservative Canadian system. Indeed, there is an additional under-appreciated insight to the U.S. government's failing role with respect to the GFC that comes by comparing it to what happened in Canada during the same period[20].

Canada was a notable exception to the crises that engulfed the U.S. and many European countries during the GFC (Bordo, Redish, & Rockoff, 2015), though it certainly had troubles of its own. (See, for example, complications with respect to asset-backed commercial paper (ABCP) (Fortin, 2014)). This stems from the fact that the Canadian banking and brokerage industries are highly regulated. As such, Canada can serve, for the sake of argumentation, as a baseline against what happened in the U.S. More particularly, as Canada was more regulated

[20] Similar comparisons can be done made with other countries. For example, Glaeser, Johnson, and Shleifer (2001) show that 1900's Poland and the Czech Republic differed sharply, with the latter sustaining the collapse of securities markets following a policy of laissez-faire to securities regulation.

with respect to housing mortgages, opportunities for predatory behavior was rather limited, as compared to the U.S. From 1996 to 2008, the ratio of assets to equity in Canadian banks was stable at approximately 20%; for banks in the U.S., it decreased from roughly 13 to 10%. The U.S. broker's ratio increased from roughly 25% in 1996 to 35% in 2008, but it decreased sharply to Canadian levels in 2008 at the heart of the GFC[21]. In Canada, mortgages in arrears of 90 days or more (as a percentage of total residential mortgages) were stable at near 0% from 1999 to 2014. In the U.S., they remained at around 2.5% from 1999 to 2007, then climbed and reached a peak of 9% in 2008 and started to decrease slowly afterwards[22].

As explained by Crawford (2015), non-prime mortgages accounted for about 5% of all mortgages in Canada in 2007 compared to 20% in the U.S., credit scores for newly-originated mortgages were stable during the GFC, and unregulated lenders were in low numbers, again in stark contrast with the U.S. As for non-traditional mortgages – those typically with higher default rates – offerings were also limited.

Several other features differentiate Canadian from U.S. policies, helping to explain the stability of the Canadian system and underscoring the deleterious effects of U.S policies. Canadian bankers have traditionally adopted a more prudent regulatory and supervisory system, through Ottawa's Office of the Superintendent of Financial Institutions (OSFI). The government requires that federally regulated lenders and most provincial lenders insure high-ratio mortgages. Safeguards against interest rate risk are more robust, with borrowers opting for variable-rate mortgages required to meet tight debt-service limits. Unlike the U.S., mortgage interest payments are not tax deductible, which reduces the incentive to contract debt and to slow down the payment of the principal. Lobbying for deregulation is more powerful and active in the U.S. than in Canada (Igan, Mishra, & Tressel, 2011). Finally,

[21] Statistics Canada (www5.statcan.gc.ca); Federal Deposit Insurance Corporation (www.fdic.gov); U.S. Securities and Exchange Commission (www.sec.gov). Accessed June, Dec. 2018.
[22] U.S. Mortgage Bankers Association (https://www.mba.org); Canadian Bankers Association (https://cba.ca). Accessed Sept. 5, 2018.

borrowers have legal recourse in Canada whereas only 11 states in the U.S. forbid such action.

Further comparison of Canada and the U.S. using Worldwide Governance Indicators (WGI) shows that Canada ranks better with respect to two key dimensions: government effectiveness (by about 4%) and regulatory quality (by about 2% but with Canada taking a strong lead starting in 2007) (Kraay, Kaufmann, & Mastruzzi, 2010).

The net effect of these fundamental differences is that Canada did not suffer a subprime crisis. In fact, house prices continued to rise in Canada well beyond 2006-2007, while they collapsed in the U.S. as in many other countries, such as Ireland, Spain, and the U.K. Construction relative to total economic activity followed the same pattern, though to a lesser degree (Miles, 2015). We would like to emphasize that while we find our comparison convincing, it is far from causal and is beyond the scope of our manuscript to explicitly test this claim. Further work is warranted.

5. CONCLUSION

Academics have made countless analyses and hypothesized numerous causes for the GFC (see Appendices 2 and 3), yet none have arrived at a final conclusion. The U.S. economic system during the GFC was indeed a complex ecosystem (Haldane & May, 2011), one that can only be analyzed in depth by using appropriate methods and tools. Our approach complements current analyses of the market by using a predatory-prey perspective. We thus resort not only to utility maximization (in the present case, it is implicit in predatory nature: sellers and lenders develop their tools and products to maximize their returns) but also to aggregates, five of them – populations of predators and prey, and aggregates of predatory mortgages, interest rates and debt. In the last, the absence of means to reimburse debt, caused at least in part by financial hardship, leads the system into a debt trap. In the model, we

propose that the predatory nature of sellers creates a positive feedback loop in a debt trap that ultimately leads to collapse. This approach has the benefit of complementing the standard analyses related to financial crises (and in particular to the GFC), and puts the crises in a dynamic framework that better captures its intricate financial, psychological and epidemiological components.

Our brief study shows that there is evidence that the U.S. government policies in the years prior to the GFC and during the GFC nurtured this crisis, or if not, were a main cause of it. Put differently, in light of the comparison with the Canadian policy making, the U.S. policy of minimal or no intervention in the market place is a policy that invited deviant behaviors, which lead to crises the like of the GFC. Several features of the Canadian regulatory system can serve as clues to avoiding toxic predatory-prey mechanisms, including stronger regulations on lenders, a conservative supervisory system, insurance on high-ratio mortgages., use of safeguards against interest rate hikes through tight debt-service limits, absence of measures to slow down the payment of the principal, limited lobbying power, and borrowers have legal recourse in Canada.

Weak policies are, in fact, policies: they send messages to market agents that free-for-all attitudes are acceptable and that free-riding is permitted, allegedly without social consequences. However, this stand has deleterious effects, which are compounded, at least in the short term, by the very cure designed to curb them. The end result is a dysfunctional market where predators take considerable advantage of prey, where some prey turn into predators (buyers of houses who flip them and lure new prey), and where some predators refine their skills to become more efficient predators (Goldman-Sachs being a prime example as it benefited hugely from the crisis, having played both sides of it – up and down). Such a financial ecosystem runs the risk of market agents' extinction, in which everyone loses. A predator-prey perspective is logically expressed as a contagion process (herding) takes place,

first in the attempt by eager sellers and buyers to benefit from the heated market, and then in the desperate flee to escape debt traps.

Our research is preliminary and intends to put forth a base upon which we will develop a full mathematical model in an up-coming article, in which we will present different states of predators-infected markets, such as stationary, heading towards extinction or else tampered by noise. Based on the research detailed in this paper, we argue in favor of prudent policy-driven regulation that must be of sufficient force and adequately timed in order to be effective (Brunnermeier & Sannikov, 2014). Delayed responses to market frictions and inadequate enforcement of laws drive the inevitable astute financiers and greedy consumers towards a debt trap which, in the end, harms to the entire economy.

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CAPTIONS FOR FIGURES

Figure 1 – Market data suggesting Lotka-Volterra trends in the U.S. market.
Notes: The curve "predatory mortgages" was calculated using actual predatory mortgages that existed in the U.S. market. We posit they are toxic products. The government responded to these by increasing interest rates to reduce the capacity of buyers to borrow money. However, buyers who had purchased predatory mortgages found themselves unable to pay as their grace period came to an end. Thus, foreclosures followed. All curves were built from market data, adjusted to emphasize their tendencies through exponentiation, and standardized to allow comparisons.

Figure 2 – Owners' equity and debt.
Notes: Debt kept mounting despite disinvestment of buyers in the housing market. This is due not only to interest rates but also to the delayed effects of predatory mortgages. Government intervention initially exacerbated the problem, much like chemotherapy initially makes the patient worse off before improvement.

Figure 3 – The GFC as a predator-prey phenomenon.
Notes: Sellers and buyers of predatory mortgages interact in typical predator-prey fashion. Debt is a stock that can accumulate, but a high rate of reimbursement can overcome the influx of indebtedness. Interest rates are stocks of which the accumulation is conditioned by market frictions; however, the more efficient the interest rate is at curbing debt, the less there is a need to adjust interest rates. Innovation in predatory mortgages boosts the opportunity to hide risk in toxic products while high interest rates and tougher regulations discourage the buying (and selling) of these products, making them obsolete.

APPENDIX 1 – A BRIEF HISTORY OF THE GFC EVENTS

Date	Event
2007	
Jan-Jul	Institutional bankruptcies start (e.g., Ownit Mortgage Solutions)
August	The interbank market, countrywide suffer
September	Bank run in the U.K. (Northern Rock)
2008	
March 11	Creation of the Term Securities Lending Facility by the Fed to foster liquidity
March 16	JP Morgan Chase agrees to buy Bear Stearns
June 15	SEC bans naked short-selling of financial stocks
September 7	Fannie Mae and Freddie Mac fall under the federal government control
September 15	Lehman Brothers files for bankruptcy
September 25	Government seizes the largest savings and loans company in the U.S. (300 billion USD in assets)
October 3	U.S. Congress approves 700-billion USD financial-aid package
October 14	Nine major banks receive 250-billion USD from the U.S. Treasury
2009	
October	Unemployment rate peaks at 10 percent

APPENDIX 2 – A BRIEF HISTORY OF REGULATIONS[23] THAT WERE NEVER SIGNED INTO LAW

We present this to underline that fact that the legislative branch of the U.S. government sometimes proposed tougher measures that might have prevented the crisis but that the U.S. ultimately did not have the motivation to adopt them. Prior to these regulations, many Acts and Laws worked in opposite directions, attempting to curb overstretched borrowing but also to encourage home ownership among the middle class. For example, the Community Reinvestment Act (CRA[24]) encouraged commercial banks and savings associations to facilitate borrowing among the low- and moderate-income households.

Regulations (Acts, Laws) – a few examples	Date introduced
Consumer Mortgage Protection Act	April 6, 2000
Predatory Lending Consumer Protection Act	April 12, 2000
Predatory Lending Consumer Protection	March 15, 2001
Protecting Our Communities from Predatory Lending Practices Act	Dec. 20, 2001
Predatory Mortgage Lending Practices Reduction Act	Feb. 27, 2002
Mortgage Loan Consumer Protection Act	May 22, 2002
Predatory Mortgage Lending Practices Reduction Act	April 8, 2003
Prevention of Predatory Lending Through Education Act	April 29, 2003
Prohibit Predatory Lending Act 2005	March 9, 2005
Responsible Lending Act	March 15, 2005
Fair and Responsible Lending Act	Dec. 8, 2005

[23] Igan, Mishra, & Tressel, 2011.
[24] https://www.federalreserve.gov/consumerscommunities/cra_about.htm. Accessed Jan. 30, 2020.

Financial Services Relief Act	May 18, 2006[25]
Mortgage Reform and Anti-Predatory Lending Act of 2007	Oct. 22, 2007

Notes: In his memoirs, former U.S. president Bill Clinton gives an eye-opening account of how difficult it is to pass laws and Acts given the relentless tensions between the Republicans and the Democrats (Clinton, 2004). He cites, for example, the *Private Securities Litigation Reform Act* (p. 727), which, in his mind, was limiting too much access to tribunals for investors who had been victims of fraud. Many feuds involve attempts at controlling the national debt, health care, and regulations *versus* deregulations (e.g., gun control, consumerism, etc.)

[25] Passed by the U.S. Senate on May 25, 2006 and soon signed into law, it imposed a huge debt on U.S. taxpayers.

APPENDIX 3 – A BRIEF ACCOUNT OF GREED AND RISK HIDING RELATED TO POTENTIAL CAUSES OF THE GFC

Potential source	Example of authors
Likely associated with greed and hidden, predatory agendas	
Window-dressing "sweetheart deals" and teaser rates	Akerlof and Shiller (2009)
Enjoying peer pressure predatory webs, network effect and oligopolies	Scherbina and Schlusche (2013)
Fostering predatory behaviors with such tools as predatory mortgages	Various authors
Leveraging	Scherbina and Schlusche (2013)
Rewarding predatory behaviors with extravagant bonuses	Graafland and van de Ven (2011)
Close financial ties among the most influential market players	Rajan (2010)
Deceitful over-estimation of credit ratings granted to large financial institutions.	Various authors
Overall weaknesses of policy-making	Krugman (2009)
"Too big to fail" philosophy	Reinhart (2015)
Building-up volatility an element that made consumers nervous	Cochrane (2005)
Creating an artificial boom	Glaeser, Gyourkob, and Saizb (2008)

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Potential source	Example of authors
Likely associated with risk hiding (reducing the fear of the debt trap)	
A mounting predilection for excess deficit spending	Reinhart (2015)
Fostering weak controls and unjustified tax breaks	Rajan (2010)
Lacking of product standardization	International Monetary Fund (2009a)
Moral hazard, securitization and risk hiding	Brunnermeier and Sannikov (2014)
Providing a false sense of security (e.g. The use of the Federal Reserve Bank as a lender of last resort)	Various authors
Resorting to creative accounting	Akerlof and Shiller (2009)
Risk hiding and securitization	Various authors
Shadow banking	Fernandez and Wigger (2016)
Taking advantage of market frictions and friction-loaded mechanisms	Fenzl and Pelzmann (2012) (e.g., use of complexity)
Absence of proper controls	Acharya and Richardson (2009)
Amalgamation of real and hidden risks in the U.S. financial sector and their hiding in complex financial instruments	Caballero and Krishnamurthi (2009)
Financial imbalances of capital flows crossing borders across various economies	Acharya and Schnabl (2010)
Lenient monetary and regulation *laissez-faire* policies (that were initiated in 1977 with a loose regulation setup of the U.S. CRA)	Posner (2009)
Reckless and institutionalized credit lending practices	Reinhart and Rogoff (2009)
Use of technological innovation to hide risk	DeMarzo et al. (2007)
Abusing asymmetry of information	Milgrom and Roberts (1982)

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APPENDIX 4 – A BRIEF OVERVIEW OF LOTKA-VOLTERRA EQUATIONS

Lotka-Volterra equations are well-known in ecology for modeling the interactions between two or more species (Edelstein-Keshet, 2005; Gotelli, 1995; Lotka, 1920; Volterra, 1928). Specifically, we focus on a predator-prey interaction, in which one species benefits (the predator) at the expense of the other (the prey). The classic example is that of the lynx and the hare (Gotelli, 1995), where the populations of each species fluctuate according to the rise and fall of the other (Figure S1). In its simplest form, a Lotka-Volterra system is composed of two equations of four parameters such that

$$\frac{dx}{dt} = rx - \alpha xy \qquad \text{for prey}$$

$$\frac{dy}{dt} = \alpha\beta xy - my \qquad \text{for predators}$$

where dx/dt and dy/dt are the changes in the aggregates or populations ("bathtubs" in the main text) of prey and predators. The parameters r and m represent the natural growth and death rates of the prey and predator respectively. The parameter α is the predation rate, or the fraction of the prey population that is consumed per predator. In epidemiology, this is equilvalent to the "contact rate" between types of individuals (Brauer & Castillo-Chavez, 2012). The parameter β is the conversion efficiency. It explains how much the predator population increases as a result of eating prey. For a detailed discussion of Lotka-Volterra equations and their extensions, see Gotelli (1995).

In the context of financial markets, references to predatory behavior frequent our language: "loan sharks", "predatory mortgages" and the like. Indeed, these terms reflect a predatory interaction. One market agent - in our case, sellers of subprime mortgages - preys upon another - potential buyers - to the benefit of one and the detriment of another. In this case, instead of modeling a lynx and a hare, the Lotka-Volterra equations are the changes in

the quantity of potential buyers of (prey) and sellers of predatory mortgages (predators). The parameters r and m are re-interpreted as the rates at which potential buyers and sellers leave the market. The parameter α is the probability that a potential buyer purchases a subprime mortgage (including the chance of contact between a buyer and seller), and β is a measure of the attractivity of a sold mortgage to new sellers entering the market. "Caught" or "eaten" prey are those potential buyers who purchased a subprime mortgage.

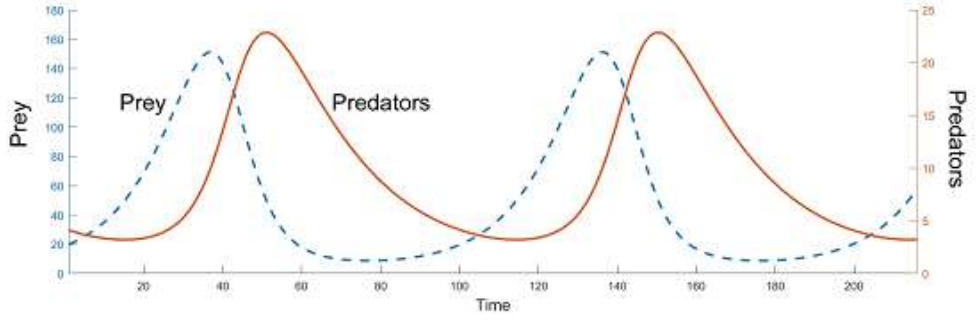

Figure S1 - Illustration of Lotka-Volterra dynamics

Notes: Line style and color indicate the prey (blue, dashed) and predator (red, solid) populations. Notice that the scale of the left, y-axis demarking the prey population is larger than the right, y-axis for the predator. In absence of outside intervention, the system will continue to exhibit fluctuates in the rise and fall the populations of prey and predator.