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Systemic Risk in the Financial Industry: "Mimetism" for the Best and for the Worst*

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Résumé/abstract

In the wake of the worst financial crisis since 1929, economists are revisiting the received understanding of how financial markets and institutions actually operate. This paper aims to contribute to this reexamination. It builds upon the traditional and widely-accepted mean-variance approach to the processing of information under conditions of risk while reconsidering an inadequately contemplated premise: the actual organization of the financial market. Now, a lot has been said about perverse incentives and contracting arrangements, firms with oligopolistic power, the pricing and market advantages of being too big to fail, and the associated inefficiencies of the regulatory and supervision systems. While we believe that much of that work is valid, we also believe that too little has been done to meld modern portfolio theory (MPT) with insights that can be drawn from recent developments in Industrial Organization. In the model presented here, the MPT finds its place through the "coordination" mechanism, which is the transmission of financial information among agents. The IO perspective finds its place in our model through a variable capturing the fragility of the system: the probability that the quality of information can itself be altered by the system's "complexity," which in its extreme from can be described as "opacity."

Mots clés : systemic risk, specific risk, systematic risk, financial industry, modern portfolio theory, complexity, opacity, Minsky moment, complex systems.

Codes JEL *:* G11, G15, G24, G28

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1 Introduction

The 2008 crisis began when major financial players realized, at more or less the same time, that many investments made in the half-decade preceeding crisis were in fact bad bets. The problem was that at the time of this realization, mortgage backed securities constructed out of assets of poor quality, including worse than reported or even fraudulent subprime mortgages. Indeed, by 2005, "Liar's Loans" (stated income loans) and Ninja Loans (No Income No Job no Asset) loans, had come to constitute a dangerously high percentage of the asset base of several large financial institutions. This dangerous situation was exacerbated by the fact that Bear Stearns, Lehman Brothers and other prominent financial firms were using these assets as collateral to anchor the funds they required to finance their day-to-day operations, often through the inter-bank Repo market (Cohan 2009).

These trends were rendered even more dangerous as a consequence of concentration in the U.S. banking industry. According to President Fisher: "As of third quarter 2012, there were approximately 5,600 commercial banking organizations in the U.S. The bulk of these—roughly 5,500—were community banks with assets of less than $10 billion. These community-focused organizations accounted for 98.6 percent of all banks but only 12 percent of total industry assets. Another group numbering nearly 70 banking organizations—with assets of between $10 billion and $250 billion—accounted for 1.2 percent of banks, while controlling 19 percent of industry assets. The remaining group, the megabanks—with assets of between $250 billion and $2.3 trillion—was made up of a mere 12 institutions. These dozen behemoths accounted for roughly 0.2 percent of all banks, but they held 69 percent of industry assets" (Fisher 2013). From an IO perspective, this is close to a textbook version of competitive oligopoly.

According to Eric Pan, "Canada so far has avoided many of the economic problems that currently plague the United States and United Kingdom" (Pan 2009). One reason is that Canada's fundamentals are better than most of its counterparts within G8 which grants it the luxury of taking a longer-term perspective. However, the U.S., UK, France, Germany, Italy, etc. are under pressure and are still trying to manage the fallout of the crisis that started in 2007-08, while simultaneously formulating regulations that will prevent - hopefully - future crises. These scenarios are sometimes discussed at the international level in a coordinated manner and, at other times,, as in the case of reregulation under the Dodd-Frank Act, are being formulated according to more or less exclusively national contexts.

The complexity of financial reregulation can be partially attributed to the dynamics of the game: financial regulations can provide a sound framework for any given market, but can also – if enacted in only one country - scare participants away. What follows is the proverbial race to the bottom; in such an event, the financial markets themselves come to be defined as too big to fail (TBTF) with the argument being that their very presence is essential to the health of the rest of the economy. One cannot let them collapse without risking severe consquences for the real economy. This also means that financial markets are intrinsically part of any coherent explanation as to how society can best mitigate or manage systemic risk. However, at least in the 1990s, the players on the financial markets were at pains to be reassuring in explaining to one and all that they were successfully managing these risks. None of this is wrong or right, the whole system is a subtle equilibrium and most of the time it is a stable cobweb and sometimes - crisis times - it is an unstable cobweb. For instance, in 2007-08, "market correction" took the form of a bank run as counterparties refused, more or less en masse, to roll over the short-term debt of prominent financial institutions such as Bear Stearns. As a consequence, Bear and others were obliged to dump their higher quality assets (as these were still liquid) at "fire-sale" prices in an effort to "make position by selling position." In this time-honored manner a crisis originating within an isolated class of "bad assets" readily spread to higher quality assets. The result was a collapse that included almost every class of assets and even undermined firms that might otherwise have had little or no exposure to assets constructed out of subprime mortgage loans.

The question is: have we learned anything from the build-up and collapse of this gigantic bubble in housing and mortgage-backed securities? This is especially pressing since we only recently recovered from crises in emerging market debt and technology stocks in the 1990s. Specifically, is the financial system itself forcing otherwise rational and well-educated people to mimic their counterparts' behavior, thereby reinforcing the bubbles that periodically emerge?

This question is actually not all that new. It has been arisen in the wake of every boom-bust cycle. Indeed, Minsky, rather famously, made the case that human psychology, organizational memory, and the nature of the competitive process were so constituted that the greatest single cause of financial instability was a prolonged period of stability (Minsky 1986). While this paper is not a commentary on Minsky, we do share his view that it is time for economists to stop thinking in silos. We need to reconcile the different approaches from different subfields. To our knowledge, what follows is one among only a few efforts to bring the Industrial Organization (IO) literature to the analysis of Finance (the exceptions are primarily in behavioral finance, which is close to the following IO criticism of some of the limitations of the Modern Portfolio Theory (MPT)).

The originality of this paper comes from the fact that it relies on the traditional and widely accepted mean-variance approach. It builds on this theoretical model while reconfiguring one of its unstated assumptions: the organization of the financial market. While much has been said about incentive contracts, the existence of oligopolistic power, too big to fail and the implicit subsidy deriving therefrom, the inefficiencies of the regulatory and supervision systems, very little has been done to bridge MPT with an IO perspective. In the model presented below, MPT finds its place through the "coordination" mechanism, that is to say through a effort to explicit model the transmission of the financial information. The ensuing IO perspective finds its place in our model through a variable capturing the notion of fragility: the probability that the quality of the information can be altered by the "complexity" of the system, which taken to an extreme could be described as "opacity."

In this context, the coordination mechanism can be seen as the search for transparency - and thus stability - in the spirit of Minsky's analysis (Minsky 1986). Also, the probability that information can be sufficiently altered by the complexity of the system itself to contribute to the instability of the financial system. In this manner, the model presented here affirms Minsky's argument as to the endogeneity of financial instability.

> *"Units that engage in speculative finance are vulnerable on three fronts. One is that they must meet the market as they refinance debt. A rise in interest rates can cause their cash payment commitments relative to cash receipts to rise. The second is that, as their assets are of longer term than their liabilities, a rise in both long- and short-term interest rates will lead to a greater fall in the market value of their assets than of their liabilities. The market value of assets can become smaller than the value of their debts. The third front of vulnerability is that the views as to acceptable liability structures are subjective, and a shortfall of cash receipts relative to cash payment commitments anyplace in the economy can lead to quick and wide revaluations of desired and acceptable financial structures. Whereas experimentation with extending debt structures can go on for years and is a process of gradual testing of the limits of the market, the revaluation of acceptable debt structures, when anything goes wrong, can be quite sudden" (Minsky 1977, p.25).*

To review briefly, Minsky was famously of the view that a widespread perception of stability was not only misleading, but the complacency it induces contributes to the formation of bubbles. These, in turn, eventually burst, causing the authorities to intervene either immediately or after some lag. After the crash, lower leverage ratios, revised notions of what constitutes safe assets, and greater regulation, all contribute to another period of extended stability, etc. For behavioral finance, psychology matters: for instance, prolonged stability may reassure investors and thereby make them overly optimistic, thereby fueling the creation of a bubble. In what follows, we wish to add another dimension to the story: what if investors were truly “rational,” and for that reason fully aware of the probable existence of a bubble, but that the dynamics of the game essentially force them to remain in the market, continuing to fuel it through the positions they take, perhaps all the while retaining some hope that they will be able to safely exit their positions before the crash? So, in addition to Minsky's observations on stability and instability, and alongside behavioral finance, we hope to bring a game theoretical approach to MPT so as to better understand the role of perception in the building up of risky positions.

Other lessons can be drawn from the industrial organization (IO) literature: financial markets are not simply about finance and the calculation of the expected value and variance of the assets therein, but also about markets and their organization. Indeed, many concepts and analyses from IO can be brought to the diagnosis: the nature of goods, the market structure (pure and perfect competition, monopoly, oligopoly, dominant firm, etc.), mergers and acquisitions strategies (cartels, strategic alliances, joint ventures, etc.), price strategies (limit pricing, discriminatory pricing, bundling, etc.), product and differentiation strategies (Hotelling, Salop, vertical differentiation), innovation strategies, contract theory (moral hazard, compensation, etc.), regulatory context, international interactions, etc.

Endogeneity is represented in our model by positing mimetism within the financial industry. Given the importance of this idea to what follows, we would like to highlight the difference between mimetism and herd behavior. The latter assumes a high level of bounded rationality. In its extreme version, it supports the assumption that there are only very few intelligent players on the markets, with the rest being relatively uninformed players whose best strategy is to simply follow the herd. This is not our prior. We propose staying with the definition of mimetism: even when markets are constituted with intelligent and very rational people, uncertainty about the future - in game theoretical wording: incomplete information - forces players to seek coordination even in the event that a crisis is in formation. Endogeneity will create the fragility that fuels instability in the financial system.

2 Literature review

Defining the concept of systemic crisis is by no means an easy task. One could characterize it as a situation "where a crisis in the financial sector has a large-scale impact on the real economy" (Lamfalussy 2003). If it is easy to understand the definition of systemic risk, it is not easy to apprehend what generates a risky situation. In his account of the Savings and Loan episode, Balderston shows that from the market structure to the liquidity issue through the question of regulations, financial stability is a fragile equilibrium (Balderston 1966). [Thierry: This reference seems very dated. Do you have a more recent one????]

2.1 An IO/Political economy perspective

Financial markets have dramatically evolved since 1933, and most importantly since the 1970s with MPT. For all of its faults, MPT provided academics with a tractable and reliable theory. With this new theoretical framework, academics could more readily model and theorize the underpinnings and dynamics of financial markets. With such an improved understanding, the financial industry could institute revised and more efficient management of financial risks as well as develop a series of innovations including new products and services. In the wake of the 2010s, questions have been raised as to whether this framework needs to be augmented to understand the implications of too much "financial innovation" for the stability of the financial industry (Prasch and Warin 2012). Many authors, Minsky included, argue that these many changes suggested that we had to have an equally dynamic understanding of financial regulation. However, in formulating new regulations it is essential that we acknowledge that the financial system and thereby the most appropriate regulatory regime will always be evolving, and "failing to do so risks the creation of new regulation that suffers from the same deficiencies as the current framework" (Whitehead 2010).

Regulation is the main theme when considering the causes and consequences of systemic risk. Arestis and Basu (2004) argue that the emergence of financial globalization is premised on some convergence of the regulation of financially globalized markets. In their view, the main objective of national financial regulation was to "bring financial stability and to promote governments' economic and social objectives." They also observed that financial globalization has also had a causal impact on financial deregulation. The main hypothesis of the financial liberalization discourse was that the absence of competition due to the rigidities generated and amplified by the national regulations would increase the inefficiencies in the financial sector. In other words, beginning from an oligopolistic sector, one should target regulations promoting and supporting pure and perfect competition. Arestis and Basu (2004) explain that this neo-classical view had succeeded in the manner that its promoters that it would, and for that reason had contributed to a series of financial crises. They highlight that one of the problems associated with financial globalization has been an increase in macroeconomic volatility that have been especially detrimental to developing countries with low levels of physical capital.

Financial regulation is at the origin of a long lasting debate (Peretz and Schroedel 2009). Should we regulate, how should we regulate, and how much should we regulate? In the aftermath of the disintermediation induced by the inflation experienced in the 1970s, the U.S. financial sector was very vocal in calling for the reform of the regulations under which it operated (Helleiner 1994). These demands were supported by authors who argued that "the emerging economic environments demands corresponding changes in the regulatory structure. There needs to be a single coherent policy toward financial institutions" (Carron 1984). Over time, regulations were increasingly eased in a series of steps that culminated in the Riegle-Neal Interstate Banking and Branching Efficiency Act (1994), the repeal of the Glass-Steagall Act in 1999, and the Financial Services Modernization Act of 2000, which effectively forbade federal and state officials from regulating “Over the Counter” financial derivatives between “sophisticated parties,” thereby effectively freeing Credit Default Swaps and many other varieties of financial derivatives from virtually any oversight.

From the beginning of the financial crisis, a debate arose over the content of what would constitute more and better regulations. Some, including the U. S. Treasury Department, pushed to postpone reregulation until after the crisis was resolved and further, wait until all of the G8 could be involved so as to put together a revised international financial architecture, one that – in their view – would feature the correct incentives for all financial institutions (Davies 2008). Some authors call for the reinforcement of the "big three": (1) prudential regulation, (2) internal control and (3) market discipline (Couppey-Soubeyran 2010). Some highlighted one big and single principle, one that they saw as a substantial contributor to problems even before the onset of the 2007 crisis: the question of insufficient monitoring of the rules already on the books (Marjit 2003).

A prominent concern of most bankers and governments is that their firms will lose a competitive edge on what otherwise would be a profitable industry. This fear is exacerbated by the fact that national financial markets are so interconnected that they have increasingly become "supra-national" markets, and in the political context of national regulations, various locales appear increasingly interchangeable. This induces the concern that national regulations are being forced into a race to the bottom. Without exaggerating this fear (Pan 2009; Fourcans and Warin 2010), the globalization of financial markets and the need to reduce systemic risk are compelling reasons to carefully design a national, and ideally, international financial regulatory system. Such a design would have to set out the objectives of the regulatory system, determine the system’s ideal characteristics, decide the strategies to achieve those objectives and attend to all the concerns with implementation, including costs associated with monitoring and compliance.

In the traditional mean-variance framework, diversification is key to a safer and sounder financial system. Long ago, Wagner and Lau explained that "In a rising market, average return increases as the quality of individual issues declines. And indeed, the U.S. has long favored disclosure and diversification as the pillars of its regulatory approach. On the other hand, whereas the level of return variability falls as the number of issues held in a portfolio increases, average return is unaffected. Hence the investor is better off holding a large number of low quality stocks than a smaller number of high quality stocks; return on the former portfolio will be higher for a given level of over-all price variability" (Wagner and Lau 1971). In short, what matters was that investors hold a large number of assets, even low quality ones. Thus, a large combination of high risk assets is better than a small combination of low risk assets. Missing from this analysis, however, is the endogeneity created by having a large number of high risk assets. Anyway, MPT came with the notion of systematic risk (events that affect aggregate outcomes and have a macroeconomic impact). Systematic risk sounds similar to systemic risk, but there is a nuance: a systemic risk causes the financial system to collapse.

As has been widely recognized, the practice of securitization and the associated high degrees of leveraging has been closely associated with the 2008 financial crisis. Securitized products such as collateralized debt obligations (CDO) are exposed to systematic risk and tend to show higher tail risk (Fujii 2010). As a consequence, this will create some endogeneity and lead to a higher systemic risk. In order to achieve greater stability of the financial system and avoid a higher degree of systemic risk, macro-prudential regulations should be implemented (Fujii 2010).

2.2 Minsky's stability criticism

Referring to endogeneity, Hyman Minsky famously theorized that the greatest single cause of financial instability was an extended period of stability (Minsky 1986; Wray 2009; R. E. Prasch 2010). Stability had a tendency to reward increased complacency as banks and firms found that they were successful despite ever increasing risks and ever-greater degrees of leverage. In a recent and insightful article, Philip Mirowski noted that Minsky's argument was accurate but could be faulted for being uni-dimensional (Mirowski 2010). Mirowski suggests that we heed another element of the problem; that an extended period of stability contributes to the complexity of the financial system. Over the cycle, banks and firms become increasingly intertwined as they derive increasingly "innovative" contracts and payment commitments, at least in part so as to skirt regulations over leverage ratios. In Mirowski's view, the economy becomes increasingly complex and leveraged over an extended period of stability and that each of these trends adds materially to the growing degree of financial fragility. To Minsky, echoing his old teacher Joseph Schumpeter, the ensuing financial crisis can be understood as a period of rapid and forced de-leveraging (Whalen 2001).

In what follows, we will try to go beyond the stability criticism by evoking the notion of complexity. This matters for recent experience as a number of investigators have highlighted the fact that the specifics and consequences of recent financial innovation or financial engineering was not well understood by the regulatory agencies and that this lack of understanding has aggravated the level of systemic risk on the financial markets (Yener 2011).

Minsky's instability approach is by nature an IO approach. How can we reconcile the financial approach with the IO perspective? So long as IO concepts are talked about exclusively by IO scholars, it will fail to influence the literature on monetary economics. Of course, the reverse also holds true. Hopefully, the following will make some contribution toward overcoming this divide.

3 Model

This article is not about the creation of a bubble that fails to garner the attention of market insiders or even players more generally. By extension, the collapse of the bubble is also not a surprise (although the timing of its collapse is unknown to all). Here we give more credit to financial markets participants, and we assume that they understand that they have entered into a bubble and that the bubble will blow up at some point. The questions we pose are rather: (1) can a player avoid entering into a bubble and thus prevent its inflation? (2) can a player know or learn when it will blow up? In game theoretical wording, these two questions can be interpreted as: can a player stop playing strategies that will contribute to a sub-optimal equilibrium for the whole system even when the player is well aware that a bubble is looming?

To begin, let us define the three types of risk. The first two are traditional in the mean-variance framework, and the third definition may be slightly different from standard definitions, but it is necessary to the following analysis.

(1) Definition of specific risk: Specific risk is the one attached to the asset itself.

(2) Definition of systematic or market risk: It is the undiversifiable risk, it captures the vulnerability to events beyond the financial market itself: natural catastrophes, unexpected macroeconomic changes, etc.

(3) Definition of systemic risk: Systemic risk rises is endogenous in the sense that it rises with the level of complexity or opacity in the overall market. It captures the risk of collapse of the entire financial system due to idiosyncratic elements.

Even if this looks like a prisoner's dilemma, we will build a model that will not lead to such an outcome. Moreover, we recognize that our model relies on a certain level of mimetism, what people may also call herd behavior, or bounded rationality.[2] We also assume that that some players have more information than others. This does not imply that insider trading is rife or the core of the problem, but it does mean that we are assuming that financial markets are closer to Stackelberg oligopoly in which some big players can have a disproportionate impact on the markets by leading them in one or another direction. We understand that these assumptions are contrary to the usual assumptions of perfect information, perfect rationality, and atomicity. Finally, we will assume that market dynamics are such that coordination between the players is periodically needed to avoid chaos.

3.1 Hypotheses and structural equation

The assumptions of our model are coming directly from Markowitz, Sharpe, Treynor, Lintner, Mossin (1963) and the subsequent literature (Portait and Poncet 2009):

1. Investors are risk-averse and assess their portfolios in the mean-variance framework,
2. Markets are perfect,
3. The assumption of the absence of arbitrage opportunity holds,
4. Expectations on returns (mean, variance, covariance) are identical.

Let us consider a portfolio composed by *n* different assets (stocks), then its return can be represented by:

$$R_P = \alpha_P + \beta_P \cdot R_M + \varepsilon_P \tag{1}$$

[2] For a discussion on the difference between herd behaviors and mimetism, though in a different context, see Warin and Blakely (2009).

As in the original Sharpe framework, let us also assume that R_M and ε_P are independent, then (see appendix 1 for further details):

$$\underbrace{\sigma_P^2}_{\text{portfolio total risk}} = \underbrace{\beta_P^2 \cdot \sigma_M^2}_{\text{portfolio systematic risk}} + \underbrace{\sigma_{\varepsilon_P}^2}_{\text{portfolio specific risk}} \tag{2}$$

About the systematic risk: in the original framework, when an investor adds stocks with a beta superior (inferior) to 1, then the systematic risk rises (drops).

About the specific risk, it is measured by $\sigma_{\varepsilon_P}^2$:

$$\sigma_{\varepsilon_P}^2 = \sum_{i=1}^{n} x_i \cdot x_j \cdot \sigma_{\varepsilon_i}^2 + \sum_{i=1}^{n} \sum_{j \neq i} x_i \cdot x_j \cdot \operatorname{cov}(\varepsilon_i, \varepsilon_j) \tag{3}$$

In order to make some simplifications that will not have an impact on the results apart from making it understandable and less relying on a complex equation, we make the assumption that all stocks are held in the same proportion in the portfolio, then $x_i = x_j = 1/n$ leading to:

$$\sigma_{\varepsilon_P}^2 = \sum_{i=1}^{n} x_i^{\,2} \cdot \sigma_{\varepsilon_i}^2 + \sum_{i=1}^{n} \sum_{j \neq i} x_i^{\,2} \cdot \operatorname{cov}(\varepsilon_i, \varepsilon_j) \tag{4}$$

If we simplify further by assuming that the stocks are not correlated, and the stocks' variances are all equal[3], then $\operatorname{cov}(\varepsilon_i, \varepsilon_j) = 0$:

$$\sigma_{\varepsilon_P}^2 = \left(\frac{1}{n}\right)^2 \cdot \sum_{i=1}^{n} \sigma_{\varepsilon_i}^2 = \left(\frac{1}{n}\right)^2 \cdot n \cdot \sigma_{\varepsilon_i}^2 = \frac{\sigma_{\varepsilon_i}^2}{n} \tag{5}$$

Unsurprisingly, this is the standard result that follows from the Sharpe-Lintner framework: the specific risk diminishes with the number of stocks in a portfolio. When $n \to \infty$, then $\sigma_{\varepsilon_i}^2 / n \to 0$, we have an hyperbolic curve. Portfolio diversification within this equation requires: (1) a large number of stocks, (2) uncorrelated assets and (3) identical variances. However, considering n can range to a number as high as infinity, it outweighs any other parameter such as correlation of stocks or the variance of stocks. If one believes in the Law of Large Numbers, then the bigger n, the lower the specific risk. Indeed, all kinds of assets with all kinds of correlations and variances will be mixed, making the covariance close to the uncorrelated result. It follows that n is the key variable. Wagner and Lau have represented graphically these two risks (systematic and specific) (Wagner and Lau 1971) (see Figure 1).

3.2 Uncertainty and complexity are inherent to the financial system

We will now summarize the dynamics of the financial markets with two players, one knowing what the state of nature is (node N_0) and communicating this information to the second player. Player 1 represents the Stackelberg, and player 2 represents the follower. We assume player 1 gives a fair account of the state of

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3 $\rho_{i,j} = \dfrac{COV(R_i, R_j)}{\sqrt{Var(R_i) \cdot Var(R_j)}} = \dfrac{\sigma_{ij}}{\sigma_i \cdot \sigma_j}$

nature, and cannot hide his position. At the beginning of each game, the first player is aware of the state of nature *S*:

$$S = \left\{ \bar{b}, b \right\} \tag{6}$$

with $\bar{b}$ corresponds to a situation with no bubble in the future and *b* corresponds to a situation in which the market is entering into a financial bubble. The profit functions are characterized by:

$$\Pi\left(C_{i,S}\right) \tag{7}$$

where $C_{i,S}$ represents the total cost for players $i = \{1,2\}$.

Players have two possible strategies: the first one is to engage in mimetic behavior with the second being to develop a different strategy. The first strategy implies lower costs, but it adds fuel to the existing bubble. The second strategy is costly in that it eschews the immediate reward that can be expected from participating the asset price inflation resulting from the bubble and also in terms of search costs to find new and original opportunities. The costs will be represented by $C_{i,S}^{l}$ for the first strategy (low costs) versus $C_{i,S}^{h}$ for the second strategy (high costs). The total cost function is:

$$\left\{ C_i^l \middle| \bar{b}; C_i^h \middle| \bar{b} \right\} \text{ or } \left\{ C_i^l \middle| b; C_i^h \middle| b \right\} \tag{8}$$

We will assume that payments follow these conditions:

$$\left\{ \Pi_i^l \middle| \bar{b} \right\} > \left\{ \Pi_i^h \middle| \bar{b} \right\} \text{ and } \left\{ \Pi_i^h \middle| b \right\} > \left\{ \Pi_i^l \middle| b \right\} \tag{9}$$

These assumptions allow us to define the following Pareto optimal solution:

$$\left\{ \left(\Pi_1^l, \Pi_2^l \right) \middle| \bar{b}; \left(\Pi_1^h, \Pi_2^h \right) \middle| b \right\} \tag{10}$$

These payments prevent a situation in which the prisoner's dilemma would have played a role.

In terms of information, the model is built around the assumption of imperfect information. We propose to use the approach pioneered by Rubinstein's (1989) in one of his famous papers that captures perfectly the consequences of imperfect information in terms of a game solution. In this regard, this part of the model is another example of the substantial contribution made by Rubinstein's paper to the literature on information. We also benefit from Demange and Ponssard (1994)'s extension of Rubinstein's article.

We model the interaction between both players based on incomplete information concerning the 'state of nature.' We assume that the first player has private information on this state of nature. If the state of nature features no asset price inflation, and thus no forthcoming bubble, then player 1 does not communicate this information to player 2. However, if the state of nature reveals asset price inflation and thus the formation of a bubble, then player 1 communicates this private information to player 2. We assume that the most probable event is state of nature is $\bar{b}$, i.e. a no bubble situation. In a more formal way, at the beginning of the game, player 1 discovers that the state of nature is either $\bar{b}$ or *b* with the probability distribution $(\alpha, 1-\alpha)$ and $\alpha > 1/2$.

If b occurs, the Stackelberg player communicates the information to player 2. Player 2 receives the information, understands the warning about the creation of the bubble, and communicates with player 1 revealing that there is a bubble in the making. Player 1 then responds with another confirmation. This entire exchange is made necessary by potential communication failures: the information contained in the message sent by one of the players has a small probability of being lost or misunderstood by the other player, which we call β, with $\beta > 0$. The probability that a message still circulates beyond a very large number of exchanges is thus *a priori* weak, but still exists and is not insignificant. The interesting feature that follows from this assumption and the model more generally is that even when the uncertainty seems to be resolved, the outcome may still be Pareto inefficient. The game has an infinite horizon because of the back-and-forth transmission of messages. The procedure of sending messages does not form part of the strategy: the real game begins only when no further messages are exchanged between the two players.

We will define the information set I_t of both players using the following nomenclature:

(1) $I_{\bar{b}}$ represents the information set of player 1 when he discovers that the state of nature is $\bar{b}$, and thus does not communicate with player 2,
(2) I_1 is when player 1 discovers that the state of nature is *b* and then communicates with player 2,
(3) I_0 is when player 2 did not receive any information either because communication got lost or because state of nature was $\bar{b}$, and
(4) I_2 when player 2 receives the information, understood that the state of nature was *b* and then sends a confirmation message.

Let us use a demonstration based on the following three steps:

1. Let us demonstrate that, whatever $\beta > 0$ and whatever the number of messages that have been sent to each player, communication is always uncertain.
2. Also, let us demonstrate that if a player sends a message and does not receive a confirmation of its reception, it is more probable that the original message got lost than its confirmation got lost.
3. Finally, let us demonstrate that whatever the state of nature, both players should favor the low cost strategy (*l*).

Step 1: Considering $\alpha > 1/2$, we have:

$$P\left(I_{\bar{b}} \middle| I_0\right) = P/\left(P + (1-\alpha)\cdot\beta\right) > P\left(I_1 \middle| I_0\right) \tag{11}$$

In other words, if player 2 did not receive any messages, she thinks that it is more likely that the state of nature is $\bar{b}$, rather than that the first message was lost. In conclusion, in I_0, player 2 plays the lost cost strategy, namely *l*. To obtain perfect coordination, player 1 must thus play *l* if $\bar{b}$ by backward induction.

Step 2: In a different situation, if the first communication goes through, then player 2 knows by definition that the state of nature is *b*. Thus, apart from $I_{\bar{b}}$ and I_0, the uncertainty is no longer due to the initial event, which is now known to both players, but rather to the state of information of the other player. For example, in I_2, player 2 replied to the first message and if the exchange stops here, as she does not receive any further messages, she does not know if player 1 is in I_1 (player 1 sent the first message but did not receive the confirmation from player 2) or in I_3 (player 1 received the confirmation but did not send anything after that). More generally, if the player's state of information is I_t, she does not know whether the other is informed (i.e. I_{t-1}) or the confirmation got lost (i.e. I_{t+1}).

This verifies also in general terms: there is a greater chance that the communication was lost rather than the confirmation did not arrive. Indeed, we can calculate the conditional probabilities of I_{t-1} and I_{t+1} for any $t \geq 1$:

$$\begin{cases} \text{if } P\left(I_{t-1} \middle| I_t\right) = \left(\beta / \left(\beta + (1-\beta)\cdot\beta\right)\right) \\ \text{and } P\left(I_{t+1} \middle| I_t\right) = (1-\beta)\cdot\beta / \left(\beta + (1-\beta)\cdot\beta\right) \end{cases} \tag{12}$$

then:

$$P\left(I_{t-1} \middle| I_t\right) / P\left(I_{t+1} \middle| I_t\right) = 1/(1-\beta) > 1 \tag{13}$$

In conclusion, when in the set of information I_t, a player knows that the other player is more likely to be in I_{t-1} than in I_{t+1}. In other words, if player 2 did not receive a message, she thinks that it is more likely that player 1 plays as if the state of nature was $\bar{b}$ since player 1 is not certain that player 2 got the message. Hence player 2 will decide a low cost strategy, namely *l* even though the state of nature would require *h*.

Step 3: When the state of nature is $\bar{b}$ (no bubble), then both players should play the low cost strategy (*l*).

Indeed, in I_0, the optimization program for player 2 is:

$$\begin{cases} E(2|l) = P\left(I_{\bar{b}} \middle| I_0\right)\cdot\Pi_2^l\left(\bar{b}\right) + P\left(I_1 \middle| I_0\right)\cdot\Pi_2^l(b) \\ E(2|h) = P\left(I_{\bar{b}} \middle| I_0\right)\cdot\Pi_2^h\left(\bar{b}\right) + P\left(I_1 \middle| I_0\right)\cdot\Pi_2^h(b) \end{cases} \tag{14}$$

As $P\left(I_{\bar{b}} \middle| I_0\right) > P\left(I_1 \middle| I_0\right)$ and $\Pi_2^l\left(\bar{b}\right) > \Pi_2^h\left(\bar{b}\right)$, then player 2 always plays *l* when $\bar{b}$ and knowing that, player 1 plays *l* by backward induction.

When the state of nature is b, at I_1, player 1 knows b and knows that player 2 chooses l in I_0. Her expectations are then:

$$\begin{cases} E(1|l) = P\left(I_0 \middle| I_1\right)\cdot\Pi_1^l\left(\bar{b}\right) + P\left(I_2 \middle| I_1\right)\cdot\Pi_1^l(b) \\ E(1|h) = P\left(I_0 \middle| I_1\right)\cdot\Pi_1^h\left(\bar{b}\right) + P\left(I_2 \middle| I_1\right)\cdot\Pi_1^h(b) \end{cases} \tag{15}$$

As $P\left(I_0 \middle| I_1\right) > P\left(I_2 \middle| I_1\right)$ and $\Pi_1^l\left(\bar{b}\right) > \Pi_1^h\left(\bar{b}\right)$, then player 1 plays *l*.

To sum up, independently of the state of nature, both players always choose the low cost strategy. For that reason they follow a mimetic behavior since coordination is the goal. This equilibrium is obviously sub-optimal and sets the stage for the systemic risk. If the trend is positive, every player goes in the positive direction, and if the trend is negative, every player goes in the negative direction -- even if they know that the overall system is behaving perversely. They just follow the herd since coordination (also "benefitting from the bubble") is the goal.

Considering this result, we need now to reintegrate this reality into the MPT framework. Clearly, we have identified a new risk coming from mimetism. Mimetism is the cause here, systemic risk is the consequence. But mimetism is only a proxy here, the aim of which is to highlight the existence of systemic risk. Mimetism serves as a way to reconcile Finance with Industrial Organization. Later, we will propose a couple of other options from IO that will impact systemic risk. For now, we propose to include this new risk in the MPT framework by defining systemic risk as the endogenous risk of the financial industry:

$$\sigma_{sys}^{2} \tag{16}$$

3.3 Uncertainty and complexity introduced in the MPT framework

Let us go back to the definition of specific risk:

$$\sigma_{\varepsilon_P}^{2} = \sum_{i=1}^{n} x_i^{\,2} \cdot \sigma_{\varepsilon_i}^{2} + \sum_{i=1}^{n} \sum_{j \neq i} x_i^{\,2} \cdot \mathrm{cov}(\varepsilon_i, \varepsilon_j) \tag{17}$$

We can break down portfolio specific risk into two different components. We will use this approach then to justify the addition of the systemic risk in this framework. Indeed, (1) let us define the average of the assets' variance by ν, and let us call it the intrinsic variance since it is proper to the asset itself, with:

$$\nu = \frac{1}{n} \cdot \sum_{i=1}^{n} \sigma_{\varepsilon_i}^{2} \tag{18}$$

Then, (2) let us define the part of the portfolio specific risk coming from the mix of assets by κ , being the average covariance, with:

$$\kappa = \frac{1}{n^2 - n} \cdot \sum_{i=1}^{n} \sum_{j \neq i} \mathrm{cov}(\varepsilon_i, \varepsilon_j) \tag{19}$$

Then, specific risk can be re-written as:

$$\sigma_{\varepsilon_P}^{2} = \frac{1}{n} \cdot \nu + \frac{n^2 - n}{n^2} \cdot \kappa = \frac{1}{n} \cdot \nu + \left(1 - \frac{1}{n}\right) \cdot \kappa \tag{20}$$

Now, considering we want to bring an IO perspective, we will integrate the risk coming from the sub-optimal equilibrium from equation (16). We have two methodological options: the first is to add a third risk (the systemic risk) to both systematic and specific risks, and the second is to classify systemic risk as an intrinsic component of systematic risk. Our proposal is to use the former approach to stick to the existing literature.

Let us start with the definition of risk:

$$\sigma_P^2 = \beta_P^2 \cdot \sigma_M^2 + \sigma_{\varepsilon_P}^{2} \tag{21}$$

then if we want to add a new risk, we need to add a new variable to the portfolio return equation that will capture the premium (with a positive or negative value):

$$R_P = \alpha_P + \beta_P \cdot R_M + \varepsilon_P + \omega_P \tag{22}$$

then:

$$\sigma_P^2 = \beta_P^2 \cdot \sigma_M^2 + \sigma_{\varepsilon_P}^2 + \sigma_{sys}^2 \tag{23}$$

For illustration purpose, we propose the following representation of σ_{sys}^2 :

$$\sigma_{sys}^2 = \zeta(x) \cdot \frac{1}{\sqrt{x}} + x^{\zeta(x)} \tag{24}$$

σ_{sys}^2 is our proposal for the quantitative definition of Minsky's concept of instability. It is the endogenous risk coming from the financial market itself, in other words coming from its industrial organization. In our framework, it is not the only risk, but it is a contributor to the undiversifiable part of the model, and is rising due to mimetism. Mimetism is a dynamics that will give the big banks a strong market power, since it is reassuring to follow the leaders in the presence of unknowns. This is a well-understood story in information economics: the cascade effect. What we have done here is to maintain the mean-variance framework while augmenting it. Rather than rejecting it, obvious real world phenomena (booms and bursts) have been added while some of the attractive properties of this framework (the diversification principle, the search for better information, etc.) have been maintained.

This simple equation has multiple interesting features:

1. First of all, it has a parabolic shape, which can have the following interpretation: when the market is underdeveloped, a small number of banks has a strong market power leading to a high systemic risk, and when the market is deep, then again - due to rising uncertainty and complexity - a small number of banks (the big banks in fact) will have a strong market power due to the triggering of a mimetic strategy from the followers.
2. Second of all, let us define $\zeta(x)$ as the adjustment variable. Its properties are interesting in the sense that the higher $\zeta(x)$, the lower σ_{in}^2. The adjustment can take multiple forms, but the one we propose here is new financial regulations. The lesson of this model is that (1) we need new financial regulations and (2) we need to keep the interesting properties of the financial market. While we want to avoid going too far in terms of uncertainty, we also do not want as a society to go too far and prevent the financial markets from well-functioning.

If we were to represent how these results would translate in the mean-variance framework, a good start could be the graph inspired by Wagner and Lau (1971). Originally, the graph explains that the more assets in a portfolio, the lower the risk. This is the augmented diversification principle represented on the following graph:

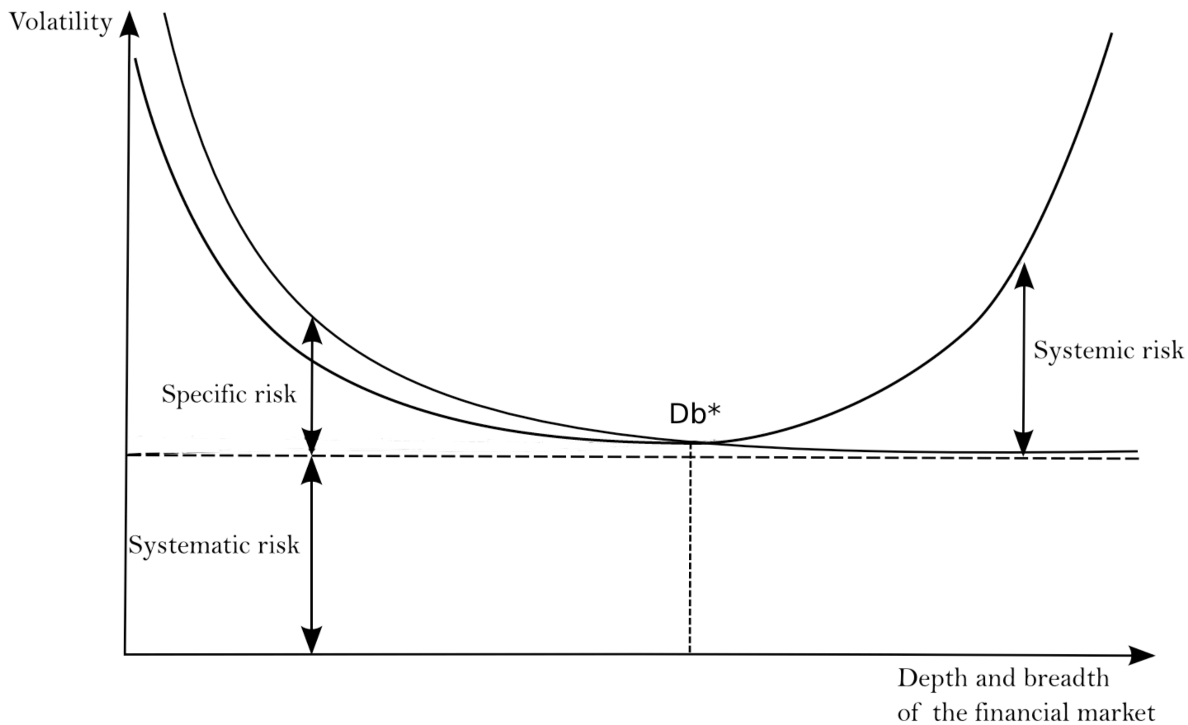

Figure 1. An interpretation and augmented version of Wagner and Lau's graph on portfolio diversification

In the above graph, the hyperbolic part of the curve captures the essence of Wagner and Lau (1971) and the MPT literature. Stated simply, the more diverse a portfolio, the lower the risk of the portfolio. Extrapolated to the financial world, the broader and the deeper a financial market, the more diversification opportunities exist, the consequence of which is a less risky market. According to the mean-variance assumptions, this leads to higher liquidity and lower risks. The whole economy becomes the beneficiary of a larger and more liquid financial market. The hyperbolic shape comes from the fact that the specific risk tends to zero, and what remains is the systematic or market risk. However, it seems that the missing element in this graph is the potential inefficiency of the financial market. We propose to use the bubble cycles to capture the financial market inefficiency. If one assumes that it is reasonable to define a bubble as a period during which the risk level goes up because the financial breadth and depth is increasing, this would translate into a new rise of the curve after a certain level of financial depth. To be fair, one can imagine three scenarios beyond point Db^*: (1) the first scenario is that the hyperbolic curve stays flat, (2) the second scenario is that the curve rises slightly, and (3) the third scenario is that the curve goes up tightly again.

From a hyperbolic curve, we move to a parabolic curve. The model presented here is captured by scenario #3. Financial broadening and deepening is seen to be beneficial as a consequence of diversification. However, at some point the costs associated with the complexity of the market begin to outweigh these benefits. Complexity enters the picture as a result of the continued broadening and deepening of the financial market. Beyond point A, complexity leads to a higher volatility of the market. What causes this volatility to reassert itself? Well, three varieties of risks are represented on this graph: (1) the specific risk, (2) the systematic or market risk, and (3) the systemic risk. Volatility is increasing: we can imagine that the specific and the market risks remain at the same level, but that the rise is due to the increase in the systemic risk. Beyond a certain point (point Db^* here), the financial is too broad and too deep to have a clear vision of the degree of interdependence of the different products and different players. The market is thus becoming too complex, and probably too interdependent. Complexity can also become opacity.

4 Results and conclusion

The main result of the above approach is methodological: we capture the dynamics of human action during a bubble. But beyond this, our aim has been to highlight the importance of integrating modern developments in IO with the portfolio theory. We see considerable value in breaking up the silos in which each discipline stands. This is even truer when it comes to the financial industry. We also wanted to stress the relative weakness of the received definition of the systematic risk. Indeed, there was a missing element: systemic risk. Systematic risk is misleading: in referring to macroeconomic impacts on the financial market, one could infer that it gathers every possible event beyond the risk ascribed to the asset, namely the specific risk. But there is a nuance: a macroeconomic risk is not the same as an industry-related risk. Moreover, a risk related to the financial industry itself - relying on this risk - is by definition different from systematic risk. This circumlocution in the definition is indirect evidence for the endogeneity of some financial system risks. This, then, is where the IO perspective enters. However, this does not mean that this systemic risk is always present. As shown on our graph, it is high when financial markets do not provide the sufficient depth and breadth to diversify risks, declines as markets become more competitive and innovative, and then rises again when this depth and breadth goes so far as to create complexity and thus uncertainty. Since the important writings of Frank Knight (1929), astute analysts working in decision theory have appreciated the difference between risk and uncertainty, what we are trying to capture with our model is the notion that when markets go beyond a certain depth, they beging to push the definition of risk to its limits and move closer to the notion of uncertainty (Knight 1929).

The way we decided to go is based on the notion of mimetism. We see several merits to such an approach. First, it deploys the conventional assumption that agents are rational and for that reason they know they are in a bubble. What they do not know is when it bursts. We think it is a little more plausible than beginning with the assumption that financial market players simply do not know what they are doing. Our approach also enables us also to incorporate Minsky's criticism and that of the post-Keynesian school, while fleshing out an important dimension of it: prolonged financial stability can lead to optimism, even though people are aware that a bubble is emerging. In this framework, we could demonstrate that the nature of information makes people select what is in fact a sub-optimal strategy. This strategy is used as our evidence for the existence of systemic risk. Mimetism is a proxy that captures systemic risk. When we integrate this first result into the mean-variance framework, we can then derive its impact on the definitions of risk, which leads to the augmented-Wagner and Lau's graph.

In a nutshell, we conclude with what we hope is a balanced perspective, a result that is perhaps rare in the literature these days. We also recognize the necessity for the existence of a financial industry while advocating for a better and more efficient financial market. Failing that, risk can become uncertainty, complexity can become opacity.

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