

# DESTRUCTIVE COORDINATION

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*An important goal of financial risk regulation is promoting coordination. Law’s coordinating function minimizes costly conflict and encourages greater uniformity among market participants. Likewise, privately developed market standards, such as standard-form contracts and rules incorporated into widely used vendor technology systems, help to lower transaction costs partly by increasing coordination.*

*By contrast, much of modern financial economics is premised on a world without coordination. Basic tools used to manage financial risk presume that changes in asset prices follow a random walk and individuals buy and sell assets independently. Thus, a bedrock premise of traditional risk management is that a portfolio manager’s actions affect neither the marketplace nor the trading decisions of others.*

*The result is a paradox: regulations and standards that benefit financial firms and markets can also impose unintended and significant costs—what I label “destructive coordination”—by inducing portfolio managers to act in unison and, in turn, affecting asset prices and eroding the core presumptions underlying much of financial risk management. Greater uniformity can increase the magnitude of a drop in the financial markets, a result that can have systemic effects.*

*Going forward, coordination’s benefits must be weighed against its costs, which are often less well understood. Expanding the scope of regulation beyond individual firms—taking into account the collective impact of coordination on the financial markets and the expectation of market participants—can help fill gaps in today’s regulatory framework. Financial regulators must also consider the role of market standards in promoting coordination, as individual firms are unlikely to have sufficient incentives (or information) to police them themselves.*

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### INTRODUCTION

Promoting coordination is an important function of the law.<sup>1</sup> A familiar example is driving on the right-hand side of the road. There is no intrinsic reason why driving on the right is superior to driving on the left, and over time (and a few near-accidents), I would likely figure out which, if any, convention exists where I was travelling. In that instance, law assists in coordinating actions—for example, it allows drivers to anticipate what others will do and adjust their responses,<sup>2</sup> ordering conduct and, in turn, minimizing the potential for costly conflict.<sup>3</sup> Even if I were to gain individually by driving on the left, I would be reluctant to risk upsetting a standard that, if uniformly followed, significantly benefitted all drivers (including myself).<sup>4</sup>

<sup>1</sup> There is extensive scholarship on law's coordinating function, a portion of which I briefly describe *infra* at notes 38–59 and accompanying text. The full scholarship includes analyses of law's effect on the ability of diverse parties to enter into and enforce agreements, set widely accepted standards, provide focal points that minimize unnecessary conflict and negotiation, and organize to bring about socially desirable goals that, pursued individually, would be more likely to fail. See TOM D. CAMPBELL, *THE LEGAL THEORY OF ETHICAL POSITIVISM* 50–51 (1996) (describing various types of coordination rules); Jules Coleman, *Authority and Reason*, in *THE AUTONOMY OF LAW: ESSAYS ON LEGAL POSITIVISM* 287, 304–05 (Robert P. George ed., 1996) [hereinafter *AUTONOMY OF LAW*] (noting that law's coordinating function makes possible social institutions that would otherwise not exist because “none of us is capable either of creating the institutions individually or of organizing the large-scale collective efforts that would otherwise be necessary”); Richard H. McAdams, *A Focal Point Theory of Expressive Law*, 86 VA. L. REV. 1649, 1666–68, 1676–78 (2000) (discussing how legal rules function as focal points for coordinating individual action); Gerald J. Postema, *Coordination and Convention at the Foundations of Law*, 11 J. LEGAL STUD. 165, 183–86 (1982) (applying coordination principles to judicial decision making); Cass R. Sunstein, *Problems with Rules*, 83 CALIF. L. REV. 953, 969–71 (1995) (describing how rules allow individuals to overcome collective action problems by encouraging coordinated behavior).

<sup>2</sup> See CAMPBELL, *supra* note 1, at 50, 53; DAVID K. LEWIS, *CONVENTION: A PHILOSOPHICAL STUDY* 44–45 (1969); Sunstein, *supra* note 1, at 976.

<sup>3</sup> See Joseph Raz, *Intention in Interpretation*, in *AUTONOMY OF LAW*, *supra* note 1, at 249, 273.

<sup>4</sup> See FREDERICK SCHAUER, *PLAYING BY THE RULES: A PHILOSOPHICAL EXAMINATION OF RULE-BASED DECISION-MAKING IN LAW AND IN LIFE* 164–66 (1991).

Yet, not all coordination is beneficial. Some coordination can have unintended and costly consequences, which I label *destructive coordination*. Consider the story of London's Millennium Bridge.<sup>5</sup> The bridge took four years to construct and, in the process, passed a series of stress tests and code requirements, including a wind tunnel test that simulated a "once every thousand years" gust and concrete supports that could withstand the impact of a 4,000-ton boat travelling at thirty-seven knots.<sup>6</sup> Nevertheless, on opening day, the bridge began to sway wildly, making it impossible for pedestrians to walk or stand.<sup>7</sup>

What went wrong? Every structure has a natural, resonant frequency. Accordingly, the British design codes (like others around the world) required engineers to model vibrations from pedestrian traffic but presumed that large crowds would walk out of step. In effect, each person's walk was expected to follow a random distribution, with one pedestrian largely cancelling out another's. What the codes failed to consider was the prospect of destructive coordination—the possibility, in this case, that large crowds could naturally begin to coordinate, with costly consequences. Chance correlation resulted in some pedestrians walking in unison.<sup>8</sup> Others changed their step in response to a slight give in the bridge.<sup>9</sup> The outcome was a positive feedback loop—the bridge swayed, prompting pedestrians to adjust their step and, in turn, cause the bridge to sway even more.<sup>10</sup> Necessary repairs took almost two years and cost \$7.5 million to complete.<sup>11</sup>

Of course, not all coordination is destructive. In the financial markets, coordination helps to minimize costs and promote stability.<sup>12</sup> Banks, for example, are required to set aside capital against prospective losses, creating a cushion against insolvency and reducing the risk of failure but also increasing the costs of traditional lending.<sup>13</sup> Regulators, therefore, needed to level the regulatory playing field. Global

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<sup>5</sup> For this analogy, I draw on observations made in Jón Daníelsson & Hyun Song Shin, *Endogenous Risk*, in *MODERN RISK MANAGEMENT: A HISTORY* 297, 297–99 (2003) [hereinafter *MODERN RISK MANAGEMENT*].

<sup>6</sup> Richard Morrison, *Bridge of Dreams*, *TIMES* (U.K.), June 6, 2000, at 4; see DEYAN SUDJIC, *BLADE OF LIGHT: THE STORY OF LONDON'S MILLENNIUM BRIDGE* 32, 36 (2001).

<sup>7</sup> See Ian Sample, *The Bridge of Sways*, *NEW SCIENTIST*, Mar. 31, 2001, at 38, 40.

<sup>8</sup> See STEVEN STROGATZ, *SYNC* 172–74 (2003); SUDJIC, *supra* note 6, at 84; Morrison, *supra* note 6.

<sup>9</sup> See Mahmoud M. Abdulrehem & Edward Ott, *Low Dimensional Description of Pedestrian-Induced Oscillation of the Millennium Bridge*, 19 *CHAOS* 013129-1, 013129-1 (2009), [http://chaos.aip.org/resource/1/chaoeh/v19/i1/p013129\\_s1?bypassSSO=1](http://chaos.aip.org/resource/1/chaoeh/v19/i1/p013129_s1?bypassSSO=1).

<sup>10</sup> See *id.*; Steven H. Strogatz et al., *Crowd Synchrony on the Millennium Bridge*, *NATURE*, Nov. 2005, at 43.

<sup>11</sup> See T.R. Reid, *After Shaky Start, London Bridge Reopens; Nearly Two Years of Modifications Take the Wobble Out of Millennium Project*, *WASH. POST*, Feb. 23, 2002, at A14.

<sup>12</sup> See Robert B. Ahdieh, *The Visible Hand: Coordination Functions of the Regulatory State*, 95 *MINN. L. REV.* (forthcoming 2010) (manuscript at 32–35) (on file with author).

<sup>13</sup> See Charles K. Whitehead, *Reframing Financial Regulation*, 90 *B.U. L. REV.* 1, 14–16 (2010).

standards were developed in part so that banks in one country would not be disadvantaged relative to banks in another.<sup>14</sup>

Beyond regulation, financial market participants also reduce transaction costs by improving coordination through market standards. Standard-form contracts, for example, lower the expense of negotiating deals whose terms have become industry convention. Network benefits also flow from common use, including less uncertainty over a contract's meaning and consistent business practices around how its terms are implemented.<sup>15</sup> In addition, new technology reduces the costs of complying with regulation and best practices. Vendor-developed systems automate compliance and, in the process, make it more likely that different firms (using the same systems) will respond to market change in the same manner.<sup>16</sup>

Coordination, therefore, is a goal of many financial market participants. By contrast, the basic tools used to manage financial risk—like the British design codes—presume a world of independent actors. Within this world, one manager's decision to buy or sell assets does not influence others' actions or affect changes in the marketplace. Managers act separately, each on their own.<sup>17</sup> Coordination, therefore, is inconsistent with the analytical framework underlying much of financial risk management.

The result is a paradox: regulations and standards that benefit financial firms and markets can also be destructive. By promoting coordination, regulations and standards can erode key presumptions underlying financial risk management, reducing its effectiveness and magnifying the systemic impact of a downturn in the financial markets.<sup>18</sup> Following a drop in asset price, for example, capital regulation can increase a manager's cost of holding impaired assets. As different managers experience similar effects, they are likely to react in the same way by each selling assets, causing greater price volatility and

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<sup>14</sup> See *infra* notes 46–49 and accompanying text.

<sup>15</sup> See *infra* notes 51–59 and accompanying text.

<sup>16</sup> See *infra* notes 185–95 and accompanying text.

<sup>17</sup> See *infra* notes 62–64 and accompanying text.

<sup>18</sup> In this Article, *systemic risk* and similar terms mean those factors that increase the risk of a significant loss of value by, or confidence in, the financial system, in turn, often by limiting retail and institutional access to capital, resulting in a significant downturn in the real economy. See GROUP OF TEN, REPORT ON CONSOLIDATION IN THE FINANCIAL SECTOR 126 (2001), available at <http://www.bis.org/publ/gten05.pdf>; see also Olivier de Bandt & Philipp Hartmann, *Systemic Risk: A Survey* 10–13 (European Cent. Bank Working Paper No. 35, 2000) (establishing “a framework for the economic analysis of systemic risk”); John B. Taylor, *Defining Systemic Risk Operationally*, in ENDING GOVERNMENT BAILOUTS AS WE KNOW THEM 33, 34–37 (Kenneth E. Scott et al. eds., 2009) (producing an operational definition of systemic risk as a means to set limits on government bailouts). A catalogue of definitions of systemic risk appears in Troy A. Paredes, *On the Decision to Regulate Hedge Funds: The SEC's Regulatory Philosophy, Style, and Mission*, 2006 U. ILL. L. REV. 975, 983, and Steven L. Schwarcz, *Systemic Risk*, 97 GEO. L.J. 193, 196–204 (2008).

prompting further sales. The result is a cascading decline in value, with greater coordination impairing each firm's ability to manage its own risk exposure.<sup>19</sup> In short, although regulation and market standards can help reduce systemic risk,<sup>20</sup> they themselves can also *become* a systemic risk.<sup>21</sup>

Behavioral economists argue that herding can inflate asset prices—portfolio managers buy assets, as part of a crowd, to reduce the chance of being second-guessed or to mimic investors who are considered to be better able to assess value.<sup>22</sup> This behavior typically results in an asset bubble—a run-up in price unsupported by the asset's fundamentals.<sup>23</sup> Under those conditions, a later drop in price (or other event) can trigger more herding, but in reverse, causing some managers to sell assets, creating another drop in price and spurring further sales.<sup>24</sup> The magnitude of the drop, and how long it is sustained, will depend on the number of managers prompted by the event to sell assets. Within a diverse group, the range of such events is likely to be limited. Different managers will find different events to be more or less relevant than others, with some responses (to hold or buy) offsetting the impact of others (to sell) and vice versa.<sup>25</sup> Greater

<sup>19</sup> See *infra* notes 126–47 and accompanying text.

<sup>20</sup> See, e.g., Schwarcz, *supra* note 18, at 205–06 (advocating systemic risk regulation); Hal S. Scott, *The Reduction of Systemic Risk in the United States Financial System*, 33 HARV. J.L. & PUB. POL'Y 671, 679–732 (2010) (describing proposals to reduce systemic risk).

<sup>21</sup> My argument extends beyond the debate over the role of regulation leading up to the 2007 financial crisis. Those arguments have largely focused on regulation's inadequacy or inability to keep up with evolving financial markets. On inadequacy, see, for example, John C. Coffee, Jr. & Hillary A. Sale, *Redesigning the SEC: Does the Treasury Have a Better Idea?*, 95 VA. L. REV. 707, 727, 731–37 (2009) (arguing that under-regulation fueled the subprime mortgage meltdown and credit crisis); Patricia A. McCoy et al., *Systemic Risk Through Securitization: The Result of Deregulation and Regulatory Failure*, 41 CONN. L. REV. 1327, 1333 (2009) (stating that deregulation played a “key determining role” in the creation of products that led up to financial crisis). On regulation's inability to keep up with change in the financial markets, see, for example, James Fanto, *Anticipating the Unthinkable: The Adequacy of Risk Management in Finance and Environmental Studies*, 44 WAKE FOREST L. REV. 731, 751–55 (2009) (arguing that the complexity of new financial instruments and activities poses significant problems for regulation and risk management); Andrew W. Lo, *Regulatory Reform in the Wake of the Financial Crisis of 2007–2008*, at 15 (Mar. 10, 2009) (unpublished working paper), available at <http://ssrn.com/abstract=1398207> (noting the need for a “major overhaul” of bank and insurance regulations currently “designed to cover a much narrower and simpler set of business activities and instruments”).

<sup>22</sup> See Lawrence A. Cunningham, *Behavioral Finance and Investor Governance*, 59 WASH. & LEE L. REV. 767, 783–84 (2002); Kenneth A. Froot et al., *Herd on the Street: Informational Inefficiencies in a Market with Short-Term Speculation*, 47 J. FIN. 1461, 1461–62 (1992); David S. Scharfstein & Jeremy C. Stein, *Herd Behavior and Investment*, 80 AM. ECON. REV. 465, 465–66 (1990).

<sup>23</sup> Some famous asset bubbles, and the psychology around them, are described in BURTON G. MALKIEL, *A RANDOM WALK DOWN WALL STREET* 35–53 (1999).

<sup>24</sup> See Dilip Abreu & Markus K. Brunnermeier, *Bubbles and Crashes*, 71 ECONOMETRICA 173, 173–76 (2003).

<sup>25</sup> See *id.* In that respect, the analysis is similar to John Keynes's well-known comparison of the stock market to a beauty contest:

coordination, by contrast, broadens the range of events likely to provoke a similar response—influencing managers’ expectations and increasing the pressure to herd.<sup>26</sup> As the Committee on the Global Financial System, Bank for International Settlements, recently cautioned (regarding global regulation), “[C]onvergence to a single risk assessment or risk management framework . . . would encourage herd behaviour and weaken financial stability.”<sup>27</sup>

Perhaps the most well-known—and a more direct—example of destructive coordination in the financial markets is the feedback loop that helped fuel the Black Monday crash of 1987. Portfolio insurance, which exacerbated the feedback loop, involved widely used computer programs that automatically executed orders to sell shares when prices fell to prespecified levels. Black Monday followed a sustained bull market during which stock prices rose substantially. Concerns about overvalued stocks caused some investors to sell shares, starting a decline in price that triggered a downward spiral of selling by portfolio insurance programs across the marketplace. Those sales sparked further price declines and additional sales as shares reached new price levels.<sup>28</sup>

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[P]rofessional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each competitor has to pick, not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view.

JOHN MAYNARD KEYNES, *THE GENERAL THEORY OF EMPLOYMENT INTEREST AND MONEY* 156 (1936).

<sup>26</sup> See *infra* notes 148–52 and accompanying text.

<sup>27</sup> Bank for Int’l Settlements, Comm. on the Global Fin. Sys., *Long-Term Issues in International Banking* 31 (CGFS Papers No. 41, 2010), available at <http://www.bis.org/publ/cgfs41.pdf>; see also Roberta Romano, *Against Financial Regulation Harmonization: A Comment* 16-21 (Nov. 20, 2010) (unpublished working paper), available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1697348&download=yes](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1697348&download=yes) (describing the perils of regulatory harmonization that resulted in “converging strategies, which exacerbated [financial intermediaries’] financial difficulties as many institutions simultaneously sought to sell similar assets to shore up their capital”).

<sup>28</sup> See *infra* notes 187–90 and accompanying text. The May 2010 “flash crash” was also prompted, in part, by parallel trading activity. On May 6, 2010, a large institutional trader initiated a sell program to hedge an existing equity position, using an automated execution program to sell futures contracts without regard to price or time. Sudden price declines in the equity markets caused the automated trading systems of other large market participants to temporarily “pause” their trading—neither buying nor selling stocks. A pause can be an effective way to halt a downward spiral such as the one that occurred during Black Monday. However, when everyone pauses in unison, a pause can also make it increasingly difficult to buy and sell stocks as participants withdraw from the market, potentially causing a sudden and substantial drop in price. See FINDINGS REGARDING THE MARKET EVENTS OF MAY 6, 2010: REPORT OF THE STAFFS OF THE CFTC AND SEC TO THE JOINT ADVISORY COMMITTEE ON EMERGING REGULATORY ISSUES 1–7 (2010), available at <http://www.sec.gov/news/studies/2010/marketevents-report.pdf>.

Coordination's destructive effects suggest that regulators must be sensitive to legislation's ability to promote uniformity. In fact, the Dodd–Frank Wall Street Reform and Consumer Protection Act (the Dodd–Frank Act, or the Act),<sup>29</sup> enacted in July 2010, grants considerable discretion to regulators to implement new rules and potentially increase uniformity among financial market participants. For example, significant nonbank financial firms may now become subject to new Federal Reserve Board (FRB) oversight,<sup>30</sup> including requirements related to capital, leverage, liquidity, market concentration, and risk management.<sup>31</sup> The Act requires the FRB, to the extent possible, to take account of significant differences in business and operations when implementing new regulation.<sup>32</sup> Still, by falling under the same regulator, the Act leaves open the likelihood of greater uniformity among large nonbank financial firms. Of course, imposing the same rules on similar businesses has important benefits, such as minimizing the arbitrage that can result if small changes in business cause sharp changes in regulatory cost.<sup>33</sup> Nevertheless, as new rules are introduced, regulators must be sensitive to the negative effects of greater coordination and the system-wide consequences that may follow.

Here, the Dodd–Frank Act offers some hope. Among its duties, the new Financial Stability Oversight Council (the Oversight Council) must identify risks to U.S. financial stability arising from activities in or outside the financial services marketplace.<sup>34</sup> As part of its mandate, the Oversight Council is required to “identify gaps in regulation that could pose risks to” U.S. financial stability<sup>35</sup> and make recommendations to primary financial regulatory agencies to “apply new or heightened standards and safeguards for financial activities or practices that could create or increase risks” among financial firms and markets.<sup>36</sup> On their face, both provisions authorize the Oversight Council to assess the systemic consequences (and costs) of financial regulation and market standards that promote coordination and propose or recommend changes that take account of coordination's destructive effects. A key question is whether, in line with the Act, regulators will balance

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<sup>29</sup> Pub. L. No. 111-203, 124 Stat. 1376 (2010) (to be codified at 12 U.S.C. § 5301).

<sup>30</sup> *Id.* §§ 112(a)(2)(H), 113, 124 Stat. at 1394–1402 (to be codified at 12 U.S.C. §§ 5322, 5323).

<sup>31</sup> *Id.* §§ 115(b), 165, 124 Stat. at 1403–04, 1423 (to be codified at 12 U.S.C. §§ 5325, 5364).

<sup>32</sup> *Id.* §§ 115(b)(3), 165(b)(3), 124 Stat. at 1404, 1424–25 (to be codified at 12 U.S.C. §§ 5325(b)(3), 5365(b)(3)).

<sup>33</sup> *Id.* §§ 115(b)(3)(B), 165(b)(3)(B), 124 Stat. at 1404, 1425 (to be codified at 12 U.S.C. §§ 5325(b)(3)(B), 5365(b)(3)(B)).

<sup>34</sup> *Id.* §§ 111, 112, 124 Stat. at 1392–98 (to be codified at 12 U.S.C. §§ 5321, 5322).

<sup>35</sup> *Id.* § 112(a)(2)(G), 124 Stat. at 1395 (to be codified at 12 U.S.C. § 5322(a)(2)(G)).

<sup>36</sup> *Id.* § 112(a)(2)(K), 124 Stat. at 1395 (to be codified at 12 U.S.C. § 5322(a)(2)(K)).

coordination's benefits against its costs in developing new systemic risk regulation.

Part I of this Article reviews the benefits of coordination, drawing on specific examples from the financial markets. It then introduces basic concepts that inform a substantial portion of modern financial risk management. Those concepts, at their heart, presume that individual portfolio managers act independently and that their actions affect neither asset prices nor the actions of others. This Part also introduces Value at Risk (VaR), the most widely adopted of the risk management technologies, and discusses regulations and standards that incorporate VaR.

Part II describes the resulting paradox. Regulation and standards that promote coordination—and benefit the financial markets—can also be destructive, eroding the presumptions that make financial risk management effective. In addition, technology systems that implement regulation and best practices can reinforce standardization across financial firms. This Part also considers coordination's relationship to herding, arguing that it creates negative externalities that regulators must take into account in regulating the financial markets.

Financial regulation and standards typically center on individual firms, each considered separately.<sup>37</sup> Part III argues that, going forward, in order to fill gaps in today's regulatory framework, regulation's scope must extend beyond individual firms and take into account coordination's collective impact on the financial markets. In addition, regulators must oversee market standards that, like regulation, can promote coordination. Those standards reduce transaction costs, and so individual firms are unlikely to have sufficient incentives (or information) to police them themselves.

## I

### COORDINATION AND RANDOMNESS

Coordination's benefits must be balanced against its destructive potential. This Part begins by describing those benefits, drawing on examples from the financial markets. It then reviews key presumptions underlying financial risk management, as well as the example of VaR. The next Part considers the resulting paradox—the likelihood that, in a world that presumes randomness, regulation and market standards that promote coordination can also be destructive.

#### A. Coordination

Three game theory models—the Stag Hunt, the Dove–Hawk, and the Battle of the Sexes Games—help illustrate coordination problems

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<sup>37</sup> See *infra* note 126 and accompanying text.



in the financial markets.<sup>38</sup> A coordination problem arises when the outcome of one person's decision rests on the uncertain actions of third parties.<sup>39</sup> This problem involves a cost—the risk that the decision will not be optimal in light of the outcome's dependence.<sup>40</sup> In response, regulation and market standards can increase certainty and lower costs by mandating some actions and ruling out others.<sup>41</sup>

Figure 1 depicts the Stag Hunt Game, which involves two players who have the same preferences. If Player 2 selects Strategy A (a payout of 4 or 0, depending on Player 1's decision), then Player 1 would be better off also selecting Strategy A (a payout of 4) rather than Strategy B (a payout of 3). If Player 2 instead selects Strategy B (a payout of 3 in both cases), then Player 1 would also be better off selecting Strategy B (a payout of 3) rather than Strategy A (a payout of 0). The key to the Stag Hunt is in each strategy's relative riskiness for each player. There are two coordinated outcomes—A/A and B/B. Selecting Strategy A can result in a payout of 4, but if the other player picks Strategy B, it instead yields a payout of 0. Strategy B is less risky for both players because it always results in a payout of 3, but at the expense of reducing the maximum possible return. On balance, absent assurance over what the other player will do, each player is likely to pick Strategy B—the safer approach—resulting in a B/B equilibrium, even though A/A would have yielded a higher payout for both.<sup>42</sup>

FIGURE 1: STAG HUNT GAME

Player 2 Player 1	Strategy A	Strategy B
Strategy A	4, 4	0, 3
Strategy B	3, 0	3, 3

<sup>38</sup> Descriptions of the three coordination games come from Richard H. McAdams, *Beyond the Prisoners' Dilemma: Coordination, Game Theory, and Law*, 82 S. CAL. L. REV. 209, 219–24 (2009).

<sup>39</sup> See Postema, *supra* note 1, at 173.

<sup>40</sup> See LARRY ALEXANDER & EMILY SHERWIN, *THE RULE OF RULES: MORALITY, RULES, AND THE DILEMMAS OF LAW* 14–15 (2001); LEWIS, *supra* note 2, at 24–25; Joseph Raz, *Facing Up: A Reply*, 62 S. CAL. L. REV. 1153, 1188–89 (1989); Sunstein, *supra* note 1, at 970–71.

<sup>41</sup> See Scott A. Beaulier et al., *Knowledge, Economics, and Coordination: Understanding Hayek's Legal Theory*, 1 N.Y.U. J.L. & LIBERTY 209, 211–15 (2005); Emily Sherwin, *Legal Rules and Social Reform*, 36 SAN DIEGO L. REV. 455, 462–63 (1999).

<sup>42</sup> The game's reference to a "stag hunt" comes from Jean-Jacques Rousseau's brief illustration of the choice between hunting stag and hunting hare. See JEAN-JACQUES ROUSSEAU, *DISCOURSE ON THE ORIGIN OF INEQUALITY* 57–58 (Patrick Coleman ed., Franklin Philip trans., Oxford Univ. Press 1994). In the parable, the hunters must work as a team in order to catch a stag—which is the best outcome (A/A). Hunting hare is less risky, since

The Stag Hunt Game has a parallel in the financial markets. Banks typically rely on short-term credit (deposits) to invest in a portfolio of longer-term assets (loans). Depositors, as a whole, benefit by pooling money that the bank can then lend (an A/A outcome) but suffer if a substantial number of other depositors withdraw funds first (an A/B or B/A outcome). In the latter circumstance, a bank may not be able to sell its assets quickly enough or at the right prices to repay everyone.<sup>43</sup> Even if the bank is healthy, a loss of confidence may cause depositors to rush to withdraw money first—a bank run—rather than risk being last in line to be repaid (a B/B outcome, assuming all depositors are made whole).<sup>44</sup> Depositors, therefore, face a collective action problem. If none of them withdraws, the bank can continue business as usual. Panicked depositors, however, without the ability to gauge a bank's health or each other's actions, may rush to withdraw money from a stable bank, thereby causing the rumor of failure to become a self-fulfilling prophecy. A credible commitment among depositors that they will all keep their money in the bank is practically impossible, since depositors are dispersed and constantly changing. The alternative has been to create an insurance program, directed by the Federal Deposit Insurance Corporation, which protects depositors up to \$250,000.<sup>45</sup> An A/A outcome—no bank run—is more likely, because depositors have assurances of repayment (regardless of why the bank failed) and are now less likely to withdraw funds first.

Figure 2 depicts the Dove–Hawk Game, also involving two players, but whose interests are in greater conflict than in the Stag Hunt Game. The optimal coordinated response is Dove/Dove, but the pressure to defect is significant because it doubles the defector's return. If Player 2 is a Dove (a payout of 2 or 0, depending on Player 1's decision), Player 1's optimal response is to be a Hawk (a payout of 4 in-

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each hunter can easily do so on his own. The problem is that if one hunter later decides to catch hare, the entire stag hunt will fail (A/B or B/A). *See id.* Like Players 1 and 2, the hunters face a coordination problem and, absent a means for all hunters to credibly commit to hunting stag, each of them will likely decide to simply hunt hare (B/B).

<sup>43</sup> *See* Whitehead, *supra* note 13, at 13 (describing the impact of a bank run on a bank's sale of assets).

<sup>44</sup> *See* Douglas W. Diamond & Philip H. Dybvig, *Banking Theory, Deposit Insurance, and Bank Regulation*, 59 J. Bus. 55, 63 (1986); *see also* Ahdieh, *supra* note 12, at 15; McAdams, *supra* note 38, at 221. Although less common today, the United States has had bank runs in the past—the basis for the scene in Frank Capra's 1946 film, *IT'S A WONDERFUL LIFE* (Liberty Films 1946), when residents of the Bedford Falls township flocked to the struggling Bailey Brothers Building and Loan to get their money back.

<sup>45</sup> Brief descriptions of the Federal Deposit Insurance Corporation program and other government-directed insurance programs appear in Appendix A of Whitehead, *supra* note 13, at 45–46. Historically, other alternatives to prevent bank runs included the suspension of convertibility of notes and deposits into cash and the use of collateral. *See* Gary Gorton & Andrew Metrick, *Regulating the Shadow Banking System*, at 17–19 (Oct. 18, 2010) (unpublished working paper), *available at* [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1676947](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1676947).

stead of 2). Likewise, if Player 1 is a Dove (a payout of 2 or 0), Player 2's optimal response is to be a Hawk (a payout of 4 instead of 2). Each player, therefore, prefers to be a Hawk, but only if the other is a Dove. If both players defect, the result will be Hawk/Hawk—an outcome that neither prefers, as it is the worst possible payout for both (each receives a payout of -1).

FIGURE 2: DOVE–HAWK GAME

Player 1 \ Player 2	Dove	Hawk
Dove	2, 2	0, 4
Hawk	4, 0	-1, -1

The Dove–Hawk Game also has a parallel in the financial markets. During the 1980s, global competition caused bank-capital levels to fall dangerously low.<sup>46</sup> Capital provides a cushion against loans and other losses, but it can be expensive for banks to set aside, thereby increasing the cost of extending loans and reducing profitability.<sup>47</sup> The Basel Capital Accord (the Basel Accord, or the Accord), first adopted in 1988, called for regulators to impose a minimum capital level of 8% of risk-weighted assets on internationally active banks.<sup>48</sup>

<sup>46</sup> See SECRETARIAT OF THE BASEL COMM. ON BANKING SUPERVISION, THE NEW BASEL CAPITAL ACCORD: AN EXPLANATORY NOTE 11 (2001), available at <http://www.bis.org/publ/bcbcsca01.pdf>.

<sup>47</sup> See Stavros Gadinis, *The Politics of Competition in International Financial Regulation*, 49 HARV. INT'L L.J. 447, 500–01 (2008). Financial regulation directly and indirectly restricts the amounts and types of risk bearing that a financial firm can assume: directly by circumscribing the riskiness of a firm's portfolio and capital structure and indirectly through rules regarding the firm's net worth, capital, or surplus that effectively cap its risk-taking activities. See Robert Charles Clark, *The Soundness of Financial Intermediaries*, 86 YALE L.J. 1, 15–18, 23–24 (1976); Howell E. Jackson, *Regulation in a Multisectoral Financial Services Industry: An Exploratory Essay*, 77 WASH. U. L.Q. 319, 352–59 (1999); Jonathan R. Macey & Geoffrey P. Miller, *Bank Failures, Risk Monitoring, and the Market for Bank Control*, 88 COLUM. L. REV. 1153, 1165 (1988).

<sup>48</sup> Patricia A. McCoy, *Musings on the Seeming Inevitability of Global Convergence in Banking Law*, 7 CONN. INS. L.J. 433, 438 (2001). The Basel Committee on Banking Supervision adopted the Accord. The Basel Committee, established in 1974 by the central bank governors of the G10 countries under the auspices of the Bank for International Settlements, is comprised of central bankers and regulators from the world's principal financial markets. See *History of the Basel Committee and Its Membership*, BANK FOR INT'L SETTLEMENTS, <http://www.bis.org/bchs/history.htm> (last visited Sept. 3, 2010). Its purpose is to foster international cooperation on supervisory standards, practices, and guidelines for banks. Committee decisions are reached by a consensus, although the Committee's pronouncements are nonbinding on members. Nevertheless, the Basel Committee has strongly influenced the gradual convergence in global banking regulation and supervision. Chief among its suc-

As capital is costly, setting a higher level in one country (a Dove) would give banks in other countries (each a Hawk) a competitive advantage, yielding a Dove/Hawk payout favoring banks that were subject to a lower capital requirement. Permitting banks to continue to compete without restriction would have depressed capital levels even further—a Hawk/Hawk outcome in light of the increased risk of global financial distress. The Basel Accord facilitated a Dove/Dove payout among competing players—principally U.S., U.K., and Japanese regulators and banks—both by committing them to level the global playing field<sup>49</sup> and reinforcing expectations that other participants would continue to cooperate.<sup>50</sup>

Lastly, Figure 3 depicts the Battle of the Sexes Game, involving two players who prefer different strategies but would be worse off if they failed to coordinate. If Player 2 selects Strategy B, Player 1 is better off also selecting Strategy B (a payout of 1 instead of 0). Likewise, if Player 1 selects Strategy A, Player 2 is better off also selecting Strategy A (again, a payout of 1 instead of 0). Neither player benefits if there is a mixed outcome, A/B or B/A, and so both agree it would be best to coordinate. The players disagree, however, over what strategy to follow—Player 1's optimal outcome is A/A, and Player 2's optimal outcome is B/B.<sup>51</sup>

In the financial markets, the Battle of the Sexes Game appears in the widespread use of standard-form contracts, like those created by

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cesses has been the creation of uniform bank capital requirements, embodied (as amended from time to time) in the Basel Accord. See Charles K. Whitehead, *What's Your Sign?—International Norms, Signals, and Compliance*, 27 MICH. J. INT'L L. 695, 720–25 (2006); see also Fanto, *supra* note 21, at 736–37 (summarizing the Accord's evolving approach to managing risk).

<sup>49</sup> See Gadinis, *supra* note 47, at 502–03; Whitehead, *supra* note 48, at 720–25. For a summary of the conflict that existed among national regulators and between regulators and banks, see ETHAN B. KAPSTEIN, *GOVERNING THE GLOBAL ECONOMY: INTERNATIONAL FINANCE AND THE STATE* 113–28 (1994). Some commentators have suggested that the Accord is better represented by the Battle of the Sexes Game, which I describe below. See, e.g., Pierre-Hugues Verdier, *Transnational Regulatory Networks and Their Limits*, 34 YALE J. INT'L L. 113, 124 (2009) (describing the Battle of the Sexes Game as representing one type of problem that may hinder international cooperation efforts). The Dove–Hawk Game, however, more accurately illustrates the conflict between players and the potential for one player to obtain a greater payout at the other's expense. Banks in different jurisdictions stood to gain substantially if their competitors became subject to higher capital requirements. See Gadinis, *supra* note 47, at 501–02. The cheating alleged to have occurred by some Accord signatories further evidences that conflict. See McCoy, *supra* note 48, at 449–55.

<sup>50</sup> See Whitehead, *supra* note 48, at 738–41.

<sup>51</sup> The name *Battle of the Sexes* refers to a common illustration of the game. In it, Players 1 and 2 are husband and wife who decide to spend the evening together. Player 1 prefers attending the ballet, and Player 2 prefers going to a boxing match. Notwithstanding their differences, both still prefer spending the evening together, and so an A/A or B/B outcome—being together either in orchestra seating or at ringside—is preferable to spending the evening alone. See Ahdieh, *supra* note 12, at 28.

FIGURE 3: BATTLE OF THE SEXES GAME

Player 2 Player 1 \	Strategy A	Strategy B
Strategy A	3, 1	0, 0
Strategy B	0, 0	1, 3

the International Swaps and Derivatives Association (ISDA).<sup>52</sup> All parties can benefit from standardization, as regularity in contracting lowers the cost of repeated trades.<sup>53</sup> Network externalities also flow from common use, reducing uncertainty over the meaning and implementation of contract terms.<sup>54</sup> ISDA's Credit Support Annex (CSA) is one example.<sup>55</sup> The CSA defines the credit support obligations of counterparties to derivatives when those counterparties agree to be bound by it.<sup>56</sup> Although the CSA can be amended—and some parties favor some terms over others (Strategy A vs. Strategy B)—there is an overall bias in favor of adopting it and similar instances of standardization (an A/A or B/B outcome),<sup>57</sup> in part because it reflects a market-wide consensus<sup>58</sup> that is preferable to negotiating *ad hoc* credit support terms.<sup>59</sup> Market participants, like players in the Battle of the Sexes Game, had a strong incentive to create a market standard (a payout of 3, 1 or 1, 3) and little incentive to deviate (a payout of 0, 0).

The Stag Hunt, Dove–Hawk, and Battle of the Sexes Games are all simple models based on fixed payouts. Those payouts, however,

<sup>52</sup> See Stephen J. Choi & G. Mitu Gulati, *Contract as Statute*, 104 MICH. L. REV. 1129, 1139–41 (2006).

<sup>53</sup> See Caroline Bradley, *Private International Law-Making for the Financial Markets*, 29 FORDHAM INT'L L.J. 127, 165–70 (2005); Sean M. Flanagan, *The Rise of a Trade Association: Group Interactions Within the International Swaps and Derivatives Association*, 6 HARV. NEGOT. L. REV. 211, 232–33, 236–37 (2001). For examples of increased uncertainty that can result from common use, see *infra* note 172.

<sup>54</sup> See Michael Klausner, *Corporations, Corporate Law, and Networks of Contracts*, 81 VA. L. REV. 757, 761, 774–75 (1995); Janet Koven Levit, *A Bottom-Up Approach to International Law-making: The Tale of Three Trade Finance Instruments*, 30 YALE J. INT'L L. 125, 132–33, 144–46, 157–58 (2005).

<sup>55</sup> See INT'L SWAPS & DERIVATIVES ASS'N [ISDA], 1994 ISDA CREDIT SUPPORT ANNEX (1994) (Subject to New York Law Only) [hereinafter CSA].

<sup>56</sup> See ISDA, USER'S GUIDE TO THE 1994 ISDA CREDIT SUPPORT ANNEX 1 (1994).

<sup>57</sup> See Robert B. Ahdieh, *The Strategy of Boilerplate*, 104 MICH. L. REV. 1033, 1053–55 (2006).

<sup>58</sup> See Klausner, *supra* note 54, at 827–28; Levit, *supra* note 54, at 129, 167–68, 182.

<sup>59</sup> See ISDA, 2005 ISDA COLLATERAL GUIDELINES 21–23 (2005), available at <http://www.isda.org/publications/pdf/2005isdacollateralguidelines.pdf>; Norman Menachem Feder, *Deconstructing Over-the-Counter Derivatives*, 2002 COLUM. BUS. L. REV. 677, 741; see also *infra* notes 172–77 and accompanying text.

can change over time. Greater coordination can reduce costs within a growing group of players—a network benefit that increases payouts as coordination becomes a self-reinforcing outcome. Greater coordination, however, can also be costly. Recall that, on the Millennium Bridge, the costs of coordinating grew as more pedestrians began to walk in unison. “Defection” by some—if they had walked out of step—would have benefitted everyone (including those who were already coordinating). Coordination’s costs, in that case, outweighed its benefits.<sup>60</sup>

Is there a correct balance? One alternative, if coordination is destructive, is to avoid promoting coordination altogether. Another is to limit coordination to a defined group or mandate a coordination strategy for some players and not for others. A third alternative, if the technology exists, is to adopt a strategy that takes account of greater coordination among a growing universe of players. I return to this question later,<sup>61</sup> but first describe the core presumptions underlying financial risk management and the example of VaR.

## B. Probability, Randomness, and Games Against Nature

Much of modern financial economics is premised on a world without coordination. Rational individuals separately seek to maximize wealth, each guided by their own self-interest. The aggregate result is an optimal allocation of resources to those who can use them most productively.<sup>62</sup> A risk manager is understood to also seek strategies that minimize risk (relative to return) without affecting market prices or the value of others’ holdings.<sup>63</sup> Both of these concepts pre-

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<sup>60</sup> Roberta Romano has made a similar point about regulatory harmonization. When the effects of regulation are uncertain, the potential for regulatory error may argue in favor of diversity across regulatory regimes. See Romano, *supra* note 27, at 18.

<sup>61</sup> See *infra* notes 197–212 and accompanying text.

<sup>62</sup> Recall Adam Smith’s well-known description:

[Every individual] generally, indeed, neither intends to promote the public interest, nor knows how much he is promoting it. By preferring the support of domestic to that of foreign industry, he intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention.

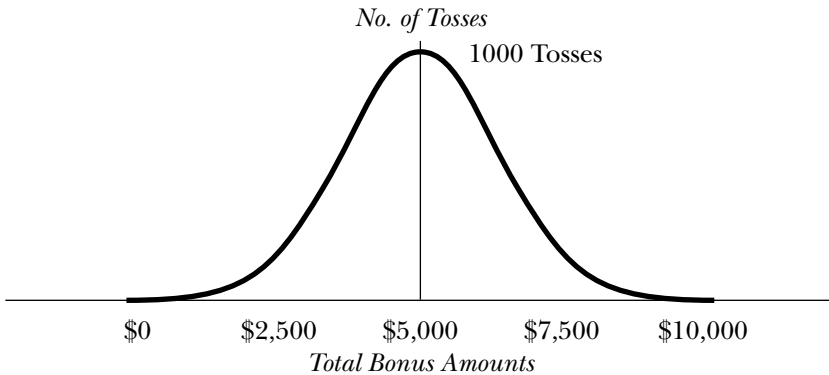
ADAM SMITH, AN INQUIRY INTO THE NATURE AND CAUSES OF THE WEALTH OF NATIONS 423 (Edwin Cannan ed., Random House, Inc. 1937) (1776). This account extends, as well, into the semistrong theory of the capital markets, which posits that stock prices efficiently adjust to information as it becomes publicly available, see Eugene F. Fama, *Efficient Capital Markets: A Review of Theory and Empirical Work*, 25 J. FIN. 383, 404 (1970); Ronald J. Gilson & Reinier H. Kraakman, *The Mechanisms of Market Efficiency*, 70 VA. L. REV. 549, 555 (1984), a concept that our federal securities laws incorporate, see *Basic Inc. v. Levinson*, 485 U.S. 224, 246 n.24 (1988).

<sup>63</sup> See Jón Daníelsson, *The Emperor Has No Clothes: Limits to Risk Modelling*, 26 J. BANKING & FIN. 1273, 1274 (2002).

sume that individuals buy and sell assets independently—a presumption integral to many of today’s financial risk management tools.<sup>64</sup>

Financial risk, in this context, can be objectively estimated.<sup>65</sup> The classic illustration is the coin toss. Suppose your law firm’s managing partner tells you that your year-end bonus will be \$5,000 but that the amount can be adjusted—potentially up to \$10,000 or down to \$0—based on the toss of a coin. You must decide up front how many times she will flip it. The rule is that, with one toss, you will receive an additional payment of \$5,000 if the coin shows heads (a total bonus of \$10,000), but you will give up the entire \$5,000 bonus if it shows tails (a total bonus of \$0). If you pick two tosses, you will receive \$2,500 each time the coin is heads and give up \$2,500 each time it is tails. If you choose three tosses, you will receive \$1,666.66 for each heads and give up \$1,666.66 for each tails, and so on. The expected value (EV) of your total bonus after one or two flips will be \$5,000. Likewise, the calculations for three, four, 500, or more flips will all result in the same EV, \$5,000.<sup>66</sup>

DIAGRAM 1: DISTRIBUTION OF YEAR-END BONUSES



<sup>64</sup> For the example of VaR, see *infra* notes 83–122 and accompanying text.

<sup>65</sup> In this Article, *financial risk* is the statistical probability that the return on a financial asset (for example, a stock, bond, or other security) will fall short of its expected outcome. See PHILIPPE JORION, *VALUE AT RISK: THE NEW BENCHMARK FOR MANAGING FINANCIAL RISK* 75 (3d ed. 2007). By contrast, “uncertainty” exists when the distribution of possible outcomes is unknown or unquantifiable. See FRANK H. KNIGHT, *RISK, UNCERTAINTY AND PROFIT* 231–35 (1921).

<sup>66</sup> For one toss, EV is the sum of a 50% chance of \$10,000 ( $50\% \times \$10,000$ ) + a 50% chance of no bonus ( $50\% \times \$0$ ). For two tosses, EV is the sum of a 25% chance of two heads ( $25\% \times \$10,000$ ) + a 50% chance of one head and one tail ( $50\% \times \$5,000$ ) + a 25% chance of two tails ( $25\% \times \$0$ ). In the case of three tosses, there is a 12.5% chance of three heads ( $12.5\% \times \$10,000$ ), a 37.5% chance of two heads and one tail ( $37.5\% \times \$6,666.67$ ), a 37.5% chance of two tails and one head ( $37.5\% \times \$3,333.33$ ), and a 12.5% chance of three tails ( $12.5\% \times \$0$ ). Totaling them up (and after rounding), the sum of  $\$1,250 + \$2,500 + \$1,250 + \$0$  results again in an EV of \$5,000.

So, if EV is a constant, why choose more than one flip of the coin? For each toss, the probability of heads or tails is 50%.<sup>67</sup> By picking just one toss, your entire bonus would rest on a single flip—you could end up with \$10,000, but you could just as equally end up with nothing. Two tosses would halve the amount you receive for each toss of heads, but your chance of receiving some amount of bonus would increase as well. The same would be true for three or more tosses. In each case, selecting more flips would lower the risk of receiving *less* than \$5,000, but in return, it would also lower the probability of receiving *more* than \$5,000. If the number of tosses your colleagues picked ranged between one and 1,000, we would expect the total number of outcomes to fall along a symmetrical bell curve (a “normal distribution”) like in Diagram 1. The graph’s x-axis is the range of possible bonuses (from \$0 to \$10,000) and the y-axis is the number of times the coin was tossed (from zero to 1,000), with the curve’s highest point (1,000 tosses) being near its middle (\$5,000).<sup>68</sup> The number of times the bonus was greater than \$5,000 roughly equals the number of times it was less, resulting in a firm-wide average of about \$5,000 per person.

For your bonus, the greater the number of flips, the greater the probability would be that the aggregate of all tosses would result in an amount falling somewhere near \$5,000. Yet, even by picking 1,000 or more tosses, there would be no guarantee of heads turning up exactly 50% of the time, resulting in a dispersion of possible outcomes around \$5,000. In some cases, you might receive more than \$5,000, but to the extent the dispersion fell below 50% heads (on the left side of the curve), it would reflect the financial risk of your receiving less than \$5,000.<sup>69</sup> That risk typically declines—the dispersion around \$5,000 contracts—as the number of coin tosses increases.<sup>70</sup>

In financial risk terms, by choosing more tosses, you will have diversified your portfolio of possible outcomes, thus reducing the risk of loss from any one toss as well as the level of dispersion around \$5,000, but doing so without reducing EV. The same concept drives the diversification principle in modern portfolio theory: an investor’s exposure to change in the market value of a portfolio of assets (“market risk”)

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<sup>67</sup> I ignore, for this purpose, a recent study that found a roughly 1% dynamical bias in favor of a coin landing in the same way it started. See Persi Diaconis et al., *Dynamical Bias in the Coin Toss*, 49 SOC’Y INDUS. & APPLIED MATHEMATICS 211, 231 (2007).

<sup>68</sup> See JEAN-PHILIPPE BOUCHARD & MARC POTTERS, *THEORY OF FINANCIAL RISKS: FROM STATISTICAL PHYSICS TO RISK MANAGEMENT* 8–10 (2000).

<sup>69</sup> See JORION, *supra* note 65, at 88 (measuring risk as the dispersion of possible outcomes); James E. Meyer et al., *Loss of Business Profits, Risk, and the Appropriate Discount Rate*, 4 J. LEGAL ECON. 27, 33 (1994).

<sup>70</sup> See MELVIN HAUSNER, *ELEMENTARY PROBABILITY THEORY* 232–33 (1977); JORION, *supra* note 65, at 163.



becomes more tractable as she diversifies her holdings.<sup>71</sup> To the extent a risk can affect the entire market (“systematic risk”), diversification is ineffective to reduce its impact on portfolio value. A general rise in interest rates, for example, would tend to cause a decline in the prices of all the shares an investor owns. Diversification, however, helps manage risks that are unique to each investment (“specific” or “nonsystematic” risk), including fluctuations in market price (“volatility”), so long as the correlation across assets is not perfectly positive.<sup>72</sup> Like the coin toss, an investor’s decision to diversify her holdings reduces the risk of loss from any one investment because gains from other investments can offset that loss. Unlike the coin toss, however, there will always be some correlation across assets—reflecting systematic risk—so that diversification can reduce total risk but cannot completely eliminate it.<sup>73</sup>

Let’s return to your bonus. Before deciding how many tosses to select, you would have no way of predicting the outcome of any one flip of the coin. Even after the first, second, and third tosses, how the coin landed next would be independent of prior and subsequent outcomes. Looking at the firm-wide results, however, you could estimate the likelihood of receiving \$5,000 based on the number of tosses selected as well as the risk that your tosses might result in a bonus below \$5,000.<sup>74</sup> In the same way, financial risk management presumes that changes in a security’s price, whether up or down, are unrelated to prior or subsequent changes or to changes in the prices of other se-

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<sup>71</sup> See HARRY M. MARKOWITZ, *PORTFOLIO SELECTION: EFFICIENT DIVERSIFICATION OF INVESTMENTS* 5 (2d ed. 1991). The literature on the use of diversification to reduce risk is vast. Harry Markowitz’s work formed the basis of further contributions by Merton Miller and William Sharpe, who shared the Nobel Prize in Economic Sciences with Markowitz in 1990.

<sup>72</sup> See RICHARD A. BREALEY, STEWART C. MYERS & FRANKLIN ALLEN, *PRINCIPLES OF CORPORATE FINANCE* 160–62 & nn.26–27 (8th ed. 2006). For example, if the investor owns shares of Companies A, B, C, and D, which are in separate business lines, a drop in Company A’s share price (resulting from a failed business project) could be offset by increases in the share prices of Companies B, C, and D (one or more of which could rise in response to a successful business project).

<sup>73</sup> See Harry Markowitz, *Portfolio Selection*, 7 J. FIN. 77, 79 (1952). The systematic risk of a security relative to the general market is also referred to as “beta” risk. A broad market index has a beta of one. Securities that are more volatile than the market index have betas greater than one, and securities that tend to be more stable than the market have betas less than one. Investors can diversify away nonsystematic risk at low cost. Thus, the capital asset pricing model (CAPM) concludes that an investor’s returns—the amount she receives for the risks she bears—are largely set by reference to her portfolio’s systematic risk exposure. A portfolio of securities whose prices vary considerably with changes in the market (like common stock) are exposed to greater systematic risk and potentially greater returns than a portfolio whose securities have little systematic exposure (like short-term Treasuries). See Lawrence A. Cunningham, *From Random Walks to Chaotic Crashes: The Linear Generalization of the Efficient Capital Market Hypothesis*, 62 GEO. WASH. L. REV. 546, 568–70 (1994).

<sup>74</sup> See BOUCHARD & POTTERS, *supra* note 68, at 1–2.

curities. Financial economists refer to this concept as “randomness.”<sup>75</sup> In an efficient market, factors that drive a change in price may not influence (or be indicative of) other changes. For example, differences of opinion over value, competition among market actors, and the release of new information all are likely to cause successive, independent changes in a security’s price.<sup>76</sup> Thus, securities prices—like single flips of a coin—follow an individually unpredictable “random walk.”<sup>77</sup> In aggregate, however, changes in price form a normal distribution—like the distribution of bonuses—from which individual investors may estimate future change.<sup>78</sup>

A risk manager’s job, in the face of randomness, is sometimes described as a “game against nature.”<sup>79</sup> The risk manager can estimate the likelihood of a change in market conditions as well as how the change can affect her portfolio’s value. Whether a portfolio gains or loses value will depend on both the risk management strategy that the risk manager selects and what actually occurs. To illustrate, a player knows the probabilities of winning and losing in roulette before the ball is spun.<sup>80</sup> Whether the player actually wins or loses will depend on how the bet is placed (strategy) and where the roulette ball lands (what actually occurs).<sup>81</sup> The strategy (putting all the chips on black) will not affect the spin of the ball, and if the player plays twice, where the ball lands first will not affect where it lands next. Like roulette, a risk manager’s strategy is presumed not to affect the world. Share prices continue to follow a random walk, unaffected by whatever strategy the risk manager selected, and the two together determine whether the portfolio is a “winner” or “loser.”<sup>82</sup>

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<sup>75</sup> See Peter H. Huang, *Securities Price Risks and Financial Derivative Markets*, 21 Nw. J. INT’L L. & BUS. 589, 590–91 (2001). VaR, for example, assumes that day-to-day fluctuations in returns are random. See LINDA ALLEN ET AL., UNDERSTANDING MARKET, CREDIT, AND OPERATIONAL RISK: THE VALUE AT RISK APPROACH 8–9 (2004).

<sup>76</sup> See Eugene F. Fama, *Random Walks in Stock Market Prices*, 21 FIN. ANALYSTS J., Sept.–Oct. 1965, at 55, 55–57.

<sup>77</sup> See RALF KORN & ELKE KORN, OPTION PRICING AND PORTFOLIO OPTIMIZATION: MODERN METHODS OF FINANCIAL MATHEMATICS ix (2001) (“There are only a few things in daily life which are regarded as a better synonym for uncertainty than security prices.”); Paul A. Samuelson, *Proof That Properly Anticipated Prices Fluctuate Randomly*, 6 INDUS. MGMT. REV. 41, 42 (1965).

<sup>78</sup> See M.G. BULMER, PRINCIPLES OF STATISTICS 115–16 (1979).

<sup>79</sup> See WILLIAM J. BAUMOL, ECONOMIC THEORY AND OPERATIONS ANALYSIS 459 (4th ed. 1977); Danielsson & Shin, *supra* note 5, at 301.

<sup>80</sup> This is true even when the gaming rules favor the house. See Robert J. Martin, *U.S. Gaming Operations: The Hospitality Subset of the Future*, 6 INT’L J. HOSPITALITY MGMT. 75, 80 (1987).

<sup>81</sup> See ANDREW M. COLMAN, GAME THEORY AND ITS APPLICATIONS IN THE SOCIAL AND BIOLOGICAL SCIENCES 10–11, 17–19 (Butterworth-Heinemann 2d ed. 1995) (1982).

<sup>82</sup> See Danielsson & Shin, *supra* note 5, at 301–02.

### C. Value at Risk

Until the 2007 financial crisis, VaR was widely regarded as the Stradivarius of risk management tools.<sup>83</sup> Like many financial risk measures,<sup>84</sup> VaR relies on the concepts described above—probability, randomness, and the presumption that portfolio managers, each operating on their own, do not affect market prices.<sup>85</sup> VaR's special attraction is its ability to sum up a portfolio's market risk—its risk of loss based on changes in market value—in a single number.<sup>86</sup> VaR has many versions, which can vary from firm to firm,<sup>87</sup> and their risk calculations may not be identical.<sup>88</sup> Nevertheless, the results of each are closely correlated when using similar parameters, data, and assumptions,<sup>89</sup> and they react in the same way (indicating greater risk) during periods of high volatility or stress.<sup>90</sup>

To calculate a portfolio's VaR, a risk manager typically considers the kinds of risks that affect value, including historical changes in market rates and prices and other historical factors.<sup>91</sup> She then generates *pro forma* estimates of value under those conditions and uses them to

<sup>83</sup> See GLYN A. HOLTON, *VALUE-AT-RISK: THEORY AND PRACTICE* 19 (2003) (noting that VaR is “not quite a household word” but is familiar to most financial professionals); INT'L MONETARY FUND, *GLOBAL FINANCIAL STABILITY REPORT: FINANCIAL MARKET TURBULENCE: CAUSES, CONSEQUENCES, AND POLICIES* 54 (2007) [hereinafter IMF, *TURBULENCE*], available at <http://www.imf.org/External/Pubs/FT/GFSR/2007/02/pdf/text.pdf> (stating that VaR is “the primary quantitative measure of market risk within most financial institutions”); Markus Leippold, *Don't Rely on VaR*, *EUROMONEY*, Nov. 2004, at FA2 (stating that the “buzz phrase” in the financial industry is VaR).

<sup>84</sup> For a description of factors contributing to the growth of new risk management strategies, see KEVIN DOWD, *BEYOND VALUE AT RISK: THE NEW SCIENCE OF RISK MANAGEMENT* 5–8 (1998); Ronald J. Gilson & Charles K. Whitehead, *Deconstructing Equity: Public Ownership, Agency Costs, and Complete Capital Markets*, 108 *COLUM. L. REV.* 231, 243–47 (2008).

<sup>85</sup> See JORION, *supra* note 65, at 79–82, 84–86, 88–89, 98 (describing the basic tools to measure risk); BENOIT B. MANDELBROT & RICHARD L. HUDSON, *THE (MIS)BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN, AND REWARD* 9–11 (2004) (describing theories that underlie modern financial economics); David Mengle, *Risk Management as a Process*, in *MODERN RISK MANAGEMENT*, *supra* note 5, at 3, 5–8 (outlining general characteristics of risk management processes).

<sup>86</sup> See HOLTON, *supra* note 83, at 22–24; Thomas J. Linsmeier & Neil D. Pearson, *Value at Risk*, 56 *FIN. ANALYSTS J.*, Mar.–Apr. 2000, at 47, 47–48.

<sup>87</sup> See IMF, *TURBULENCE*, *supra* note 83, at 69.

<sup>88</sup> See Jeremy Berkowitz & James O'Brien, *How Accurate Are Value-at-Risk Models at Commercial Banks?* 5–6 (Fed. Reserve Bd., Div. of Research & Statistics and Monetary Affairs, Fin. & Econ. Discussion Series, No. 2001–31, 2001).

<sup>89</sup> See IMF, *TURBULENCE*, *supra* note 83, at 53; David E. Allen et al., *Modelling and Forecasting Dynamic VaR Thresholds for Risk Management and Regulation* 2–5 (Sch. Accounting, Fin. & Econ. & FIMARC Working Paper Series, No. 0503, 2005), available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=926270](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=926270).

<sup>90</sup> See IMF, *TURBULENCE*, *supra* note 83, at 53.

<sup>91</sup> Appendix A of this Article illustrates how VaR is calculated. See also Darrell Duffie & Jun Pan, *An Overview of Value at Risk*, 4 *J. DERIVATIVES* 7, 9–10 (1997) (describing general tools one must consider when calculating VaR).

gauge the likelihood and magnitude of future returns.<sup>92</sup> In addition to measuring market risk, VaR is an important tool used to manage it. Financial firms regularly impose VaR limits on managers and portfolios.<sup>93</sup> Before exceeding a limit, the manager must obtain approval or reduce the portfolio's exposure, typically by diversifying its holdings<sup>94</sup> or reducing their size.<sup>95</sup>

VaR's ability to distill risk into a single number requires several simplifying assumptions that can significantly distort results.<sup>96</sup> Nevertheless, VaR is a cornerstone of global financial regulation.<sup>97</sup> Its endorsement by regulators reflects its growing use and sophistication,<sup>98</sup> which in part resulted from declining costs in developing new VaR systems.<sup>99</sup> VaR also permitted regulators to assess market risk across firms<sup>100</sup> and to tie regulation to internal measures rather than standards set by less well-informed outsiders.<sup>101</sup> VaR's incorporation into regulation and best practices included the following:

<sup>92</sup> See OESTERREICHISCHE NATIONALBANK, 3 GUIDELINES ON MARKET RISK: EVALUATION OF VALUE AT RISK-MODELS 10 (Wolfdietrich Grau ed., 1999) [hereinafter GRAU, VAR-MODELS], available at [http://www.oenb.at/en/img/band3ev40\\_tcm16-20473.pdf](http://www.oenb.at/en/img/band3ev40_tcm16-20473.pdf); Linsmeier & Pearson, *supra* note 86, at 59.

<sup>93</sup> See JORION, *supra* note 65, at 181–84, 379–87; Suleyman Basak & Alexander Shapiro, *Value-at-Risk-Based Risk Management: Optimal Policies and Asset Prices*, 14 REV. FIN. STUD. 371, 371–72 (2001).

<sup>94</sup> See HOLTON, *supra* note 83, at 26–29; JORION, *supra* note 65, at 163; Barbara Kavanagh, *A Retrospective Look at Market Risk*, in MODERN RISK MANAGEMENT, *supra* note 5, at 251, 253–54; see also GRAU, VAR-MODELS, *supra* note 92, at 3–5 (describing how credit institutions are to comply with various reporting obligations related to each institution's VaR). For example, due to diversification's benefits, J.P. Morgan's consolidated VaR is substantially lower than the sum of the VaR estimates for each of its trading units. See JORION, *supra* note 65, at 62. There are, however, questions regarding VaR's ability to fully reflect the benefits of diversification. See Philippe Artzner et al., *Coherent Measures of Risk*, 9 MATHEMATICAL FIN. 203, 216–18 (1999); Daníelsson, *supra* note 63, at 1289.

<sup>95</sup> Appendix A of this Article illustrates VaR's role in policing a portfolio's riskiness. See also JORION, *supra* note 65, at 393–95.

<sup>96</sup> Appendix A of this Article summarizes some of the key assumptions and resulting effects on accuracy. A list of VaR's limitations also appears in JORION, *supra* note 65, at 542–51, and MANDELBROT & HUDSON, *supra* note 85, at 272–74.

<sup>97</sup> See Jón Daníelsson et al., *Incentives for Effective Risk Management*, 26 J. BANKING & FIN. 1407, 1408–09 (2002); Jón Daníelsson & Jean-Pierre Zigrand, *Equilibrium Asset Pricing with Systemic Risk*, 35 ECON. THEORY 293, 294 (2008) (noting that statistical risk models used to determine bank capital and risk are the “cornerstone” of financial regulation).

<sup>98</sup> See JORION, *supra* note 65, at 61 (noting that the surge in banks using their own risk management models stemmed from recognition that the banks' own risk management models were more sophisticated than those required by regulators); Markus Leippold et al., *Equilibrium Impact of Value-at-Risk Regulation*, 30 J. ECON. DYNAMICS & CONTROL 1277, 1278 (2006).

<sup>99</sup> See DOWD, *supra* note 84, at 20.

<sup>100</sup> See Jose A. Lopez, *Regulatory Evaluation of Value-at-Risk Models*, in THE VALUE-AT-RISK REFERENCE 455, 458–59 (Jón Daníelsson ed., 2007); Darryll Hendricks & Beverly Hirtle, *Bank Capital Requirements for Market Risk: The Internal Models Approach*, FRBNY ECON. POL'Y REV., Dec. 1997, at 1, 8.

<sup>101</sup> See Risk-Based Capital Standards: Market Risk, 64 Fed. Reg. 19,034, 19,035 (Apr. 19, 1999) (to be codified at 12 C.F.R. pt. 325); DOWD, *supra* note 84, at 222.

- In 1993, the Group of Thirty, Global Derivatives Study Group, endorsed the use of VaR as a best practice by derivatives dealers,<sup>102</sup> applicable also to trading in other instruments by other financial firms;<sup>103</sup>
- The Basel Committee on Banking Supervision adopted VaR in 1996 as one means for banks to calculate required capital reserves;<sup>104</sup>
- VaR was subsequently included in U.S. risk-based capital requirements for commercial banks with significant trading activities<sup>105</sup> and in foreign bank and securities regulations;<sup>106</sup>
- VaR is used to calculate capital for some of the world's largest securities firms,<sup>107</sup> as well as for over-the-counter derivatives deal-

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<sup>102</sup> See GROUP OF THIRTY, GLOBAL DERIVATIVES STUDY GROUP, DERIVATIVES: PRACTICES AND PRINCIPLES 10 (1993) (stating that “[m]arket risk is best measured as ‘value at risk’”).

<sup>103</sup> See HOLTON, *supra* note 83, at 17.

<sup>104</sup> See BASEL COMMITTEE ON BANKING SUPERVISION, AMENDMENT TO THE CAPITAL ACCORD TO INCORPORATE MARKET RISKS 44 (1996) [hereinafter BASEL COMMITTEE, MARKET RISKS], available at <http://www.bis.org/publ/bcbs24.pdf>. For a bank that uses VaR, minimum capital is set by reference to the higher of (i) the previous day's VaR measure and (ii) the average daily VaR measures for each of the preceding sixty business days multiplied by a factor of three. See ALLEN ET AL., *supra* note 75, at 206; Jose A. Lopez, *Methods for Evaluating Value-at-Risk Estimates*, FRBSF ECON. REV., 1999 No. 2, at 4–5. The multiplier was included partly in order to offset potential inaccuracies in a bank's VaR model and partly to ensure that sufficient levels of capital are set aside. The factor is typically set at three, but can be increased if later backtesting indicates the bank was overly optimistic in its calculations. See Hendricks & Hirtle, *supra* note 100, at 5.

<sup>105</sup> See, e.g., Capital Adequacy Guidelines for State Member Banks; Market Risk Measure, 12 C.F.R. pt. 208, app. E, § 3(a)(2)(i) (2008) (state member banks); Capital Adequacy Guidelines for Bank Holding Companies: Market Risk Measure, 12 C.F.R. pt. 225, app. E, § 3(a)(2)(i) (2008) (bank holding companies).

<sup>106</sup> See HOLTON, *supra* note 83, at 14; see also GRAU, VAR-MODELS, *supra* note 92, at 3–5 (describing Austrian banking law).

<sup>107</sup> Securities firms that were part of a group whose holding company managed risk on a group-wide basis and that consented to group-wide Securities and Exchange Commission (SEC) supervision were eligible to compute capital charges using an alternative formula that incorporates VaR. See Rules 15c3-1(a)(7), 15c3-1e(d), 17 C.F.R. §§ 240.15c3-1(a)(7), 240.15c3-1e(d) (2005). The five firms that adopted the alternative calculation (Bear Stearns, Goldman Sachs, Lehman Brothers, Merrill Lynch, and Morgan Stanley) are either no longer independent companies or have become bank holding companies subject to FRB oversight. See John C. Coffee Jr., *Analyzing the Credit Crisis: Was the SEC Missing in Action?*, N.Y. L.J., Dec. 5, 2008, <http://www.law.com/jsp/cc/PubArticleCC.jsp?id=1202426495544>. All five or their successors, however, continue to rely on Rule 15c3-1e to compute regulatory capital for SEC purposes. See, e.g., The Goldman Sachs Group, Inc., Quarterly Report on Form 10-Q for the Period Ended Mar. 31, 2010, at 73 (filed May 10, 2010); JPMorgan Chase & Co., Quarterly Report on Form 10-Q for the Period Ended June 30, 2010, at 63 (filed Aug. 6, 2010) (after acquiring Bear Stearns); Merrill Lynch & Co., Inc., Quarterly Report on Form 10-Q for the Period Ended June 30, 2010, at 77 (filed Aug. 6, 2010) (after being acquired by Bank of America); Morgan Stanley, Quarterly Report on Form 10-Q for the Period Ended June 30, 2010, at 70 (filed Aug. 6, 2010). Lehman Brothers was acquired by Barclays Capital, a non-U.S. financial services firm, which obtained temporary relief from the SEC to continue to calculate capital charges pursuant to Rule 15c3-1e for the Lehman Brothers positions it purchased. See Order Granting Temporary, Conditional Relief from the Net Capital Rule for Barclays Capital, Inc., Exchange Act Release No. 58612, 94 S.E.C. Docket 9813 (Sept. 22, 2008).

ers.<sup>108</sup> VaR can also be used to calculate capital for investment bank holding companies that meet specified criteria;<sup>109</sup>

- VaR is one of three options available to public firms in disclosing their market risk exposures;<sup>110</sup> and
- The European Union has incorporated VaR into new capital requirements for insurance and reinsurance companies, anticipated to be in place by October 2012.<sup>111</sup>

In addition, VaR has been important for credit rating agencies, which considered VaR to be a best practice among financial firms when assessing their credit quality<sup>112</sup> and used VaR to calculate the amount of equity capital a bank must hold.<sup>113</sup> A firm's credit rating can directly affect its cost of capital, thereby providing the firm with a powerful incentive to adopt VaR measures.<sup>114</sup> Investors also required hedge funds to use VaR-based technology, prompting the hedge fund industry to incorporate VaR as a best practice.<sup>115</sup>

<sup>108</sup> See Rule 15c3-1f(e), 17 C.F.R. § 240.15c3-1f(e) (2008); see also OTC Derivatives Dealers, Exchange Act Release No. 34-40594, 63 Fed. Reg. 59,366, 59,367 (Nov. 3, 1998) [hereinafter OTC Derivatives Dealers].

<sup>109</sup> See Rules 17i-1-17i-8, 17 C.F.R. §§ 240.17i-1-17i-8 (2008).

<sup>110</sup> See Regulation S-K, Item 305(a)(1), 17 C.F.R. § 229.305(a)(1) (2008). VaR disclosures are generally helpful in assessing risk and prospective variability in revenues. See Philippe Jorion, *How Informative Are Value-at-Risk Disclosures?*, 77 ACCT. REV. 911, 912 (2002). There are, however, notable exceptions, such as Enron's failure to assess its derivatives exposures. See Frank Partnoy, *A Revisionist View of Enron and the Sudden Death of "May,"* 48 VILL. L. REV. 1245, 1259-60 (2003).

<sup>111</sup> See European Commission, Internal Markets & Services DG, "Solvency II": Frequently Asked Questions (FAQs) 1, 3-4 (Apr. 2009), available at [http://ec.europa.eu/internal\\_market/insurance/docs/solvency/solvency2/faq\\_en.pdf](http://ec.europa.eu/internal_market/insurance/docs/solvency/solvency2/faq_en.pdf).

<sup>112</sup> See, e.g., STANDARD & POOR'S, ENTERPRISE RISK MANAGEMENT FOR FINANCIAL INSTITUTIONS: RATING CRITERIA AND BEST PRACTICES 18 (2005) [hereinafter S&P, ENTERPRISE RISK MANAGEMENT], available at [http://mgt.ncsu.edu/erm/documents/sp\\_erm\\_busdevbk.pdf](http://mgt.ncsu.edu/erm/documents/sp_erm_busdevbk.pdf) ("Standard & Poor's considers VaR calculations to be good discipline for robust risk management practices and believes that the 'spillover' effects of the risk systems required to run these models are beneficial in many respects.").

<sup>113</sup> See JORION, *supra* note 65, at 404-07.

<sup>114</sup> See Frank Partnoy, *The Siskel and Ebert of Financial Markets?: Two Thumbs Down for the Credit Rating Agencies*, 77 WASH. U. L.Q. 619, 688-90, 698-700 (1999) (describing restrictions on the purchase of debt with lower credit ratings that result in part in an increase in the cost of commercial paper by lower-grade issuers).

<sup>115</sup> See IMF, TURBULENCE, *supra* note 83, at 69-70; MANAGED FUNDS ASS'N, SOUND PRACTICES FOR HEDGE FUND MANAGERS, at app. III 7-15 (2009), available at [http://www.managedfunds.org/files/pdfs/MFA\\_Sound\\_Practices\\_2009.pdf](http://www.managedfunds.org/files/pdfs/MFA_Sound_Practices_2009.pdf).

VaR's limitations are well-known to regulators<sup>116</sup> and risk managers.<sup>117</sup> Firms, therefore, supplement VaR with simulations ("stress tests") that, in theory, reflect a portfolio's individual risks.<sup>118</sup> In practice, however, stress tests have become more uniform. Risk managers use stress scenarios from prior employers,<sup>119</sup> while regulators coordinate tests in order to assess risk across different firms.<sup>120</sup> Standard & Poor's has also identified "commonly run" historical stress tests that it expects all financial firms to include in risk assessments.<sup>121</sup> Consequently, rather than individualizing risk, stress tests have reinforced uniformity in portfolio management.<sup>122</sup>

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<sup>116</sup> See, e.g., INT'L ORG. OF SEC. COMM'NS, TECHNICAL COMMITTEE, THE IMPLICATIONS FOR SECURITIES REGULATORS OF THE INCREASED USE OF VALUE AT RISK MODELS BY SECURITIES FIRMS 6 (1995), available at <http://www.iosco.org/library/pubdocs/pdf/IOSCOPD46.pdf> ("[VaR is] based on observed statistical relationships which are of varying levels of reliability. [VaR is] also heavily dependent on the assumptions which the model builders make about the relationships between different financial instruments [and] the observation periods over which the relationships are estimated.").

<sup>117</sup> See Michael C. Macchiarola, *Beware of Risk Everywhere: An Important Lesson from the Current Credit Crisis*, 5 HASTINGS BUS. L.J. 267, 286, 294–97 (2009).

<sup>118</sup> See JORION, *supra* note 65, at 357; Linsmeier & Pearson, *supra* note 86, at 60–61; Karl S. Okamoto, *After the Bailout: Regulating Systemic Moral Hazard*, 57 UCLA L. REV. 183, 214–15 (2009).

<sup>119</sup> See IMF, TURBULENCE, *supra* note 83, at 69.

<sup>120</sup> The Basel Committee, for example, has identified several scenarios to include in each bank's testing regimen. See BASEL COMMITTEE, MARKET RISKS, *supra* note 104, at 46–47; OESTERREICHISCHE NATIONALBANK, 5 GUIDELINES ON MARKET RISK: STRESS TESTING 21 (Wolfdietrich Grau ed., 1999) [hereinafter GRAU, STRESS TESTING], available at [http://www.oenb.at/en/img/band5ev40\\_tcm16-20475.pdf](http://www.oenb.at/en/img/band5ev40_tcm16-20475.pdf); see also BASEL COMMITTEE ON BANKING SUPERVISION, PRINCIPLES FOR SOUND LIQUIDITY RISK MANAGEMENT AND SUPERVISION 26 (2008), available at <http://www.bis.org/publ/bcbs144.pdf> (providing illustrative list of scenarios to include in stress tests of a bank's funding and market liquidity exposures). Banks also incorporate risk factors from a 1995 report prepared by the Derivatives Policy Group, an industry organization comprised of U.S. banks and broker-dealers. See GRAU, STRESS TESTING, *supra*, at 16–17. Other regulators, as well, have moved towards standardized testing. See IMF, TURBULENCE, *supra* note 83, at 56–57, 70; see also GRAU, STRESS TESTING, *supra*, at 16. The Austrian bank regulator, for example, has published tables of maximum changes in individual risk factors to be included in stress tests, even though they are "not meant as a recipe." GRAU, STRESS TESTING, *supra*, at 27–32. The SEC also requires each over-the-counter derivatives dealer to perform stress tests that reflect changes in specified pricing and volatility categories. See Rule 15c3-1f(e), 17 C.F.R. § 240.15c3-1f(e) (2008); see also OTC Derivatives Dealers, *supra* note 108, at 59386 n.244 (listing stress tests to be applied). Perhaps the most well-known example of market-wide stress testing was the Obama Administration's review of the nineteen largest U.S. financial institutions in early 2009. See Rob Cox & Richard Beales, *Stress Tests Prove a Sobering Idea*, N.Y. TIMES, May 11, 2009, at B2.

<sup>121</sup> See S&P, ENTERPRISE RISK MANAGEMENT, *supra* note 112, at 28.

<sup>122</sup> See BASEL COMMITTEE ON BANKING SUPERVISION, PRINCIPLES FOR SOUND STRESS TESTING PRACTICES AND SUPERVISION 13–21 (2009), available at <http://www.bis.org/publ/bcbs155.pdf>; SENIOR SUPERVISORS GRP., OBSERVATIONS ON RISK MANAGEMENT PRACTICES DURING THE RECENT MARKET TURBULENCE 16–17 (2008) [hereinafter SENIOR SUPERVISORS], available at [www.ny.frb.org/newsevents/news/banking/2008/SSG\\_Risk\\_Mgt\\_doc\\_final.pdf](http://www.ny.frb.org/newsevents/news/banking/2008/SSG_Risk_Mgt_doc_final.pdf); Barry Eichengreen, *Ten Questions About the Subprime Crisis*, FIN. STABILITY REV., Feb. 2008, at 19, 22.

The result is a conflict—the uniform application of a risk measure that presumes independence and randomness. Regulation, and its incorporation into best practices, has largely fuelled VaR's growth as an industry standard.<sup>123</sup> Its success, however, raises an intriguing question: What happens, in a world premised on randomness, when financial market participants assess risk in the same way? More generally, how are the markets affected when their principal actors begin to act in unison? The next Part begins to consider these questions.

## II

### COORDINATION IN A RANDOM WORLD

Coordination's costs must begin to be balanced against its benefits. Identifying those costs, however, can be difficult. In this Part, I provide examples of the potentially destructive effect of coordination in the financial markets. VaR's incorporation into regulation, and its use in market standards, can create greater market volatility. Additional examples include the Bear Stearns meltdown, growing standardization in the derivatives market, and the growth of common technology systems.

#### A. A Paradox

Coordination's benefits are well-known in the financial markets. Regulation—like the Basel Accord—promotes market stability in part by leveling the playing field.<sup>124</sup> Likewise, market standards—like the CSA—help lower transaction costs, in part by minimizing the need for extensive negotiation.<sup>125</sup> In each case, the results are coordinated outcomes that, on balance, benefit market participants.

Coordination can also be costly, and those costs are often less well-understood than the accompanying benefits. Regulation and standards typically center on individual firms that are each considered separately.<sup>126</sup> Capital regulation, for example, supports market stability by limiting each bank's risk taking, and standard-form contracts bind only the parties to each agreement. Yet, both also promote uniformity across the financial markets. Capital regulation encourages

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<sup>123</sup> See Basak & Shapiro, *supra* note 93, at 371 (describing VaR as “the industry standard by choice or by regulation”).

<sup>124</sup> See *supra* notes 46–49 and accompanying text.

<sup>125</sup> See *supra* notes 52–59 and accompanying text.

<sup>126</sup> See MARKUS BRUNNERMEIER ET AL., THE FUNDAMENTAL PRINCIPLES OF FINANCIAL REGULATION 2–3 (Geneva Reports on the World Economy, Preliminary Conference Draft, 2009), available at <http://www.princeton.edu/~markus/research/papers/Geneva11.pdf>; ANDREW CROCKETT, MARRYING THE MICRO- AND MACRO-PRUDENTIAL DIMENSIONS OF FINANCIAL STABILITY 3 (2000), available at <http://www.bis.org/review/rr000921b.pdf> (noting the “quintessential micro-prudential dictum . . . that ‘financial stability is ensured as long as each and every institution is sound’” (emphasis omitted)).



banks to assess market risk using similar tools, like VaR, and standard-form contracts cause different firms to comply with like provisions in the same way. Managers, consequently, react to events in unison—each acting individually but, as a group, influencing asset prices and affecting the trading decisions of others.

The result is a paradox—regulation and standards that promote coordination can erode risk management tools premised on randomness and independent action<sup>127</sup> and alter the dynamics that make risk management effective.<sup>128</sup> In those cases, coordination's costs can begin to outweigh its benefits.<sup>129</sup>

A good illustration of this paradox is VaR and its use in regulation and market standards. Recall that VaR presumes that portfolio managers act independently and a manager's trading decisions do not affect market prices.<sup>130</sup> Yet, VaR's incorporation into regulation, and its use as a standard, can promote greater uniformity. Managers, in that case, continue to work separately, but now a decision to buy or sell assets is more likely to be replicated by others using the same risk measure. The resulting sales (purchases) can exacerbate a decline (rise) in price and prompt further trading as managers adjust and readjust their portfolios.<sup>131</sup> Diagram 2 illustrates the feedback effects, assuming an initial drop in price. I describe each step below:

- *Box 1*—A drop in asset price increases market volatility and, in turn, the VaR level of a bank or other financial firm subject to VaR-based capital regulation, thereby raising the amount of capital each bank or financial firm must set aside. Financial institutions also use short-term repo trades—economically similar to

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<sup>127</sup> See IMF, *TURBULENCE*, *supra* note 83, at 61; Stephen Morris & Hyun Song Shin, *Risk Management with Interdependent Choice*, 15 OXFORD REV. ECON. POL'Y, Autumn 1999, at 52–53. This paradox is sometimes referred to as Goodhart's Law which, modified for financial regulation, states that the statistical relationships underlying a risk model will break down when the model is used for regulatory purposes. See Daníelsson, *supra* note 63, at 1276. Goodhart's Law originated with Charles Goodhart, who first applied the analysis to the relationship between interest rates and monetary policy. Others have extended it to additional statistical relationships. See K. Alec Chrystal & Paul D. Mizen, *Goodhart's Law: Its Origins, Meaning and Implications for Monetary Policy 2–4*, 16 (Nov. 12, 2001) (unpublished manuscript), available at [http://cyberlibris.typepad.com/blog/files/Goodharts\\_Law.pdf](http://cyberlibris.typepad.com/blog/files/Goodharts_Law.pdf).

<sup>128</sup> See IMF, *TURBULENCE*, *supra* note 83, at 62–63.

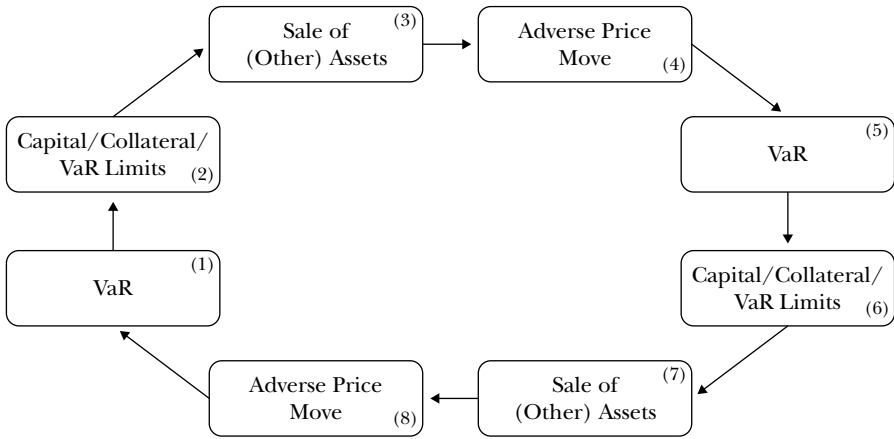
<sup>129</sup> See Morris & Shin, *supra* note 127, at 55–57, 59.

<sup>130</sup> See *supra* notes 62–64, 84–85 and accompanying text.

<sup>131</sup> See Jón Daníelsson et al., *The Impact of Risk Regulation on Price Dynamics*, 28 J. BANKING & FIN. 1069, 1070–71 (2004); Daníelsson & Zigrand, *supra* note 97, at 310–11. This may be true even across portfolios of different securities. A downturn in one portfolio, through its impact on market liquidity, can have a negative spillover effect on others, even if the portfolios are subject to different management styles. See Nicole M. Boyson et al., *Hedge Fund Contagion and Liquidity Shocks*, 65 J. FIN. 1789, 1789–92 (2010).

secured loans—to finance investments.<sup>132</sup> In a repo trade, a lender extends credit based on collateral, which it may discount (a “haircut”) below market value.<sup>133</sup> Using a simple example, if a haircut is 3%, a firm can borrow \$97 million for each \$100 million in collateral it pledges; the firm must use its own capital to finance the remaining \$3 million. Repo creditors regularly use VaR to determine collateral (and haircut) requirements, with increases in VaR resulting in a larger haircut.<sup>134</sup>

DIAGRAM 2: VaR’S FEEDBACK EFFECTS



- *Box 2*—After VaR increases, each firm must raise new capital in order to meet its regulatory obligations and, if the assets were used as collateral, to make up the gap resulting from the larger haircut.<sup>135</sup> The amounts can be substantial. For example, ac-

<sup>132</sup> See Markus K. Brunnermeier & Lasse Heje Pedersen, *Market Liquidity and Funding Liquidity*, 22 REV. FIN. STUD. 2201, 2202 (2009); Christian Laux & Christian Leuz, *Did Fair-Value Accounting Contribute to the Financial Crisis?* 10 (Eur. Corp. Governance Inst., Working Paper Series in Finance, Working Paper No. 266, 2009), available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1487905](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1487905). In a typical sale and repurchase (also known as “repo”) transaction, a securities dealer (the “repo seller”) sells securities to an investor (the “repo buyer”) for cash. The repo buyer’s objective is not to invest in the securities; rather, it expects to receive a return from the repo seller for the use of its cash. Accordingly, as part of the trade, the repo seller also agrees with the repo buyer to repurchase the same or equivalent securities at some future time, frequently overnight, at a repurchase price above the price at which the repo buyer first bought the securities. Economically, the transaction is equivalent to a secured loan—with the repo buyer lending cash to the repo seller against the underlying securities as collateral. See Jeanne L. Schroeder, *A Repo Opera: How Criimi Mae Got Repos Backwards*, 76 AM. BANKR. L.J. 565, 570–72 (2002).

<sup>133</sup> See GARY GORTON, *SLAPPED IN THE FACE BY THE INVISIBLE HAND: BANKING AND THE PANIC OF 2007*, at 44 (2010).

<sup>134</sup> See BRUNNERMEIER ET AL., *supra* note 126, at 18–19; IMF, *TURBULENCE*, *supra* note 83, at 53, 70; Brunnermeier & Pedersen, *supra* note 132, at 2202.

<sup>135</sup> See GORTON, *supra* note 133, at 47–50; IMF, *TURBULENCE*, *supra* note 83, at 62; Whitehead, *supra* note 13, at 22–23.

ording to one analyst's estimates, the repo market is between \$8 and \$10 trillion in size.<sup>136</sup> Although market-wide data is unavailable, haircuts on structured debt rose between 2% and 35% during the recent financial crisis, with creditors refusing to accept some instruments (like subprime mortgage assets) altogether.<sup>137</sup> If haircuts rose only 5% on average, borrowers would need to raise a total of \$400 to \$500 billion in new capital.

- *Box 3*—In order to raise new capital, the firm must issue equity or sell assets. New shares, in a volatile market, are likely to suffer from the well-known “lemons effect” as prospective investors with imperfect information discount their value.<sup>138</sup> Consequently, the firm will be motivated to sell assets in order to raise cash.<sup>139</sup> The higher cost of collateral (the larger haircuts) can also force it to downsize its financing arrangements.<sup>140</sup> In addition, individual traders may need to adjust their portfolios—perhaps by selling assets—in order to remain below their VaR limits.<sup>141</sup>
- *Box 4*—The result, in each case, is a greater pressure to sell assets, which when replicated among portfolio managers, causes a further drop in price.<sup>142</sup>
- *Box 5*—Declining prices cause greater market volatility<sup>143</sup> and, like in *Box 1*, prompt a further increase in VaR. Assets in a falling market can also become more correlated,<sup>144</sup> making it more diffi-

<sup>136</sup> GORTON, *supra* note 133, at 50.

<sup>137</sup> See Gary Gorton & Andrew Metrick, *The Run on Repo and the Panic of 2007–2008*, at 29–33 (Mar. 9, 2009) (unpublished working paper), available at <http://econ-www.mit.edu/files/3918>.

<sup>138</sup> See George A. Akerlof, *The Market for “Lemons”: Quality Uncertainty and the Market Mechanism*, 84 Q.J. ECON. 488, 489–92 (1970); Hayne E. Leland & David H. Pyle, *Information Asymmetries, Financial Structure, and Financial Intermediation*, 32 J. FIN. 371, 371–72 (1977).

<sup>139</sup> See Albert S. Kyle & Wei Xiong, *Contagion as a Wealth Effect*, 56 J. FIN. 1401, 1402, 1427 (2001).

<sup>140</sup> See GORTON, *supra* note 133, at 50; Gorton & Metrick, *supra* note 137, at 30.

<sup>141</sup> See IMF, *TURBULENCE*, *supra* note 83, at 61–62; Danielsson & Zigrand, *supra* note 97, at 302. In addition, traders who suffer losses may simply choose to sell assets in order to minimize the risk of any future decline. See Kyle & Xiong, *supra* note 139, at 1402.

<sup>142</sup> *The Risks of Financial Modeling: VaR and the Economic Meltdown: Hearing Before the H. Subcomm. on Investigations and Oversight, H. Comm. on Science and Technology*, 110th Cong. 5–6 (2009) (statement of Richard Bookstaber) [hereinafter Bookstaber Testimony], available at [http://democrats.science.house.gov/Media/file/Commdocs/hearings/2009/Oversight/10sep/Bookstaber\\_Testimony.pdf](http://democrats.science.house.gov/Media/file/Commdocs/hearings/2009/Oversight/10sep/Bookstaber_Testimony.pdf).

<sup>143</sup> See Anil K. Kashyap et al., *Rethinking Capital Regulation* 13–14 (Aug. 2008) (unpublished working paper), available at <http://www.davidson.edu/academic/economics/kumar/Eco%20495/Spring%202009/KashyapRajanStein.09.15.08.pdf>.

<sup>144</sup> See Danielsson & Zigrand, *supra* note 97, at 296, 308; Kyle & Xiong, *supra* note 139, at 1401–05; see also Mico Loretan & William B. English, *Evaluating “Correlation Breakdowns” During Periods of Market Volatility* 1–3 (Fed. Reserve Sys., Int’l Fin. Discussion Papers, No. 658, 2000), available at <http://www.federalreserve.gov/pubs/ifdp/2000/658/ifdp658.pdf> (finding increased correlation in asset returns when markets become volatile).

cult for firms to diversify risk<sup>145</sup> and creating a further rise in VaR.<sup>146</sup>

- *Boxes 6–8*—Increased VaR, in turn, creates additional pressure to raise or maintain capital (Box 6), causing further asset sales (Box 7) and another drop in price (Box 8) as portfolio managers again look to raise cash and manage their exposures. The resulting growth in volatility can prompt another increase in VaR, restarting the cycle as firms continue to respond to risk in the same way.<sup>147</sup>

Coordination, as Diagram 2 illustrates, can undermine risk management's effectiveness. A specific event—like a drop in price—can spark a common response, similar to what happens when there is herding. Recall that herding occurs if managers mimic the actions of others rather than risk incurring losses on their own.<sup>148</sup> If each acts separately, some responses (to hold or buy) are likely to offset others (to sell) and vice versa. The result, when reactions are mixed, is less pressure to herd. Greater uniformity has an opposite effect: as more managers respond in the same way, others will follow rather than risk standing alone, which in turn increases the pressure to herd. A manager, for example, may be unwilling to ignore a rise in VaR if she believes others using the same risk measure have adjusted their portfolios in response to this change,<sup>149</sup> even though risk managers often claim that firms can use discretion when responding to shifts in VaR.<sup>150</sup> It may be particularly difficult for her to disregard a “risky” VaR, in light of its widespread use, even if she later becomes aware of new (or contradictory) information.<sup>151</sup> The tendency is reinforced by

<sup>145</sup> See Daníelsson & Zigrand, *supra* note 97, at 307; William N. Goetzmann et al., *Long-Term Global Market Correlations*, 78 J. Bus. 1, 3 (2005).

<sup>146</sup> See IMF, *TURBULENCE*, *supra* note 83, at 60.

<sup>147</sup> See Morris & Shin, *supra* note 127, at 52–53 (noting how the coordinated actions of financial institutions during volatile times in the market led to “exaggerated price movements and the drying up of liquidity even in the most widely traded instruments”).

<sup>148</sup> See *supra* notes 22–24 and accompanying text.

<sup>149</sup> See Avinash Persaud, *Sending the Herd off the Cliff Edge: The Disturbing Interaction Between Herding and Market-Sensitive Risk Management Practices*, 2 J. RISK FIN. 59, 61–63 (2000); Scharfstein & Stein, *supra* note 22, at 465–66 (noting that “an unprofitable decision is not as bad for reputation when others make the same mistake”); see also IMF, *TURBULENCE*, *supra* note 83, at 71 (explaining that portfolio managers may adjust portfolios in light of greater volatility, rather than risk explaining to regulators why they exceeded their VaR limits).

<sup>150</sup> See IMF, *TURBULENCE*, *supra* note 83, at 53, 54, 70; JORION, *supra* note 65, at 397; S&P, *ENTERPRISE RISK MANAGEMENT*, *supra* note 112, at 22–23; see also Daníelsson, *supra* note 63, at 1283–84 (suggesting anecdotally that firms smooth risk forecasts rather than strictly adhere to VaR).

<sup>151</sup> See Chris Guthrie, Jeffrey J. Rachlinski & Andrew J. Wistrich, *Inside the Judicial Mind*, 86 CORNELL L. REV. 777, 787–89 (2001) (describing the psychological process of “anchoring”).

VaR models that generally react in the same way—signaling greater risk when there is a downturn in the market.<sup>152</sup>

A similar effect is found in the bank credit markets. Recall that global capital regulation was introduced to harmonize banking standards. Each bank is required to set aside capital—calculated, in part, using VaR—as a safety cushion against future losses in order to ensure the bank’s continued solvency.<sup>153</sup> The result, however, has been an increase in the procyclicality of the credit markets.<sup>154</sup> When the economy is strong, a borrower’s default risk is likely to be remote, minimizing the amount of capital each bank must set aside against prospective loss. When the economy sours, however, risk-based requirements can put pressure on each bank to strengthen its capital cushion, reducing its incentive to lend and, in aggregate, increasing economic instability. Like pedestrians on the Millennium Bridge, each bank acts independently, but in total, the amount of available credit increases during upturns in the economy and tightens when the economy slows.<sup>155</sup>

As VaR illustrates, coordination—reinforced by regulation and standards—can create negative externalities. With herding, for example, a portfolio manager’s decision to go with the herd imposes a cost

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<sup>152</sup> See *supra* notes 89–90 and accompanying text. In addition, medium and smaller firms are likely to use the same “off-the-shelf” risk management packages, which will all show similar changes in VaR. See IMF, *TURBULENCE*, *supra* note 83, at 69.

<sup>153</sup> See Kashyap et al., *supra* note 143, at 12, 16–18; Whitehead, *supra* note 13, at 25, 39–40.

<sup>154</sup> See CONG. OVERSIGHT PANEL, 111TH CONG., SPECIAL REPORT ON REGULATORY REFORM 26 (2009), available at <http://cop.senate.gov/documents/cop-012909-report-regulatoryreform.pdf> (recommending countercyclical capital requirements because the procyclicality of existing capital requirements “likely intensifies the ups and downs in asset markets”).

<sup>155</sup> See BRUNNERMEIER ET AL., *supra* note 126, at 14–15; George G. Pennacchi, *Risk-Based Capital Standards, Deposit Insurance, and Procyclicality*, 14 J. FIN. INTERMEDIATION 432, 433 (2005); Rafael Repullo & Javier Suarez, *The Procyclical Effects of Bank Capital Regulation 2* (Oct. 2009) (unpublished working paper), available at <http://www.cemfi.es/~suarez/repullo-suarez09.pdf>. Fair value accounting can contribute to the procyclical effect of bank capital regulation. See Alicia Novoa et al., *Procyclicality and Fair Value Accounting 7–12* (Int’l Monetary Fund, IMF Working Paper WP/09/39, 2009), available at [www.bis.org/bcbsevents/cbrworkshop09/novoascarlatasole.pdf](http://www.bis.org/bcbsevents/cbrworkshop09/novoascarlatasole.pdf). A downturn in the markets may make it difficult to value complex products. See Charles Smithson, *Valuing “Hard-to-Value” Assets and Liabilities: Notes on Valuing Structured Credit Products*, 19 J. APPLIED FIN. 1, 5 (2009). If market conditions cause a decline in the value of bank assets, banks may be required to increase loan loss provisioning, prompting a reduction in lending that, in turn, results in a further slowdown in the real economy. See Anne Beatty & Scott Liao, *Regulatory Capital Ratios, Loan Loss Provisioning and Pro-Cyclicality 5–6* (Oct. 15, 2009) (unpublished working paper), available at <http://www.kellogg.northwestern.edu/accounting/papers/beatty.pdf>. After they recognize losses, banks may also be forced to sell assets in illiquid markets to raise capital, further weakening the markets, reducing price, and compelling additional sales. See OFFICE OF THE CHIEF ACCOUNTANT, DIV. OF CORP. FIN., U.S. SECURITIES AND EXCHANGE COMMISSION, REPORT AND RECOMMENDATIONS PURSUANT TO SECTION 133 OF THE EMERGENCY ECONOMIC STABILIZATION ACT OF 2008: STUDY ON MARK-TO-MARKET ACCOUNTING 182–84 (2008), available at <http://www.sec.gov/news/studies/2008/marktomarket123008.pdf>.

on others, who are now marginally more inclined to follow her lead rather than act on their own.<sup>156</sup> VaR-based regulation magnifies that tendency by creating greater pressure to buy or sell.<sup>157</sup> Thus, ironically, unregulated firms may be better able to manage their financial risks than firms that are subject to enhanced risk regulation.<sup>158</sup> Likewise, a market standard, like the CSA, can cause managers who comply with its terms to respond to the same event in the same way.<sup>159</sup> A manager who signs a CSA is likely motivated by its benefit of reduced transaction costs without being aware of its potential costs. In both cases, the results are increased externalities that may not be readily apparent to market participants.

## B. Some Examples of Destructive Coordination

Below are three examples of coordination's costly effects. The first example ties the use of VaR to a recent real-world problem, involving Bear Stearns, during the recent financial crisis. The second example illustrates how a market standard, like the CSA, can create greater uniformity and thereby increase market volatility. The last example describes how technology systems that standardize responses to specific events can reinforce the uniformity created by regulation and market standards.

### 1. *Bear Stearns*

In many respects, Bear Stearns's meltdown in spring 2008 was similar to a bank run, but one involving a securities firm—not a bank—many of whose investors were sophisticated institutions.<sup>160</sup> Like many firms, Bear Stearns relied on short-term repo trades to fi-

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<sup>156</sup> See Abhijit V. Banerjee, *A Simple Model of Herd Behavior*, 107 Q.J. ECON. 797, 798–99 (1992).

<sup>157</sup> See IMF, *TURBULENCE*, *supra* note 83, at 54, 72–73; Morris & Shin, *supra* note 127, at 59.

<sup>158</sup> Hedge funds, for example, were not as adversely affected as banks during the recent financial crisis partly because they were not subject to capital regulations that, like with banks, would have caused them to hold risky subprime mortgage assets. See RAGHURAM G. RAJAN, *FAULT LINES: HOW HIDDEN FRACTURES STILL THREATEN THE WORLD ECONOMY* 178 (2010).

<sup>159</sup> An example of the CSA's impact on asset prices appears *infra* at notes 170–184 and accompanying text.

<sup>160</sup> See GORTON, *supra* note 133, at 45–54. Bear Stearns was not the first example of a bank run on a securities firm. Drexel Burnham declared bankruptcy in 1990 after the collapse of the secondary market for high-yield bonds. Securities that traded freely became illiquid following Michael Milken's six felony convictions, changes in regulation requiring thrifts to sell their holdings, and a collapse in confidence over the value of high-yield instruments; the result was, like in the case of Bear Stearns, an increased cost of borrowing that forced Drexel Burnham to liquidate its assets at fire sale prices. See Franklin Allen & Richard Herring, *Banking Regulation versus Securities Market Regulation* 28–34 (Wharton Fin. Inst. Center, Working Paper No. 01-29, 2001), available at <http://knowledge.wharton.upenn.edu/papers/1174.pdf>.

nance its holdings, including subprime mortgage assets<sup>161</sup> whose value began to decline as housing prices plummeted, default rates escalated, and investors came to realize that underwriting standards had eroded.<sup>162</sup> Following the drop in value, Bear Stearns's creditors required the firm to post additional (or substitute) collateral and, in some cases, refused to roll over or extend credit altogether. These new requirements effectively forced Bear Stearns to sell assets quickly, often at fire-sale prices.<sup>163</sup> The resulting drop in value affected the prices and volatility of similar assets held by others, transmitting Bear Stearns's problems across the market. Additional sales pushed the prices of Bear Stearns's assets even lower, increasing volatility and creating even greater pressure to sell.<sup>164</sup>

On its face, the Bear Stearns example appears similar to the feedback loop illustrated in Diagram 2. To be sure, the price decline may have simply reflected the natural tendencies of firms to sell risky assets<sup>165</sup> and creditors to demand additional collateral when the financial markets fall.<sup>166</sup> The speed of the decline may have also reflected the significant risks that Bear Stearns incurred—risks that only became evident when the markets slowed.<sup>167</sup> Thus, neither VaR nor any other risk management strategy is likely to be the sole cause of a drop in asset prices. What is clear, however, is that the uniformity of response was unanticipated—it was neither reflected in the risk management systems nor considered by regulators or market participants. VaR's widespread use helped reinforce the downward spiral in part by supporting greater uniformity among portfolio managers.<sup>168</sup>

## 2. *Credit Support Annex*

Credit default swaps (CDS) transfer the risk of credit loss, usually in connection with a referenced asset or entity, from one swap counterparty to another. Under a typical CDS, the beneficiary pays a premium to the credit risk holder (the "protection seller") who agrees to pay the beneficiary an amount that reflects the decline in value of the referenced asset upon the occurrence of a credit event (such as a

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<sup>161</sup> See Whitehead, *supra* note 13, at 22–23; see also *supra* notes 132–34 and accompanying text (describing short-term repo trades).

<sup>162</sup> See Laux & Leuz, *supra* note 132, at 11.

<sup>163</sup> See *id.* at 12–14; see also Ana Fostel & John Geanakoplos, *Leverage Cycles and the Anxious Economy*, 98 AM. ECON. REV. 1211, 1238 (2008) (describing "flight to collateral," where investors sell assets that cannot be used as collateral and buy assets that can be pledged to lenders at lower cost).

<sup>164</sup> See Whitehead, *supra* note 13, at 22–23.

<sup>165</sup> See IMF, *TURBULENCE*, *supra* note 83, at 53.

<sup>166</sup> See Fostel & Geanakoplos, *supra* note 163, at 1214–15.

<sup>167</sup> See Okamoto, *supra* note 118, at 189 (arguing that the root cause of the financial crisis was excessive risk taking by asset managers that remained unchecked).

<sup>168</sup> See Romano, *supra* note 27, at 15–16.

default or failure to pay).<sup>169</sup> CDS typically rely on ISDA documents, including the CSA.<sup>170</sup>

Under the CSA, banks and other protection sellers are required to post collateral depending on their prospective payment obligations. For hedge funds, as pledgors, the typical requirement is that they post collateral for 100% of their potential obligation, and in some cases, the CSA may require that they post additional collateral as a buffer against the risk of future default.<sup>171</sup>

As it has for swaps generally, the use of standard language has reduced transaction costs and expanded the scope of the CDS market.<sup>172</sup> Likewise, the CSA lowered the cost to swaps dealers of entering into contracts with new counterparties. In 1994, when the CSA was introduced, the principal swaps dealers managed approximately

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<sup>169</sup> See William K. Sjostrom, Jr., *The AIG Bailout*, 66 WASH. & LEE L. REV. 943, 947–50 (2009).

<sup>170</sup> See BARCLAYS CAPITAL, COUNTERPARTY RISK IN CREDIT MARKETS: QUANTITATIVE CREDIT STRATEGY RESEARCH REPORT 3 (2008), available at <https://ecommerce.barcap.com/research/user/article/attachment/hj20938re1in8pbiedmg/0/Counterparty%20Risk%20-%2020%20Feb%2008.pdf>.

<sup>171</sup> See *id.* The CSA requires the party with a swap payment obligation (the “pledgor”) to transfer collateral to the counterparty with the net credit exposure (the “secured party”) in order to minimize credit risk. Mechanically, the secured party must calculate the amount it is entitled to receive and then notify the pledgor by a pre-agreed time. The pledgor must then post the collateral with (or for the account of) the secured party by the close of business on the next business day. See CSA, *supra* note 55, at paras. 3, 4(b), 4(c), 13(c); see also Christian A. Johnson, *Derivatives and Rehypothecation Failure: It's 3:00 p.m., Do You Know Where Your Collateral Is?*, 39 ARIZ. L. REV. 949, 957–58 (1997) (describing various standardized documents prepared by ISDA for use in CDS transactions).

<sup>172</sup> See Frank Partnoy, *Second-Order Benefits from Standards*, 48 B.C. L. REV. 169, 184–88 (2007); Frank Partnoy & David A. Skeel, Jr., *The Promise and Perils of Credit Derivatives*, 75 U. CIN. L. REV. 1019, 1025–26 (2007). Perhaps the clearest example of coordination in the swaps markets is just beginning to become evident—namely, the fallout from litigation arising from the financial crisis. A court's interpretation of a CDS's terms in one jurisdiction may have market-wide impact due to their standardized and widespread use. Firms that were never parties to the original lawsuit but use the same CDS form may be directly affected. See Jeffrey B. Golden, *The Courts, The Financial Crisis and Systemic Risk*, 4 CAPITAL MKTS. L.J. S141, S144–46 (2009). The U.S. federal courts have recognized a similar relationship in standard-form indenture provisions, noting that “[b]oilerplate provisions are thus not the consequence of the relationship of particular borrowers and lenders and do not depend upon particularized intentions of the parties to an indenture.” Sharon Steel Corp. v. Chase Manhattan Bank, 691 F.2d 1039, 1048 (2d Cir. 1982), *cert. denied*, 460 U.S. 1012 (1983). Perhaps the most recent example is found in *Airgas, Inc. v. Air Products and Chemicals, Inc.*, No. 649, 2010 (Del. Nov. 23, 2010), where the Delaware Supreme Court was asked to interpret a standardized charter provision involving the election of directors to a staggered board. The Court described the widespread use of identical language among firms incorporated in Delaware, *id.*, slip op. at 15–16, and the use of similar language in the ABA's model incorporation forms, *id.*, slip op. at 17–18, finding them to be “overwhelming and uncontroverted extrinsic evidence” of the meaning of the Airgas provision, *id.*, slip op. at 22. Adopting a different meaning would have affected some of Delaware's largest corporations, prompting the Court to note it could not “ignore [the] widespread corporate practice and understanding it represents.” *Id.*, slip op. at 16.



\$4.7 billion in collateral.<sup>173</sup> Privately negotiated support arrangements involved significant time and expense to structure and negotiate.<sup>174</sup> As a result, the major swaps dealers concentrated their business on firms that had investment-grade credit ratings.<sup>175</sup> The CSA streamlined the credit process. At the end of 2008, collateral deposited under CSAs totaled about \$4 trillion, an 850-fold increase over 1994—with approximately 65% of all derivatives being subject to CSAs or other collateral arrangements.<sup>176</sup> Approximately 50% of CSAs involve hedge funds and institutional investors, followed by corporations, banks, and others.<sup>177</sup>

A rise in the cost of a CDS above the protection seller's premium often indicates a greater probability that a credit event will occur, in turn requiring the protection seller to post additional collateral.<sup>178</sup> CDS costs surged following the collapse of Lehman Brothers in September 2008, reflecting market-wide concern over the stability of other firms.<sup>179</sup> The result was a significant increase in the amount of collateral that protection sellers were required to post. The CSA form leaves open how often a CDS is revalued and, reflecting any increase or decrease in value, how often collateral ("variation margin") is provided or returned<sup>180</sup> (referred to as "marking-to-market"<sup>181</sup>). CDS counterparties, however, typically agree that the seller's obligations will be marked-to-market on a daily basis, transferring collateral back and forth between them depending on the net increase or decrease in the value of the CDS.<sup>182</sup> Following the Lehman Brothers collapse, protection sellers (many of them hedge funds) were required to post a significant amount of additional collateral within a single day, totaling \$140 billion across the industry. To raise money, they sold other

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<sup>173</sup> See U.S. GEN. ACCOUNTING OFFICE, GAO/GGD-94-133, FINANCIAL DERIVATIVES: ACTIONS NEEDED TO PROTECT THE FINANCIAL SYSTEM 58, 156 (1994).

<sup>174</sup> See Nina Hval, *Credit Risk Reduction in the International Over-the-Counter Derivatives Market: Collateralizing the Net Exposure with Support Agreements*, 31 INT'L LAW. 801, 809 (1997).

<sup>175</sup> See Roberta Romano, *A Thumbnail Sketch of Derivative Securities and Their Regulation*, 55 MD. L. REV. 1, 51 (1996).

<sup>176</sup> See ISDA, ISDA MARGIN SURVEY 2009, at 3, 7 (2009), available at [http://www.isda.org/c\\_and\\_a/pdf/ISDA-Margin-Survey-2009.pdf](http://www.isda.org/c_and_a/pdf/ISDA-Margin-Survey-2009.pdf).

<sup>177</sup> See *id.* at 8.

<sup>178</sup> See Sjostrom, *supra* note 169, at 951.

<sup>179</sup> See *Causes and Effects of the Lehman Brothers Bankruptcy: Hearing Before the H. Comm. on Oversight and Government Reform*, 110th Cong. 13–14 (Oct. 6, 2008) (statement of Prof. Luigi Zingales, University of Chicago Graduate School of Business).

<sup>180</sup> See CSA, *supra* note 55, at para. 13(c).

<sup>181</sup> See VCG Special Opportunities Master Fund Ltd. v. Citibank, N.A., 594 F. Supp. 2d 334, 338 n.4 (S.D.N.Y. 2008), *aff'd*, 2009 U.S. App. LEXIS 26621 (2d Cir. 2009).

<sup>182</sup> See COMPTROLLER OF THE CURRENCY, ADM'R OF NAT'L BANKS, OCC'S QUARTERLY REPORT ON BANK TRADING AND DERIVATIVES ACTIVITIES: THIRD QUARTER 2008, at 5 (2008) available at <http://www.occ.gov/topics/capital-markets/financial-markets/trading/derivatives/dq408.pdf>; RESERVE BANK OF AUSTRALIA, FINANCIAL STABILITY REVIEW 69 (2009), available at <http://www.rba.gov.au/publications/fsr/2009/mar/pdf/0309.pdf>.

assets in unison, contributing to a substantial decline in securities prices around the world.<sup>183</sup>

Protection sellers, in the absence of a CSA, would likely still have been required to post collateral. Creation of the CSA, however, significantly increased the amount of collateral used by market participants and, like VaR-based regulation, promoted uniformity in the derivatives markets. Standard provisions in the CSA caused protection sellers to react to the increase in CDS prices in the same way and at roughly the same time, simultaneously driving prices lower, which in turn required additional sales to raise further funds.<sup>184</sup>

### 3. *Technology Systems*

The third example highlights a growing area of standardization that is likely to increase uniformity in the financial markets. As regulatory requirements have grown, so too have the costs of compliance and reporting. One response has been the growth of technology systems in the risk management area to quantify and report the financial risks to which a firm is subject. Those systems include decision controls that automate business rules intended to mitigate risk consistent with operational and regulatory requirements.<sup>185</sup>

Creating a compliance system can be expensive. As a result, vendors have developed comprehensive risk management packages—frequently out-of-the-box systems based on the vendors’ understanding of industry best practices that firms can directly implement. Relying on third-party vendors lowers costs and provides users with some level of comfort that their approach to compliance is consistent with the approach taken by others.<sup>186</sup>

Perhaps the best-known example of technology’s impact on the financial markets is the feedback loop—triggered by “portfolio insurance”—that helped fuel the Black Monday crash of 1987.<sup>187</sup> Portfolio insurance involved the computer trading of common stock using a program that automatically executed orders to sell shares when prices fell to prespecified levels. Institutional investors intended to

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<sup>183</sup> See Carrick Mollenkamp et al., *Lehman’s Demise Triggered Cash Crunch Around Globe*, WALL ST. J., Sept. 29, 2008, at A1.

<sup>184</sup> One casualty was American International Group, whose subsidiary was required to post \$6.0 billion of additional collateral when securities prices were declining, making it incrementally more difficult for it to meet its CSA obligations. See Sjostrom, *supra* note 169, at 960–61, 962–63, 977–83.

<sup>185</sup> See Kenneth A. Bamberger, *Technologies of Compliance: Risk and Regulation in a Digital Age*, 88 TEX. L. REV. 669, 685–87, 689–92 (2010).

<sup>186</sup> See *id.* at 692–93.

<sup>187</sup> See Mark Carlson, *A Brief History of the 1987 Stock Market Crash with a Discussion of the Federal Reserve Response* 15–16 (Fed. Reserve Bd., Fin. & Econ. Discussion Series, No. 2007-13, 2006), available at <http://www.federalreserve.gov/pubs/feds/2007/200713/200713abs.html>.

rebalance a stock portfolio between risky and less risky investments so that its return would not drop below a targeted minimum. Using a computer program, they would automatically sell shares if they reached a trigger price, reducing exposure to a falling market.<sup>188</sup> Black Monday followed a sustained bull market, during which stock prices had risen substantially. Changing perceptions, prompted by concern about overvalued stocks, caused some investors to sell shares, starting a decline in price that triggered selling under some portfolio insurance programs. Those sales sparked a further decline and additional sales as shares reached new price levels, fueling a downward spiral. Large trades were automatically executed without regard to the unusual circumstances.<sup>189</sup> Other investors—including those who anticipated further computer-driven sales—sold their portfolios, creating even greater downward pressure on price.<sup>190</sup> The result was the greatest stock market collapse (at the time) since the 1929 crash, with the Dow Jones Industrial Average losing over 20% of its value in a single day.<sup>191</sup>

Black Monday is an extreme example; the role of technology systems today is more subtle, but still as important.<sup>192</sup> Lawrence Lessig famously observed that “code is law.”<sup>193</sup> In that respect, systems that implement compliance regimes can have the force of law, telling portfolio managers what they can and cannot do.<sup>194</sup> Like regulation, they can promote uniformity among different firms, each of which has purchased or developed a similar risk management system, potentially reinforcing the cascade effect of a downturn in asset prices.<sup>195</sup>

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<sup>188</sup> See Lewis D. Solomon & Howard B. Dicker, *The Crash of 1987: A Legal and Public Policy Analysis*, 57 *FORDHAM L. REV.* 191, 200–01, 210–13 (1988).

<sup>189</sup> See Jerry W. Markham & Rita McCloy Stephanz, *The Stock Market Crash of 1987—The United States Looks at New Recommendations*, 76 *GEO. L.J.* 1993, 2007–11 (1988); Solomon & Dicker, *supra* note 188, at 222–28.

<sup>190</sup> See Jonathan Macey & Hideki Kanda, *The Stock Exchange as a Firm: The Emergence of Close Substitutes for the New York and Tokyo Stock Exchanges*, 75 *CORNELL L. REV.* 1007, 1028–30 (1990).

<sup>191</sup> See PRESIDENTIAL TASK FORCE ON MARKET MECHANISMS, REPORT OF THE PRESIDENTIAL TASK FORCE ON MARKET MECHANISMS 1 (1988).

<sup>192</sup> Recall that the May 2010 “flash crash” was also prompted by technology-based trading programs. See *supra* note 28.

<sup>193</sup> LAWRENCE LESSIG, CODE: VERSION 2.0, at 5 (2006).

<sup>194</sup> See Lawrence Lessig, *Foreword*, 52 *STAN. L. REV.* 987, 990 (2000); Joel R. Reidenberg, *Lex Informatica: The Formulation of Information Policy Rules Through Technology*, 76 *TEX. L. REV.* 553, 565, 568–69 (1998) (noting the role of network technology in imposing a “parallel rule system” on participants).

<sup>195</sup> See Erik F. Gerding, *Code, Crash, and Open Source: The Outsourcing of Financial Regulation to Risk Models and the Global Financial Crisis*, 84 *WASH. L. REV.* 127, 184–85 (2009).

### III BALANCING COSTS AND BENEFITS

So, if financial regulation can increase systemic risk, why not simply do away with it altogether? In part, regulation helps minimize costs,<sup>196</sup> notwithstanding its own negative externalities.<sup>197</sup> Among financial firms, the costs of incurring financial risk extend well beyond those who decide to do so—a negative externality unlikely to be fully considered (or priced) by managers or shareholders when selecting what risk levels are optimal. Regulation induces firms to internalize some of those costs, rather than having them fully borne by the public. Absent that regulation, firms are likely to assume more financial risk than is socially optimal.<sup>198</sup>

An alternative is to separate financial firms into different categories, resulting in different levels of regulation for different types of firms. Separate regulatory standards can minimize the number of events likely to trigger a common response. Problems with this approach, however, largely overtake its benefits. First, a substantial amount of financial activity is concentrated within a limited universe. For example, the banking industry's five largest firms hold more than 90% of the industry's derivatives.<sup>199</sup> Differentiating among them may not be practical. Second, creating different regulatory standards can result in arbitrage, with firms adjusting businesses in order to minimize regulatory cost. The resulting impact is difficult to anticipate and, in any event, would still be likely to result in greater uniformity as firms moved to the lowest-cost standard. And, third, focusing only on regulation overlooks the importance of nonregulatory market standards. VaR's use in the repo market, for example, can still increase uniformity even if it is not a regulatory requirement for all firms.

New technologies may also break the feedback effect of VaR-based regulation. A new measure has been developed (but not yet

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<sup>196</sup> See BRUNNERMEIER ET AL., *supra* note 126, at 2–3.

<sup>197</sup> See *supra* notes 156–58 and accompanying text.

<sup>198</sup> For example, the costs of a bank run resulting from the bank's decision to assume a risky loan portfolio can be substantial. The bank, its shareholders, and its customers are harmed as the bank is forced to sell assets at below-market prices. Other banks may also experience a decline in business, or even a run, as concerns over financial instability spread across the market. Borrowers, as a result, may not be able to obtain funding at the same cost, restricting their ability to invest in new, value-enhancing projects and causing a slowdown in the general economy. A description of the economic impact of a systemic shock appears in Ben S. Bernanke, *Nonmonetary Effects of the Financial Crisis in the Propagation of the Great Depression*, 73 AM. ECON. REV. 257, 264–65 (1983), and Charles W. Calomiris, *Is Deposit Insurance Necessary? A Historical Perspective*, 50 J. ECON. HIST. 283, 284 (1990). Thus, financial regulation restricts the amounts and types of risk bearing that a financial firm can assume. See *supra* notes 47–49 and accompanying text.

<sup>199</sup> See COMPTROLLER OF THE CURRENCY, ADM'R OF NAT'L BANKS, OCC'S QUARTERLY REPORT ON BANK TRADING AND DERIVATIVES ACTIVITIES: THIRD QUARTER 2008, at 1, 5–7 (2008), available at <http://www.occ.treas.gov/ftp/release/2008-152a.pdf>.

tested) to estimate a firm's contribution to systemic risk, taking into account the impact of its trading activities on others (and the impact of others' activities on the firm).<sup>200</sup> Other proposals would create countercyclical capital regulation—intended to raise capital levels when the economy is strong and lower them during a downturn, softening the impact of a decline in lending when the markets weaken.<sup>201</sup> Both technologies are directed at the financial markets as a whole, rather than individual firms, which is a step beyond the current regulatory focus. Yet, even if they address specific problems with capital regulation, they are not a solution to the broader consequences of greater coordination.

These solutions—and their inability to fully address coordination's effects—suggest a more basic problem with how the financial markets are regulated. Recall the earlier description of coordination in the financial markets. Each of the three coordination models—the Stag Hunt, Dove–Hawk, and Battle of the Sexes Games—is based on the players' *collective* expectation of how each of them will behave, with the outcome driven by each player's *individual* actions in response to that expectation.<sup>202</sup> Changes in expectation can have a sudden and significant impact on how individual participants react. And, to the extent individuals are encouraged to act in the same way, we would expect the impact—prompted by a uniform response—to be magnified.<sup>203</sup> As the Stag Hunt Game illustrates, bank runs are prompted by collective expectations over how other depositors will behave.<sup>204</sup> Banks are in the business of balancing depositors' interests in liquid assets against investments they make in less liquid loans. Depositors benefit so long as each of them remains confident in the bank's stability. If they panic, however, their expectation that others will withdraw money first is likely to cause them to withdraw as well, making the bank vulnerable to runs.<sup>205</sup> The key, then, to stopping a bank run is to adjust depositors' expectations.<sup>206</sup> Bank runs would be common if everyone were encouraged to react in the same way.<sup>207</sup> Deposit insur-

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<sup>200</sup> See Tobias Adrian & Markus K. Brunnermeier, *CoVar* 1–6 (Fed. Reserve Bank of New York, Staff Reports, Staff Report No. 348, 2010), available at [http://www.ny.frb.org/research/staff\\_reports/sr348.pdf](http://www.ny.frb.org/research/staff_reports/sr348.pdf).

<sup>201</sup> See, e.g., BRUNNERMEIER ET AL., *supra* note 126, at 31–37.

<sup>202</sup> See *supra* notes 38–59 and accompanying text.

<sup>203</sup> See Daniel A. Farber, *Uncertainty* 17–19, 51 (UC Berkeley Sch. of Law Public Law & Legal Theory Research Paper Series, Paper No. 1555343, 2010), available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1555343](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1555343).

<sup>204</sup> See *supra* notes 42–45 and accompanying text.

<sup>205</sup> See Douglas W. Diamond & Philip H. Dybvig, *Bank Runs, Deposit Insurance, and Liquidity*, 91 J. POL. ECON. 401, 403–04 (1983).

<sup>206</sup> See Robert B. Ahdieh, *Beyond Individualism in Law and Economics* 48–49 (Emory Univ. Sch. of Law, Law & Econ. Research Paper No. 09-48, 2010), available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1518836](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1518836).

<sup>207</sup> See Diamond & Dybvig, *supra* note 205, at 409.

ance, in response, lowers the likelihood of panic-induced withdrawals by assuring each depositor that others will continue, as they have, to invest in the bank.<sup>208</sup> In the same way, financial regulation must anticipate the impact of rules and market standards that encourage uniform behavior, either by changing expectations or minimizing the negative effects of coordination.

A focus on individuals alone—without taking account of group-wide expectations—would be inadequate. Yet, financial regulation and market standards typically center on individual firms, each considered separately,<sup>209</sup> with market participants often looking to minimize their own transaction costs through greater standardization.<sup>210</sup> The result is that new regulation and standards can create their own negative externalities, reinforcing downturns in the financial markets. Expanding the scope of regulation beyond individual firms—taking account of the system-wide costs of greater uniformity—can help fill gaps in today's regulatory framework. Regulators must monitor the impact of new regulation on uniformity and, going forward, adjust regulation to take account of unanticipated costs. Doing so requires a system-wide perspective on financial risk management, beyond simply a focus on the stability of individual firms. The Dodd-Frank Act is a positive step in the right direction, permitting continued monitoring of systemic risk and the costs of new regulation.<sup>211</sup> The key, of course, is how this new authority will be implemented.

In addition, regulators must begin to monitor market standards more closely—to date, largely the role of trade associations and private firms—as well as manage how market standards develop. To be clear, my purpose is not to throw the baby out with the bath water. Greater standardization can minimize transaction costs and further enhance market efficiency. Market standards, however, can have the same negative effects as regulation, raising many of the same concerns. Consequently, a comprehensive review of financial market stability must take market standards into account. Financial firms benefit individually from standards that reduce transaction costs, and so individual firms have little incentive (and limited information) to police those standards themselves.<sup>212</sup>

#### CONCLUSION

This Article has argued that coordination—reinforced by regulation and market standards—can magnify a downturn in the financial

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<sup>208</sup> See *supra* note 45 and accompanying text.

<sup>209</sup> See *supra* note 126 and accompanying text.

<sup>210</sup> See *supra* notes 52–59, 125 and accompanying text.

<sup>211</sup> See *supra* notes 29–35 and accompanying text.

<sup>212</sup> See Bookstaber Testimony, *supra* note 142, at 6.

markets. Greater coordination erodes the randomness presumed by financial risk management, creating new costs that new regulation must take into account. Measuring those costs can be difficult. In extreme cases, coordination can result in a rapid decline in asset values as market participants are driven to sell in a volatile market. Under normal circumstances, however, coordination's costs are less clear. Aspects may be open to empirical measurement, for example, by assessing VaR's impact on a firm's decision to buy or sell assets. Likewise, it may be possible to measure the extent to which uniform contracts like the CSA affect asset prices under ordinary conditions.

But perhaps the problem is more fundamental. The core issue may be that randomness is simply not how the markets operate, and regulations and standards that promote coordination are only one facet of an overall inclination toward uniformity. There is evidence that, even without regulation or standards, a group of people—each acting separately—can naturally begin to act in synchrony. The science in this area is still developing—it ranges from studies involving fireflies and crickets (which, as a group, can begin to flash and chirp in concert)<sup>213</sup> to self-organizing traffic patterns that can optimize travel flow.<sup>214</sup> What it suggests, however, is that even in Adam Smith's world,<sup>215</sup> individuals who act separately can also begin to act in unison.<sup>216</sup> If that is true in the financial markets, then perhaps we should reconsider the basic approach to financial risk management. It also suggests a new role for regulation—a principal function, in that case, may need to be in managing market expectations in light of the natural tendency toward greater coordination.

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<sup>213</sup> See STROGATZ, *supra* note 8, at 11–14, 234–37.

<sup>214</sup> See Dirk Helbing & Bernardo A. Huberman, *Coherent Moving States in Highway Traffic*, 396 NATURE 738, 738–40 (1998).

<sup>215</sup> See *supra* notes 62–64 and accompanying text.

<sup>216</sup> See STROGATZ, *supra* note 8, at 250–51.

## APPENDIX A—VALUE AT RISK

J.P. Morgan developed VaR in the 1980s before VaR became public (under the RiskMetrics brand name) at no charge in 1994.<sup>217</sup> Initially, VaR was a specialized tool primarily known to a closed universe of risk managers. It quickly became a standard of both financial and nonfinancial firms, largely due to J.P. Morgan's efforts, which included providing clients with both detailed directions on how to implement VaR as well as key factors necessary to calculate it that were updated daily on the Internet.<sup>218</sup> Within six years, over 100,000 physical copies of J.P. Morgan's technical manual had been distributed, and over 1,000 online copies were being downloaded every month.<sup>219</sup> By 2001, over 5,000 firms around the world had adopted RiskMetrics's version of VaR as a standard measure of market risk.<sup>220</sup>

VaR estimates the maximum potential loss a portfolio can suffer over  $x$  period of time at  $y$  probability ("confidence level") under normal circumstances.<sup>221</sup> To use a simple illustration,<sup>222</sup> suppose a risk manager is asked to estimate VaR for a \$100 million portfolio of high investment-grade five-year corporate bonds over a one-month time horizon and with a 99% confidence level. In plain English, she would be asked to determine the maximum loss the portfolio could suffer during ninety-nine out of 100 months. To do so, she would need to first simulate prospective returns on the portfolio, typically by using historical data. If data on the bonds were unavailable or insufficient, she would rely instead on data from a comparable security, such as five-year U.S. Treasury notes (for which there is a substantial history). A fifty-year period would yield 600 one-month observations of when the Treasuries rose in value, declined, or stayed the same, and the magnitude of any change. For simplicity, I will assume that (i) the changes in monthly value ranged between minus- and plus-4.2%, (ii) the two highest loss rates were 4% and 4.2%, and (iii) there were three separate, one-month periods when losses were 4% and three other one-month periods when losses were 4.2%. As illustrated in Diagram 3, if the results were graphed, with the x-axis as the range of possible returns (-4.2% to +4.2%) and the y-axis as the number of occurrences, the risk manager would see the following:

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<sup>217</sup> See DOWD, *supra* note 84, at 18; Till Guldimann, *The Story of RiskMetrics*, RISK, Jan. 2000, at 56, 58.

<sup>218</sup> See DOWD, *supra* note 84, at 19–20; HOLTON, *supra* note 83, at 18–19.

<sup>219</sup> See JORGE MINA & JERRY YI XIAO, RETURN TO RISKMETRICS: THE EVOLUTION OF A STANDARD 1 (2001), available at <http://www.riskmetrics.com/system/files/private/rrm-final.pdf>.

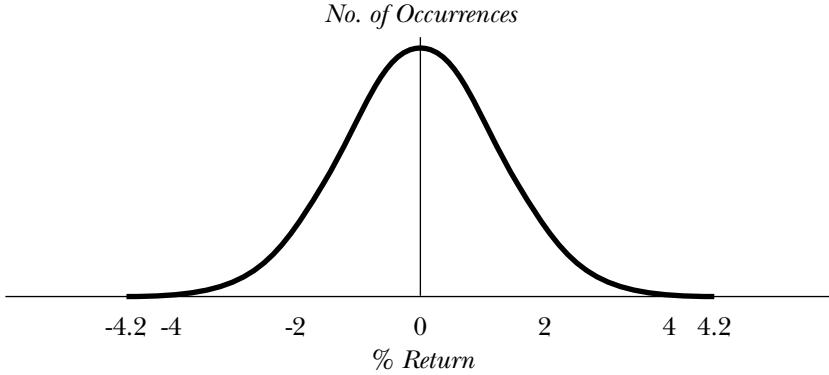
<sup>220</sup> See Henry T. C. Hu, *The New Portfolio Society, SEC Mutual Fund Disclosure, and the Public Corporation Model*, 60 BUS. L. 1303, 1346 (2005).

<sup>221</sup> See DOWD, *supra* note 84, at 38–39.

<sup>222</sup> This illustration is derived from JORION, *supra* note 65, at 17–20.



DIAGRAM 3: DISTRIBUTION OF MONTHLY RETURNS ON A PORTFOLIO OF FIVE-YEAR TREASURIES



At a 99% confidence level, the risk manager would need to determine the worst 1% of possible losses which, extrapolating from the Treasury observations, would be the six occurrences ( $6 \div 600 = 1\%$ ) when losses were 4% or worse. The risk manager could then conclude that, at a 99% confidence level, the \$100 million bond portfolio would lose no more than 4% of its value, resulting in a VaR of \$4 million ( $4\% \times \$100$  million). Stated differently, a VaR of \$4 million would mean that the portfolio's maximum loss was projected to exceed \$4 million during only one out of 100 one-month periods.<sup>223</sup> VaR, however, does not predict the magnitude of losses during the remaining one-month period (the "tail" of the distribution), which may be considerably greater than \$4 million.<sup>224</sup>

What if the firm imposed a VaR limit of \$3 million on the portfolio? To avoid violating the cap, the portfolio manager would need to lower the portfolio's estimated risk of loss from \$4 million to \$3 million. Selling bonds and buying five-year Treasuries would have no ef-

<sup>223</sup> See Duffie & Pan, *supra* note 91, at 8–9; Leippold, *supra* note 83, at FA2.

<sup>224</sup> See Berkowitz & O'Brien, *supra* note 88, at 4–5; Darryll Hendricks, *Evaluation of Value-at-Risk Models Using Historical Data*, FRBNY ECON. POL'Y REV., Apr. 1996, at 39, 51–53; see also Roger Lowenstein, *Long-Term Capital: It's a Short-Term Memory*, N.Y. TIMES, Sept. 7, 2008, at BU1 (noting that the recent financial crisis prompted Wall Street to realize that even models such as VaR are "subject to error and . . . uncertainties that inevitably afflict human forecasts"). As a result, two portfolios can have similar VaRs, even though one is projected, like in the example, to lose up to \$4.2 million during the remaining one-month period and the other could lose up to \$42 million (or greater) during the same period. See Danf elsson, *supra* note 63, at 1289–90; Duffie & Pan, *supra* note 91, at 11–13; Leippold, *supra* note 83, at FA2–FA3. Consequently, in an effort to enhance returns, a VaR-constrained manager may have an incentive to increase overall risk, but only to the extent any probable loss materializes in a significantly declining market (beyond the normal distribution). See Basak & Shapiro, *supra* note 93, at 372–73; Arjan Berkelaar et al., *The Effect of VaR Based Risk Management on Asset Prices and the Volatility Smile*, 8 EUR. FIN. MGMT. 139, 161–62 (2002); Kashyap et al., *supra* note 143, at 9.

fect on VaR, since the model presumes that both respond to similar risks in the same way. Instead, the manager could diversify into other instruments—selling bonds and buying assets with lower correlations (and a lower level of losses at 1%) than five-year Treasuries. She might also decide to sell \$25 million in bonds, reducing her total portfolio to \$75 million and her VaR to \$3 million (4% x \$75 million).<sup>225</sup>

Among its simplifications, VaR assumes that market factors and portfolio returns fall along a normal distribution.<sup>226</sup> Actual returns, however, typically do not, particularly if the market is volatile or correlations increase across a portfolio's assets.<sup>227</sup> VaR can also understate risk if market conditions have changed or the portfolio's assets have only a limited performance history.<sup>228</sup> In addition, extreme events—like the 2007 financial crisis—are sufficiently rare that they are unlikely to be reflected in historical data or a normal distribution.<sup>229</sup>

VaR's reliance on historical data can also impair its accuracy.<sup>230</sup> For example, VaR may not fully reflect a portfolio's riskiness if it is based on data from a period when market volatility was unusually low.<sup>231</sup> UBS (a large, multinational financial services firm) relied on VaR to manage its structured investments, including instruments tied to the subprime mortgage market. Following substantial losses, its investigation revealed that VaR had been based on data during a period of positive growth that did not adequately reflect its portfolio's risks.<sup>232</sup>

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<sup>225</sup> See ALLEN ET AL., *supra* note 75, at 13–18 (illustrating the impact of diversification on VaR).

<sup>226</sup> See GRAU, STRESS TESTING, *supra* note 120, at 3–4.

<sup>227</sup> See ALLEN ET AL., *supra* note 75, at 9–10; Tanya Styblo Beder, *VAR: Seductive but Dangerous*, 51 FIN. ANALYSTS J., Sept.–Oct. 1995, at 12, 20; Szilard Páfka & Imre Kondor, *Evaluating the RiskMetrics Methodology in Measuring Volatility and Value-at-Risk in Financial Markets*, 299 PHYSICA A 305, 309 (2001).

<sup>228</sup> See SENIOR SUPERVISORS, *supra* note 122, at 15; Loretan & English, *supra* note 144, at 15–17.

<sup>229</sup> See Bookstaber Testimony, *supra* note 142, at 3–5; Beder, *supra* note 227, at 20; Hu, *supra* note 220, at 1347.

<sup>230</sup> See DOWD, *supra* note 84, at 22.

<sup>231</sup> See Linsmeier & Pearson, *supra* note 86, at 59–60.

<sup>232</sup> See UBS AG, SHAREHOLDER REPORT ON UBS'S WRITE-DOWNS 38 (2008), available at [http://www.ubs.com/1/ShowMedia/investors/share\\_information/shareholderreport/remediation?contentId=140333&name=080418ShareholderReport.pdf](http://www.ubs.com/1/ShowMedia/investors/share_information/shareholderreport/remediation?contentId=140333&name=080418ShareholderReport.pdf).