VENTURE CAPITAL AS DYNAMIC REGULATION OF DISRUPTIVE INNOVATION

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ABSTRACT

Disruptive innovation creates increasing regulatory challenges. Venture capital's assessment of innovative products, businesses, and initiatives generates highly relevant institution- and industry-specific decentralized information on innovation trends. Using a dataset comprising over 75,000 venture capital deals with over 35,000 companies in the United States from 2005 to 2015, we show how venture capitalists' innovation driven finance allocation can provide feedback on innovation trends and associated risks for rulemakers, optimize the timing of regulation, and support anticipatory rulemaking.

Keywords: *Disruptive Innovation, Growth of Technology, Venture Capital, Venture Investments, Seed Capital and Series, Dynamic Regulation, Feedback Effects, Optimized Information for Regulation, Anticipatory Regulation, Big Data, Panel Data*

***JEL Classification*:**

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I. Introduction

Disruptive innovation has shaped and reshaped industries throughout history. Disruptive innovation can take the form of new business models, new products or services, or new ways of delivering existing products and services to consumers, while addressing unmet consumer needs.[1] Disruptive innovation is characterized by scientific discoveries that change existing technological product paradigms and provide the foundation for more competitive new technologies and products to emerge.[2] Disruptive technological innovation is often associated with the emergence of completely new technologies, the new combination and application of existing technologies, and the application of new technologies to specific societal problem areas, each precipitating a significant paradigm shift for product technology or creating entirely new paradigms.[3] The combination of these factors facilitates sudden exponential improvements in the value proposition for customers by enabling discontinuous innovations of processes, products, and services.[4] Human-robot collaboration, constant body monitoring, and driverless cars[5] are examples of disruptive technological innovations that will transform our markets, transport, and health systems.

Disruptive innovation presents significant regulatory challenges. As disruptive technologies emerge and grow, they are bound to morph, shift, and merge with other

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[1] DIRECTORATE FOR FINANCIAL AND ENTERPRISE AFFAIRS COMPETITION COMMITTEE, HEARING ON DISRUPTIVE INNOVATION (2015), https://goo.gl/3kSCi6.

[2] The original "disruptive innovation" terminology came from the famous Bower and Christensen article in the Harvard Business Review. Joseph L. Bower & Clayton M. Christensen, *Disruptive Technologies: Catching the Wave*, 73 HARV. BUS. REV. 43, 44 (1995) ("The technological changes that damage established companies are usually not radically new or difficult from a technological point of view. They do, however, have two important characteristics: First, they typically present a different package of performance attributes - ones that, at least at the outset, are not valued by existing customers. Second, the performance attributes that existing customers do value improve at such a rapid rate that the new technology can later invade those established markets"). There is no widely accepted definition that exists for discontinuous and disruptive innovation. Instead, many scholars focus on different aspects: such as industry-wide product technology factors to the gap between substitutable technological learning curves on a cost or performance basis, definitions of discontinuous innovation focus on customer behaviour, product newness, market factors or a combination of these factors. For an overview of the disruptive innovation definitions used in the literature, *see* Ronald N. Kostoff et al., *Disruptive Technology Roadmaps*, 71 TECH. FORECASTING & SOCIAL CHANGE 141, 142-144 (2004).

[3] *Id*.

[4] *See* Robert W. Veryzer, Jr., *Discontinuous Innovation and the New Product Development Process*, 15 J. PROD. INNOV. MANAG. 304 (1998); Gary S. Lynn et al., *Marketing and Discontinuous Innovation: The Probe and Learn Process*, 38 CAL. MANAGEMENT REV. 8 (1996). *See also* Steven T. Walsh, *Roadmapping a Disruptive Technology: A Case Study, The Emerging Microsystems and Top-Down Nanosystems Industry*, 71 TECH. FORECASTING & SOC. CHANGE 161, 165 (2004) ("Two views of disruptive technologies arise from this literature. One emphasizes the 'different' nature of the technology, whereas the other emphasizes the emerging high technology nature. Bower and Christensen champion the 'different' nature of disruptive technologies emphasizing that they may not be 'radically new from a technological point of view' but have superior 'performance trajectories' along critical dimensions that customers value. Abernathy and Clark and others argue that disruptive technologies' radical newness or emergent character is an important element in its definition since robust manufacturing infrastructure is either limited or nonexistent.").

[5] Gavriel Avigdor & Rene Wintjes, *Trend Report: Disruptive innovations and Forward-Looking Policies Towards Smart Value Chains* 5-7 (European Union, Business Innovation Observatory No. 190, 2015), http://goo.gl/PUwnwn.

emerging disruptive trends in constantly accelerating and changing ways. Disruptive technology convergence can bring with it unexpected and sudden changes in areas that are already quietly incubating. These new developments and trends are going to increasingly impact consumer preferences and behavior, products, the financial industry,[6] industry practices, delivery channels, and possible regulatory responses to changes in any of these. The ex-post trial-and-error-rulemaking with stable and presumptively optimal rules[7] in the existing regulatory framework[8] often produces suboptimal regulatory outcomes that are no longer sustainable in an environment of exponential disruptive innovation. While ex-post trial-and-error-rulemaking with stable and presumptively optimal rules in the historically evolved legal infrastructure was sufficiently able to cope with its inherent collective action problems,[9] regulatory cycles,[10] trial-and-error rulemaking,[11] systemic constraints, and path dependencies, the exponential growth of

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[6] Chris Brummer, *Disruptive Technology and Securities Regulation*, FORDHAM L. REV. (forthcoming 2015-2016) (manuscript at 1), http://goo.gl/kBelUm ("This [a]rticle explains how technological innovation not only "disrupts" capital markets—but also the exercise of regulatory supervision and oversight. It provides the first theoretical account tracking the migration of technology across multiple domains of today's securities infrastructure and argues that an array of technological innovations are facilitating what can be understood as the disintermediation of the traditional gatekeepers that regulatory authorities have relied on (and regulated) since the 1930s for investor protection and market integrity.").

[7] The existing regulatory infrastructure, including Congress, regulatory agencies, self-regulatory bodies, and the literature on regulation, relies almost exclusively on stable and presumptively optimal rules. Stable and presumptively optimal rules are created to address perceived regulatory issues identified by lawmakers through centralized information in the then existing economic and market conditions. Stable and presumptively optimal rules are tailored and drafted to attain permanent solutions for perceived regulatory issues that have sufficient political support at the time of drafting. *See* Wulf A. Kaal, *Evolution of Law: Dynamic Regulation in a New Institutional Economics Framework in* FESTSCHRIFT ZU EHREN VON CHRISTIAN KIRCHNER (Wulf A. Kaal, Matthias Schmidt & Andreas Schwartze eds., 2014) 1211, 1212 [hereinafter Kaal in FS Kirchner]. ("[T]he institutional infrastructure for rulemaking was geared towards the creation of rules for governing a relatively stable society with less upward mobility and relatively stable economic and market environments."); Wulf A. Kaal, *Dynamic Regulation of the Financial Services Industry,* 48 WAKE FOREST L. REV. 791 (2013)[hereinafter Kaal Wake Forest]; Wulf A. Kaal, *Dynamic Regulation via Governmental Contracts, in* FESTSCHRIFT FÜR PETER NOBEL ZUM 70 (Peter Sester et al. eds., 2015) 65, http://ssrn.com/abstract=2517677 [hereinafter Kaal in Liber Amicorum Peter Nobel]; Wulf A. Kaal & Timothy Lacine, *The Effect of Deferred and Non-Prosecution Agreements on Corporate Governance: Evidence from 1993-2013,* 70 BUS. LAW. 61 (2014) [hereinafter Kaal & Lacine 2014].

[8] *See* KARL POPPER, THE POVERTY OF HISTORICISM (1957)*;* Kaal in FS Kirchner*, supra* note 7, at 2 ("Since then, society and markets have evolved rapidly and are becoming increasingly more complex. The growing number of rule enactments, revisions, and revocations suggests that existing rules and institutional structures for rulemaking are becoming less capable of addressing the rapid pace of change.").

[9] John C. Coffee, Jr., *The Political Economy of Dodd-Frank: Why Financial Reform Tends To Be Frustrated and Systemic Risk Perpetuated*, 97 CORNELL L. REV. 1019, 1020-1022 (2012); Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal Wake Forest, *supra* note 7; Kaal in FS Kirchner, *supra* note 7. Smaller and better-organized special interest groups typically control dispersed investors and other dominant latent groups in the competition to influence the rulemaking process. MANCUR OLSON, JR., THE LOGIC OF COLLECTIVE ACTION, (1965). The predominance of special interest groups in the rulemaking process can be temporarily overcome during and after crises when political entrepreneurs assume the transaction costs of organizing the otherwise disinterested latent groups. ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION (1990).

[10] Coffee, *supra* note 9; Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal in FS Kirchner, *supra* note 7.

[11] Kaal Wake Forest*, supra* note 7; Kaal in FS Kirchner, *supra* note 7; Popper, *supra* note 8; Christian Kirchner, *Evolution of Law—Interplay Between Private and Public Rule-Making: A New Institutional*

disruptive innovation is likely to expose the depth of insufficiencies and design flaws of the existing regulatory and institutional infrastructure. More specifically, in an environment of exponential disruptive innovation, relevant information for rulemaking is less likely to materialize soon enough for traditional trial-and-error rulemaking to be effective, regulatory issues become increasingly complex, and unknown future contingencies increase substantially in the rulemaking process.[12] In short, exponential disruptive innovation has the potential to overwhelm the existing regulatory process.[13]

Policy makers and scholars are debating possible policy responses to address the regulatory challenges associated with disruptive innovation. Some suggest that the regulatory challenges associated with disruptive innovation can only be effectively addressed through principles-based regulation because the existing rulemaking procedures lack sufficient speed and flexibility.[14] Others see disruptive innovation predominantly as a competition law and antitrust issue.[15] Early intervention,[16] rulemaking petitions, and retrospective review may be more appropriate remedies for the effects of disruptive innovation that also can help address the regulatory sine curve.[17] Assuming that regulatory innovation is subject to an interdependent ecological system, others propose networks for the diffusion of improved regulatory technology.[18] Recognizing that ex ante regulation has diminished significance in the context of regulation disruptive innovation and AI, others see research, development, and public operation as the only ways to identify harmful innovation.[19] Chris Brummer suggests a form of regulatory experimentalism including selectively adopt trial periods for new regulatory

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Economics Analysis, 4 ERASMUS L. REV. 161 (2012).

[12] See *infra* Fn. [_]-[_] and accompanying text.

[13] Because rulemakers are still attempting to comprehend the regulatory demands of the last wave of innovative solutions, technologies, and applications while the next wave of innovation is already in full force, exponential disruptive innovation is likely to intensify the frequencies of the regulatory sine curve that is recognized by the literature. Kaal Wake Forest, *supra* note 7; Coffee, *supra* note 9 at 1029-1037; John C. Coffee, Jr., *Systemic Risk After Dodd-Frank: Contingent Capital and the Need For Regulatory Strategies Beyond Oversight*, 111 COLUM. L. REV. 795, 821 (2011).

[14] Barefoot, *supra* note 52, at 9.

[15] Inge Graef et al., *How Google and Others Upset Competition Analysis: Disruptive Innovation and European Competition Law* (Conference Paper, 25th European Regional Conference of the International Telecommunications Society, Brussels, Belgium, Jun. 22-25, 2014), http://econstor.eu/bitstream/10419/101378/1/795226780.pdf.

[16] Nathan Cortez, *Regulating Disruptive Innovation*, 29 BERKELEY TECH. L.J. 175, 175 (2014) ("With novel technologies, agencies also risk paralysis by analysis. New technologies often present unforeseen risks if under-regulated and dramatic opportunity costs if overregulated. The inclination of most regulators is to avoid both extremes. . . . Regulators also tend to overvalue gathering information about new technologies, which further distorts decisions on regulatory timing. . . . early interventions can benefit both regulated industry and regulatory beneficiaries. . . . early interventions may also benefit from a more objective regulatory atmosphere, before parties become entrenched and adversarial.").

[17] Reeve T. Bull, *Building A Framework for Governance: Retrospective Review and Rulemaking Petitions*, 67 ADMIN. L. REV. 265, 293-306 (2015) (urging regulatory agencies to expand the use of petitions for rulemaking and retrospective review to achieve smarter regulation).

[18] Jonathan B. Wiener, *The regulation of technology, and the technology of regulation*, 26 TECH. IN SOC'Y 483, 496 (2004) ("Fourth, we should foster networks for the diffusion of regulatory innovations. Just as private technology diffusion is crucial to economic prosperity, so the diffusion of improved public regulatory technology is crucial to social progress.").

[19] Scherer, *supra* note 73, at 43-44.

approaches.[20] This form of micro-level regulatory experimentation could later be expanded to "system-wide enterprise zones for financial market compliance and regulatory adaptation."[21]

An emerging literature explores the use of informal regulation.[22] Wu suggests that traditional rulemaking is regularly impracticable in rapidly developing industries where highly informal methods can be justified.[23] Rather than relying on traditional regulatory means in the existing regulatory framework, Wu suggests regulatory agencies confronting disruptive innovations should utilize "threats" for the disruptive industries packaged in guidance documents, warning letters etc., because such threats can help avoid regulation that is inappropriately calibrated or premature.[24] Threats are less burdensome than traditional regulatory approaches, more flexible, can be better fine-tuned, and signal regulatory intent appropriately.[25]

We apply the theoretical framework on dynamic regulation as established by Kaal[26] to regulatory issues associated with disruptive innovation. The theory of dynamic regulation conceptualizes the study of regulatory phenomena in relation to preceding and

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[20] Brummer, *supra* note 6, at 50 ("So for example, the ban on general solicitation could be lifted for five years, with a sunset provision triggered absent some additional regulatory blessing. Or more onerous investigatory requirements on portals could be lifted where other (statistical or algorithmic) technologies are used to test or limit exposures of retail investors in crowdfunded securities, but likewise set to expire absent some regulatory finding that they insufficiently track or identify breaches in prudential requirements for investors.").

[21] *Id*. at 53 ("for example, avenues of special information sharing and expedited assistance could be opened with targeted industry members for the fulfillment of desired regulatory objectives. Or investment tax credits could be provided for market participants that undertake strategies to bolster investor protection or market stability.").

[22] *See e.g*., Tim Wu, *Agency Threats*, 60 DUKE L.J. 1841 (2011).

[23] *Id*. at 1841 ("There are three main ways in which agencies regulate: rulemaking; adjudication; and informal tools of guidance, also called nonlegislative or interpretative rules. Over the last two decades, agencies have increasingly favored the use of the last of these three, which can include statements of best practices, interpretative guides, private warning letters, and press releases.").

[24] *Id*. at 1849 ("Of the three options, the first--making law--may be the worst alternative. What sounds attractive is the prospect of an orderly, planned approach to the future. The problem is that, with so little known about the industry, issuing specific rules based on guesses about the future runs a grave risk of creating a bad law, or at least a law that is much worse than one issued after more development. Such lawmaking suffers from all of the defects that Friedrich Hayek identified with central planning--impressive in a world of perfect information, but terrible in this world."); *Contra* Cortez, *supra* note 16, at 175 (arguing that "a flexible initial posture based primarily on "threats" can calcify, creating weak defaults that lead to suboptimal regulation in the long term. . . .If agencies are concerned about regulating prematurely or in error, then they can experiment with timing rules, alternative enforcement mechanisms, and other variations on traditional interventions. If agencies do choose to proceed by making threats, then they should use them as a short-term precursor to more decisive, legally binding action, as the FCC did, and avoid relying on them as a long-term crutch, as the FDA did."); Jerry Brito, *"Agency Threats" and the Rule of Law: An Offer You Can't Refuse*, 37 HARV. J.L. & PUB. POL'Y 553, 554 (2014) ("I conclude that not only is Wu's thesis wrong, but it is also dangerous. Part I of this article reviews Wu's essay, defining what constitutes an agency threat and when it is justified according to Wu. Part II critiques Wu's thesis by showing, among other things, that it is based on a false dilemma; that it assumes an unwarranted level of knowledge on the part of regulators; that it assumes--contrary to evidence--that regulators are good proxies for the public interest; and that it ignores the costs of eschewing the regulatory process.").

[25] Wu, *supra* note 25 at 1843 ("Both agency and industry will sometimes share an interest in an informal and flexible regime that resembles an unenforceable "letter of intent" in the world of private contracts.")

[26] Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal Wake Forest, *supra* note 7; Kaal in FS Kirchner, *supra* note 7.

succeeding events, using institution-specific and decentralized information to facilitate feedback effects for anticipatory rulemaking.[27] The dynamic regulatory framework allows rulemaking to overcome its historic constraints and path dependencies that traditionally focused the rulemaking process on stable and presumptively optimal rules. Evolving from a historically reactive process based only on preceding events and driven by the agency- and collective-action problem of rulemaking, rulemaking in a dynamic framework allows for the anticipation of future innovation trends and their associated contingencies. Most important for the context of this article, the rapid pace of technological developments in the telecommunications industry necessitated the use of dynamic elements in regulation.[28] The exponential growth of innovation discussed in this article[29] shows some parallels to the pace of technological developments in telecommunications markets.

We show that venture capital can function as a dynamic regulatory supplement for disruptive innovation. Venture capital's financial allocations to innovative projects can provide feedback for dynamic regulation of disruptive innovation. We show how this approach can help optimize the timing of regulation and provide anticipatory rules. We use a PitchBook Data, Inc. dataset on venture capital investments with over 75,000 venture capital deals to illustrate that venture capital finance allocation and deal flow, among other venture capital related data, provide institution-specific decentralized information on innovation trends that can provide feedback effects for dynamic regulation of disruptive innovation. Venture capitalists' investment allocations can measure both the risks associated with innovative developments as well as the economic opportunities associated with such innovation.

This article has six parts. After a short introduction in Part I, Part II defines the phenomenon of disruptive innovation and outlines the challenges presented by disruptive innovation. Part III evaluates the literature on the effect of venture capital on innovation. Part IV analyzes the regulatory challenges presented by disruptive innovation. Part V introduces the theoretical framework for dynamic regulation before Part VI introduces the data and evaluates different venture capital metrics that provide feedback for regulators on innovation. In Part VII we discuss how the information and feedback provided by venture capital data can be used as a dynamic supplement for regulation. Part VI concludes.

II. Characteristics of Disruptive Innovation

Disruptive innovation is characterized by scientific discoveries that change the existing technological product paradigms and provide the foundation for more

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[27] *Id* at 11.

[28] *See* Johannes M. Bauer & Erik Bohlin, *From Static to Dynamic Regulation: Recent Developments in US Telecommunications Policy*, 2008 INTERECONOMICS 38, 40–42 (discussing competition in telecommunications); Paul W.J. de Bijl & Martin Peitz, *Dynamic Regulation and Entry in Telecommunications Markets: A Policy Framework*, 16 INFO. ECON. & POL'Y 411, 411 (2004); Machiel van Dijk & Machiel Mulder, *Regulation of Telecommunication and Deployment of Broadband* (CPB Netherlands Bureau for Economic Policy Analysis No. 121, Dec. 2005), https://ideas.repec.org/p/cpb/memodm/131.html (exploring whether telecommunication regulations encourage or hamper new technological development).

[29] See *infra* Parts Fn. [_]-[_] and accompanying text.

competitive new technologies and products to emerge.[30] By enabling discontinuous innovations of processes, products, and services, disruptive technological innovations facilitate exponential improvements in the value proposition for customers.[31] Disruptive technological innovation can be characterized by the emergence of completely new technologies, the new combination and application of existing technologies, and the application of new technologies to specific societal problem areas, each precipitating a significant paradigm shift for product technology or creating entirely new paradigms.[32] Disruptive innovation exemplifies Schumpeter's "Creative Destruction,"[33] i.e., the creation of competitive strength through innovation that is followed by new demand in new markets while destroying older and less competitive technologies and existing markets that are based on older and less competitive technologies.[34]

The literature on management has studied the implications of disruptive technologies and innovation since the mid 1990s.[35] The literature warned businesses that disrupter startups would attract new lower-end consumers by offering inexpensive substitutes for products and would then gradually move upmarket by attracting higher-end consumers, suggesting that businesses act quickly when disrupters appear and either acquire the disrupter or incubate a competing business that embraces the disruptive technology.[36] A market leader's lack of investment in disruptive technologies often results in the abrupt loss of market dominance and often even total replacement in such

[30] *See* supra note 2.
[31] *See* supra note 4.
[32] Kostoff et al., *supra* note 2, at 142; Steven T. Walsh & Jonathan D. Linton, *Infrastructure for Emergent Industries Based on Discontinuous Innovations*, 12 ENG. MANAG. J. 23, 24 (2000).
[33] Schumpeter described the "gaels of creative destruction", often unleashed by technology, that periodically sweep through industries and sink weak and outdated firms. JOSEPH A. SCHUMPETER, CAPITALISM, SOCIALISM, AND DEMOCRACY 83-84 (3rd ed. 1962) ("The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in . . . Every piece of business strategy acquires its true significance only against the background of that process and within the situation created by it. It must be seen in its role in the perennial gale of creative destruction; it cannot be understood irrespective of it or, in fact, on the hypothesis that there is a perennial lull.")
[34] Aron S. Spencer & Bruce A. Kirchhoff, *Schumpeter and New Technology Based Firms: Towards a Framework for How NTBFs Cause Creative Destruction*, 2 INT'L ENTREPRENEURSHIP & MGMT. J. 145, 148 (2006) ("However, the new entrant is able to find or create a market for the innovation, where it matures, and improves in performance. When the performance achieves rough parity with the old product, the new product sweeps through the market, offering equal or superior performance along with a smaller size and reduced price. The old product, and frequently the firm that produced it, exit the market. It is quite clear that this phenomenon is, in fact, "creative destruction".").
[35] CLAYTON M. CHRISTENSEN, THE INNOVATOR'S DILEMMA: WHEN NEW TECHNOLOGIES CAUSE GREAT FIRMS TO FAIL (1997); GEOFFREY MOORE, CROSSING THE CHASM (1991).
[36] Bower & Christensen, *supra* note 2; LARRY DOWNES & PAUL NUNES, BIG BANG DISRUPTION (2013). *Contra* Andrew A. King & Baljir Baatartogokh, *How Useful is the Theory of Disruptive Innovation*?, 57 MIT SLOAN MGMT. REV. 77 (2015) ("In summary, although Christensen and Raynor selected the 77 cases as examples of the theory of disruptive innovation, our survey of experts reveals that many of the cases do not correspond closely with the theory. In fact, their responses suggest that only seven of the cases (9%) contained all four elements of the theory that we asked about.").

markets.[37] Market leaders often shortsightedly refuse to cannibalize their market dominance through the use of disruptive technologies. This enables small entrepreneurial firms with no established customer base to take advantage of disruptive technologies and redefine such markets.[38] Market leaders, successful institutions, and managers fail when they do not distinguish sustaining technologies from disruptive technologies.[39]

Successful disruptive products of the last fifteen years displayed shared core characteristics that were facilitated by growth and advancement in core disruptive technologies. Revolutionizing products in the past few decades that were based on disruptive technological innovation were typically smaller in size, lighter, cheaper, more convenient and flexible, more reliable, had better unit performance with higher efficiency, and were more user friendly than prior products.[40] These characteristics typically require significant advances and growth in artificial intelligence and technologies including micro- or nanotechnologies, as well as materials- and component technologies.

Disruptive innovation via so-called big-bang disruptions differs from more-traditional innovation. Big-bang disruptors not only often offer a much cheaper product in comparison with the established products but they are also better integrated with other

[37] Bower & Christensen, *supra* note 2, at 43 ("One of the most consistent patterns in business is the failure of leading companies to stay at the top of their industries when technologies or markets change").

[38] *Id*. at 51 ("Small, hungry organizations are good at placing economical bets, rolling with the punches, and agilely changing product and market strategies in response to feedback from initial forays into the market"); Constantinos D. Charitou & Constantinos C. Markides, *Responses to Disruptive Strategic Innovation*, 44 MIT SLOAN MGMT. REV. 55, 56 (2003) ("Second, disruptive strategic innovations usually start out as small and low-margin businesses. That's why they rarely gain support or long-term commitment from established competitors. The innovations are small and are not attractive until they start growing."); *Contra* Larry Downes & Paul Nunes, *Big-Bang Disruption*, 91 HARV. BUS. REV. 44, 46 (2013), https://hbr.org/2013/03/big-bang-disruption/ ("The strategic model of disruptive innovation we've all become comfortable with has a blind spot. It assumes that disrupters start with a lower-priced, inferior alternative that chips away at the least profitable segments, giving an incumbent business time to start a skunkworks and develop its own next-generation products. That advice hasn't been much help to navigation-product makers like TomTom, Garmin, and Magellan. Free navigation apps, now preloaded on every smartphone, are not only cheaper but better than the stand-alone devices those companies sell. And thanks to the robust platform provided by the iOS and Android operating systems, navigation apps are constantly improving, with new versions distributed automatically through the cloud.").

[39] Sustaining technologies are technologies that improve the performance of existing products through close cooperation with customers. By contrast, disruptive technologies provide value parameters not recognized by the mainstream market and in the short-run can even show less product performance in comparison with the existing products that are valued by the mainstream market. Kostoff et al., *supra* note 2 at 144 ("The near-term individual rewards from sustaining technologies that yield short-term low-risk payoffs displace the longer term social benefits that could result from proactive high-risk high-payoff disruptive technology selection. The procedural problem is that technology selection decisions, especially in large established commercial and government organizations, are increasingly being made by larger and more inclusive committees, a process traditionally steeped in tradition and conservatism. Revolutionary disruptive concepts are less likely (on average) to receive committee approval than evolutionary sustaining concepts.").

[40] Kostoff et al., *supra* note 2, at 143; Walsh, *supra* note 4, at 170 ("Bower and Christensen champion the "different" nature of disruptive technologies emphasizing that they may not be "radically new from a technological point of view" but have superior "performance trajectories" along critical dimensions that customers' value. Abernathy and Clark and others argue that disruptive technologies' radical newness or emergent character is an important element in its definition since robust manufacturing infrastructure is either limited or nonexistent.").

products and services and are often more inventive.[41] In today's age of social media, big-bang disruptors can successfully exploit consumers' advanced access to product information and consumers' ability to contribute to products and share such contributions and products improvements via social media and other outlets.[42] Internet fads and products can be accessible to consumers in the entire world within a matter of days.[43] Big-bang disrupters typically launch businesses without a foundation using cloud computing, open platforms built on the internet, and fast-cycling mobile devices. Big-bang disrupters often produce multiple new products to identify which products may take hold in the market. While most such products will fail, the payoff associated with the unconstrained growth of those products that succeed is substantial and facilitates and often accelerates other forms of disruptive innovation.[44]

Big data is a significant driver of disruptive innovation. The idea of N=All, facilitated by big data, allows researchers to understand correlations that are completely unprecedented and to revolutionize our world.[45] Big data in the form of digitized data that grows at exponential rates and can be captured and manipulated electronically draws on several core sources including the internet of things, public records, social media, and cameras, as well as satellite tracking.[46] Big data benefits not only industry and researchers; it also increases consumer choice through publicly available websites providing big data analyses intended to support consumers' decision-making processes. Despite the overwhelming benefits associated with big data, big data's use of such

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[41] Downes & Nunes, *supra* note 38, at 46 ("The first key to survival is understanding that big-bang disruptions differ from more-traditional innovations not just in degree but in kind. Besides being cheaper than established offerings, they're also more inventive and better integrated with other products and services. And today many of them exploit consumers' growing access to product information and ability to contribute to and share it.").

[42] Steve Denning, *The Business Disease With No Cure: Big Bang Disruption*, FORBES (Feb. 22, 2014, 3:55PM), http://www.forbes.com/sites/stevedenning/2014/02/22/the-business-disease-without-a-cure-big-bang-disruption/ ("And, in today's world of "near perfect market information" and social media, the best quickly becomes a function of social consensus, not objective reality. That is why we say marketing's main function has shifted from selling to creating social consensus.").

[43] For instance, consumers downloaded an ad-supported version of a game called "Angry Birds" over a million times within the first 24 hours of its release. Seven months thereafter, consumers downloaded that game more than 200 million times. Larry Downes & Paul Nunes, *supra* note 38, at 46.

[44] *Id*. at 48 ("In the bizarro world of big-bang disrupters, it is perfectly rational to churn out dozens of new products and see which ones take hold. Like venture capital investments, most will fail outright. But just one success can pay off big.").

[45] KENNETH CUKIER & VIKTOR MAYER-SCHONBERGER, BIG DATA: A REVOLUTION THAT WILL TRANSFORM HOW WE LIVE, WORK AND THINK (2013).

[46] *Id*.; EXEC. OFFICE OF THE PRESIDENT, BIG DATA: SEIZING OPPORTUNITIES, PRESERVING VALUES (2014), https://goo.gl/xtDerj ("Big data technologies, together with the sensors that ride on the "Internet of Things," pierce many spaces that were previously private. Signals from home WiFi networks reveal how many people are in a room and where they are seated."); James Manyika et al., *Big Data: The Next Frontier for Innovation, Competition, and Productivity* 15 (McKinsey Global Institute Report May 2011), http://goo.gl/GBzeLR ("We estimate that new data stored by enterprises exceeded 7 exabytes of data globally in 2010 and that new data stored by consumers around the world that year exceeded an additional 6 exabytes. To put these very large numbers in context, the data that companies and individuals are producing and storing is equivalent to filling more than 60,000 US Libraries of Congress. If all words spoken by humans were digitized as text, they would total about 5 exabytes—less than the new data stored by consumers in a year. The increasing volume and detail of information captured by enterprises, together with the rise of multimedia, social media, and the Internet of Things will fuel exponential growth in data for the foreseeable future.").

disparate sources creates challenges for the integration of data and normalizing.[47] The literature mostly takes issue with the big data inaccuracies that occur when collecting data from databases that merely require generalized accuracy.[48] Big data are often not the output of instruments designed to generate valid and reliable data suitable for scientific analysis. Foundational data issues of construct validity, measurement, reliability, and data dependencies are the same regardless of data quantities.[49] Some critique the implicit assumption of big data researchers that big data is a substitute for traditional data collection and analysis rather than a mere supplement[50] while others see big data and small data not as mutually exclusive but as reinforcing and supporting each other.[51] Big data shortcomings can largely be addressed with artificial intelligence, and the

[47] *Id*. at 12 ("To capture value from big data, organizations will have to deploy new technologies (e.g., storage, computing, and analytical software) and techniques (i.e., new types of analyses). The range of technology challenges and the priorities set for tackling them will differ depending on the data maturity of the institution. Legacy systems and incompatible standards and formats too often prevent the integration of data and the more sophisticated analytics that create value from big data. New problems and growing computing power will spur the development of new analytical techniques. There is also a need for ongoing innovation in technologies and techniques that will help individuals and organizations to integrate, analyze, visualize, and consume the growing torrent of big data."); Christian Bizer et al., *The Meaningful Use of Big Data: Four Perspectives—Four Challenges*, 40 ACM SIGMOD REC. 56, 57 (2012) ("My challenge is meaningful data integration in the real, messy, often schema-less, and complex Big Data World of databases and the (Semantic) Web using multi-disciplinary, multi-technology methods.").

[48] *Id*. at 57 ("The Web is an open medium in which everybody can publish data on the Web. As the classic document Web, the Web of Data contains data that is outdated, conflicting, or intentionally wrong (SPAM). Thus, one of the main challenges that Linked Data applications need to handle is to assess the quality of Web data and determine the subset of the available data that should be treated as trustworthy."); IAN AYRES, SUPER CRUNCHERS: WHY THINKING-BY-NUMBERS IS THE NEW WAY TO BE SMART 60-63 (2007) (identifying big data phenomenon); Andrea Lancichinetti et al., *High-Reproducibility and High-Accuracy Method for Automated Topic Classification*, 5 PHYSICAL REV. X 011007 (2015)(detailing the inaccuracy problems associated with big data text analysis/machine reading (called LDA)).

[49] *See* David Lazer et al., *The Parable of Google Flue: Traps in Big Data Analysis*, 343 SCIENCE 1203 (2014); Gary Marcus & Ernest Davis, *Eight (No, Nine!) Problems With Big Data*, N.Y. TIMES (Apr. 6, 2014), http://www.nytimes.com/2014/04/07/opinion/eight-no-nine-problems-with-big-data.html ("Reliable statistical information can be compiled about common trigrams, precisely because they appear frequently. But no existing body of data will ever be large enough to include all the trigrams that people might use, because of the continuing inventiveness of language."); Tim Harford, *Big Data: Are We Making a Big Mistake?*, FIN. TIMES (Mar. 28, 2014), http://goo.gl/2dyox2 ("Statisticians have spent the past 200 years figuring out what traps lie in wait when we try to understand the world through data. The data are bigger, faster and cheaper these days – but we must not pretend that the traps have all been made safe. They have not.").

[50] Jeff Leek, *Why Big Data is in Trouble: They Forgot about Applied Statistics*, SIMPLYSTATS (May 7, 2014), http://goo.gl/2dyox2 ("Statistical thinking has also been conspicuously absent from major public big data efforts so far.").

[51] Lazer et al., *supra* note 49, at 1205 ("There is a tendency for big data research and more traditional applied statistics to live in two different realms—aware of each other's existence but generally not very trusting of each other. Big data offer enormous possibilities for understanding human interactions at a societal scale, with rich spatial and temporal dynamics, and for detecting complex interactions and nonlinearities among variables. We contend that these are the most exciting frontiers in studying human behavior. However, traditional 'small data' often offer information that is not contained (or containable) in big data, and the very factors that have enabled big data are enabling more traditional data collection. The Internet has opened the way for improving standard surveys, experiments, and health reporting. Instead of focusing on a 'big data revolution,' perhaps it is time we were focused on an 'all data revolution,' where we recognize that the critical change in the world has been innovative analytics, using data from all traditional and new sources, and providing a deeper, clearer understanding of our world.").

combination of big data and artificial intelligence opens up significant additional big data applications.[52]

Artificial intelligence (AI) presents another significant field of disruptive innovation. AI is different from a regular computer algorithm. AI tries to emulate human thought processes and rational human behavior through self-learning and storage of experiences.[53] Because it emulates human behavior, AI can act differently in the same situations, depending on the actions previously performed. Many sectors of the economy are already significantly affected by the rapid advances in AI during the past decade.[54] The exponential development of AI and the associated disruptive innovation pose

[52] Jo Ann S. Barefoot, *Disrupting Fintech Law*, 18 FINTECH L. REP., no. 2, 2015 at 6 ("Terms like 'machine learning, 'deep learning,' and 'neural networks are entering the lexicon, referring to the fast-growing ability of machines to gather and analyze vast volumes of information in ways, and at speeds, hitherto unimaginable. …Computers today can take on a question or task; search all the digitized information in the world; analyze what might be responsive to the goal; suggest possibilities; learn from feedback; and endlessly improve results. In the medical realm, for instance, machines can diagnose cancer with accuracy rivaling and surpassing that of human pathologists, and can 'collaborate' with humans to enhance the outcomes that either could reach alone. Importantly, machines have 'noticed' things they were not even asked to find, such as characteristics of tissue outside a malignancy, bringing such observations to the attention of doctors who then have pursued new pathways of study and medical diagnosis. Computers can conduct searches in seconds, hours, or days that would take humans hours, months, or even years to execute. They efficiently synthesize images, data, and words, in any language, from across the globe, and then present analysis and conclusions in conversational language and useful graphics."); Daniel E. O'Leary, *Artificial Intelligence and Big Data*, 28 IEEE INTELLIGENT SYS. 96, 97 (2013)("AI researchers have long been interested in building applications that analyze unstructured data, and in somehow categorizing or structuring that data so that the resulting information can be used directly to understand a process or to interface with other applications. As an example, Johan Bollen and Huina Mao8 found that stock market predictions of the Dow Jones Industrial average were improved by considering the overall "sentiment" of the stock market— this is an unstructured concept, but based on structured data generated from Google."); Maryam M. Najabadi et al., *Deep Learning Applications and Challenges in Big Data Analytics*, 2 J. BIG DATA 11 (2015) ("[P]erforming discriminative tasks in Big Data Analytics one can use Deep Learning algorithms to extract complicated nonlinear features from the raw data, and then use simple linear models to perform discriminative tasks using the extracted features as input. This approach has two advantages: (1) extracting features with Deep Learning adds nonlinearity to the data analysis, associating the discriminative tasks closely to Artificial Intelligence, and (2) applying relatively simple linear analytical models on the extracted features is more computationally efficient, which is important for Big Data Analytics.").

[53] Robert D. Hof, *10 Breakthrough Technologies 2013: Deep Learning*, MIT TECH. REV. (Apr. 23, 2013), http://www.technologyreview.com/featuredstory/513696/deep-learning/ ("With massive amounts of computational power, machines can now recognize objects and translate speech in real time. Artificial intelligence is finally getting smart"); STUART RUSSELL & PETER NORVIG, ARTIFICIAL INTELLIGENCE: A MODERN APPROACH 5 (2013) (describing the different major definitions for AI); Paulius Cerka et al., *Liability for Damages Caused by Artificial Intelligence*, 31 COMPUTER L. & SEC. REV. 376, 378 (2015) ("This belief began to change due to constant improvement of computer systems. Intellect, i.e. the ability to know, understand, and think, may not only be innate (natural), but also artificially created. AI is a broad area that includes such subfields as: (i) natural language systems; (ii) machine learning; (iii) simulation of senses; (iv)neural networks; (v) computer games; (vi) expert systems; and (vii) robotics.").

[54] Craig E. Karl, *The Three Breakthroughts That Have Finally Unleashed AI on the World*, WIRED (Oct. 27, 2014, 6:30AM), http://www.wired.com/2014/10/future-of-artificial-intelligence/ ("Over the past five years, cheap computing, novel algorithms, and mountains of data have enabled new AI-based services that were previously the domain of sci-fi and academic white papers. [Products such as the:] Self-Driving Car…Body Tracker…Personal Photo Archivist…Universal Translator…Smarter News Feed").

substantial challenges for policy makers in education, financial markets, labor markets, and other areas.[55]

III. Venture Capital Impact on Innovation

The interdependent nature of venture capital investments and innovation is widely recognized. Evidence exists that a productive and active venture capital industry boosts innovation-based growth.[56] Through selection of promising companies, financing, collective learning, embedding, and signaling, VC firms can both interact with other members of complex networks of innovation and support the robustness of that system.[57] VC involvement in businesses helps lower information and opportunity costs and venture capital networks support businesses in entering an industry and can create a virtuous circle of new enterprise formation, innovation, and economic development.[58] Studies using patent rates almost universally suggest that venture capital has a positive effect on innovation.[59] Kortum and Lerner showed that venture capital is significantly more effective at stimulating patents compared to corporate research and development (R&D).[60] Moreover, while high innovation ventures benefit most from venture capitalist involvement,[61] there is some evidence that VCs added most value to those ventures already performing well.[62]

Despite the overwhelming evidence of a positive relationship between innovation and VC, an emerging literature questions the relationship between VC and innovation, using measures such as total factor productivity (TFP). Some suggest that older studies on VCs interaction with patent rates misinterpreted the casual relationship, e.g. rather than the VC creating the innovation, the money goes where the innovation is.[63]

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[55] ERIK BRYNJOLFSSON & ANDREW MCAFEE, THE SECOND MACHINE AGE: WORK, PROGRESS, AND PROSPERITY IN A TIME OF BRILLIANT TECHNOLOGIES 205-228 (2014) (discussing policy in face of projected automation of low-skill labor); Tess Townsend, *Peter Diamandis: A.I. Will Lead to Massive Disruption Across Industries*, INC. (Sept. 24, 2015), http://www.inc.com/tess-townsend/diamandis-artificial-intelligence.html ("He said self-driving cars will render car insurance and the need for more roads obsolete. He anticipates his children will never drive. He projected that advances in camera technology will lead to cameras woven into clothes, biometric sensing will "massively disrupt" medicine, and satellites will be able to watch raw materials entering factories and finished products leaving them, enabling smart AI to extract financial performance data ahead of the markets.").

[56] Christian Keuschnigg, *Venture capital backed growth*, 9 J. Econ. Growth 239 (2004).

[57] Michael Ferrary & Mark Granovetter, *The role of venture capital firms in Silicon Valley's complex innovation network*, 38 Econ. & Soc'y 326 (2009).

[58] Richard Florida & Martin Kenney, *Venture capital and high technology entrepreneurship*, 3 J. Bus. Venturing 301 (1988).

[59] CITE all

[60] Samuel Kortum & Josh Lerner, *Assessing the Contribution of Venture Capital to Innovation*, 31 Rand J. Econ. 674 (2000).

[61] Harry J. Sapienza, *When do venture capitalists add value*?, 7 J. Bus. Venturing 9 (1992).

[62] Harry J. Sapienza et al., *Venture capitalist governance and value added in four countries*, 11 J. Bus. Venturing 439 (1996).

[63] Masayuki Hirukawa & Masako Ueda, *Venture Capital and Innovation: Which is First?*, 16 Pacific Econ. Rev. 421 (2011). ("Policy-makers typically interpret positive relations between venture capital (VC) investments and innovations as evidence that VC investments stimulate innovation (VC-first hypothesis). This interpretation is, however, one-sided because there may be a reverse causality that innovations induce VC investments (innovation-first hypothesis): an arrival of new technology increases demand for VC. We analyze this causality issue of VC and innovation in the US manufacturing industry using both total factor productivity growth and patent counts as measures of innovation. We find that, consistent with the

IV. Disruptive Innovation as a Regulatory Challenge

Regulatory concerns associated with disruptive technologies will likely increase in the coming years. Disruptive innovative technology often does not fit into existing legal categories created by recalcitrant regulatory structures.[64] Examples of existing regulatory concerns that may be exacerbated by future developments include the possible hacking of digital devices either to obtain information or to take control, the remote controlling of a driverless car, the hacking of pacemakers of influential elites, the remote controlling of an individual's computer to demand a ransom, among many others.[65] AI may not only fundamentally challenge traditional employment law structures,[66] AI and automation may eventually play important roles in causing large dislocations in labor markets.[67] In finance, it remains unclear how to treat crowdfunding technology that allows firms and

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innovation-first hypothesis, total factor productivity growth is often positively and significantly related with future VC investment. We find little evidence that supports the VC-first hypothesis."); Michael Peneder, *The impact of venture capital on innovation behavior and firm growth*, 12 Venture Capital: Int'l J. of Entrepreneurial Fin. 83 (2010)("This paper uses a novel research design to investigate the effects of venture capital financing on corporate performance by applying a two-stage propensity score matching on Austrian micro-data. Controlling for differences in industry, location, legal status, size, age, credit rating, export and innovation behaviour, the findings (i) assert the financing function of venture capital, showing that recipients lacked access to satisfactory alternative sources of capital; (ii) identify selection effects, where venture capital is invested in firms with high performance potential; and finally (iii) confirm the value adding function in terms of a genuine causal impact of venture capital on firm growth, yet not on innovation output."); Stefano Caselli et al., *Are venture capitalists a catalyst for innovation*, 15 Euro. Fin. Mgmt. 92 (2009); Bart Stuck & Michael Weingarten, *How Venture Capital Thwarts Innovation*, 42 IEEE Spectrum 50 (2005).

[64] For example, the question of how to categorize those that participate in the sharing economy into the standard employee-independent contractor framework, how crowdfunding works with the regulatory structure of private securities offerings or how cryptocurrencies (such as BitCoin) fit with regulatory structure around currencies and bank reporting requirements. *See* Felix Salmon, *When disruption meets regulation*, REUTERS (Jan. 30, 2014), http://blogs.reuters.com/felix-salmon/2014/01/30/when-disruption-meets-regulation/; Balaji S. Srinivasan, *Regulation, Disruption, and the Technologies of 2013* (Center for Ethics and Entrepreneurship), http://goo.gl/sjZ3tF (providing an overview of the major conflicts between the traditional regulatory structures and innovative disruptors, with quotes from Elon Musk, AirBnB founders, other top entrepreneurs).

[65] Mark Harris, *Researcher Hacks Self-driving Car Sensors*, IEEE SPECTRUM (Sept. 4, 2015, 19:00 GMT), http://goo.gl/rrlnP6; Aarti Shanani, *Ransomware: When Hackers Lock Your Files, To Pay Or Not To Pay*, NPR ALLTECHCONSIDERED (Dec. 8, 2014, 6:27AM ET), http://goo.gl/8Ybj8o; Tarun Wadhwa, *Yes, You Can Hack A Pacemaker (And Other Medical Devices Too*), FORBES (Dec. 6, 2012 8:31AM), http://goo.gl/oglPhS.

[66] There are major issues of whether to classify uber and lyft drivers as independent contractors or employees- Uber's innovative model essentially requires them to be non-employees but many claim such classification harms existing firms that have to comply with California's extensive labor law requirements. *Berwick v. Uber Tech., Inc*., Case No. 11-46739 EK, 2015 WL 4153765 (CA Dep't of Labor Jun. 3, 2015) (deciding Uber workers were indeed employees and Uber must comply with California labor law in this regard). See also Mike Isaac & Natasha Singer, *California Says Uber Driver is Employee, Not a Contractor*, N.Y. TIMES, Jun. 17, 2015, http://www.nytimes.com/2015/06/18/business/uber-contests-california-labor-ruting-that-says-drivers-should-be-employees.html?_r=0.

[67] John Komlos, *Has Creative Destruction Become More Destructive?* (NBER Working Paper No. 20379), http://www.nber.org/papers/w20379 (suggesting that the creative destruction aspect of capitalism is being amplified, especially in labor markets, by the exponential pace of technology).

individuals to raise money through bottom-up funding rather than traditional capital markets.[68] While acknowledging positive traits associated with crowdfunding technology, many commentators are concerned about the possibility of fraud, the breakdown of traditional protections for small investors, privacy violations, and intellectual property issues.[69]

AI and its disruptive capabilities present significant regulatory challenges in the existing regulatory framework. AI's ability to accumulate and learn from experiences, to make individual decisions, and to act without supervision creates the possibility of causing damage to other technologies or humans. [70] Should AI unknowingly cause damage, any forms of compensation would have to be addressed through existing legal provisions in the existing regulatory framework. However, national and international law do not (currently) recognize AI as a subject of law. Without legal personality, AI cannot be personally liable for damages.[71] With autonomous AI playing an expanding role in society, an increasing number of scientists and entrepreneurs suggest that government regulation may be necessary to reduce the risks to the public associated with the rapid advances in AI.[72] While some favor an indirect form of AI regulation based on

[68] Thomas L. Hazen, *Crowdfunding or Fraudfunding? Social Networks and the Securities Laws--Why the Specially Tailored Exemption must be Conditioned on Meaningful Disclosure*, 90 N.C. L. REV. 1735, 1736 (2012) ("Social networks have been used as a medium for financing films and other forms of art, as well as for charitable solicitations. These and similar fundraising endeavors are known as crowdfunding. Crowdfunding is the fundraising analog to crowdsourcing, which refers to mass collaboration efforts through large numbers of people, generally using social media or the Internet.").

[69] *See generally Id*.; Letter from William F. Galvin, Secretary of the Commonwealth of Massachusetts, to Elizabeth M. Murphy, Secretary, U.S. Securities and Exchange Commission 1-2 (Aug. 8, 2012), http://www.sec.gov/comments/jobs-title-iii/jobstitleiii-121.pdf ("Crowdfunding represents a significant departure from long-established rules for public offerings of securities . . . Crowdfunding is designed to permit the smallest investors to participate in securities offerings by early-stage companies. Our experience is that these investors are especially vulnerable in the small-company segment of the market.").

[70] Cerka et al., *supra* note 53, at 376 ("The ability to accumulate experience and learn from it, as well as the ability to act independently and make individual decisions, creates preconditions for damage. Factors leading to the occurrence of damage identified in the article confirm that the operation of AI is based on the pursuit of goals. This means that with its actions AI may cause damage for one reason or another; and thus issues of compensation will have to be addressed in accordance with the existing legal provisions.").

[71] *Id*. ("In the absence of direct legal regulation of AI, we can apply article 12 of United Nations Convention on the Use of Electronic Communications in International Contracts, which states that a person (whether a natural person or a legal entity) on whose behalf a computer was programmed should ultimately be responsible for any message generated by the machine. Such an interpretation complies with a general rule that the principal of a tool is responsible for the results obtained by the use of that tool since the tool has no independent volition of its own. So the concept of AI-as-Tool arises in the context of AI liability issues, which means that in some cases vicarious and strict liability is applicable for AI actions.").

[72] Sharon Gaudin, *A.I. Researchers Say Elon Musk's Fears 'Not Completely Crazy'*, COMPUTERWORLD (Oct. 29, 2014, 1:16PM PT), http://goo.gl/3K91LD ("I think we should be very careful about artificial intelligence," Musk said when answering a question about the state of AI. "If I were to guess at what our biggest existential threat is, it's probably that …With artificial intelligence, we are summoning the demon. In all those stories with the guy with the pentagram and the holy water, and he's sure he can control the demon. It doesn't work out."); Rory Cellan-Jones, *Stephen Hawking Warns Artificial Intelligence Could End Mankind*, BBC NEWS (Dec. 2, 2014), http://www.bbc.com/news/technology-30290540 ("He told the BBC: 'The development of full artificial intelligence could spell the end of the human race.'").

differential tort liability,[73] others oppose rigid regulation of AI because regulation may inhibit the socially beneficial innovations associated with AI or suggest such regulation is impossible in the face of such a powerful and exponentially growing technology.[74] AI is currently not able to match human-level reasoning,[75] but it can still have an impact on the service industries, among others.[76]

A regulatory response to disruptive innovation requires policymakers to balance legitimate policy objectives such as consumer protection, privacy, and public welfare while avoiding regulatory capture and policies that predominantly protect incumbent firms. In the startup phase and before gaining substantial market share, disruptive firms often create products or provide services that either do not fit into the existing regulatory framework and the protections provided thereby, or such disruptive products and services do not or do not fully comply with existing regulatory protections. In the latter case, disruptive firms often argue that because of the unprecedented nature of the disruptive product or service the existing rules do not or should not apply or compliance with the existing rules is not necessary to protect the public because more appropriate consumer protections are available through the disruptive firm.[77] If disruptive firms do not comply

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[73] Matthew U. Scherer, *Regulating Artificial Intelligence Systems: Risks, Challenges, Competencies, and Strategies*, 29 HARV. J. L. & TECH. (forthcoming 2016), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2609777.

[74] *You, robot*?, THE ECONOMIST (Sept. 1, 2012), http://www.economist.com/node/21560986 ("Regulators must tread carefully. Noel Sharkey, a computer scientist at the University of Sheffield, observes that overly rigid regulations might stifle innovation. But a lack of legal clarity leaves device-makers, doctors, patients and insurers in the dark. The RoboLaw researchers hope to square this circle when they deliver their findings in 2014. So far, though, they seem to have more questions than answers."); John Danaher, *Is Regulation of Artificial Intelligence Possible*?, H+ MAGAZINE (Jul. 15, 2015), http://goo.gl/vMw8et ("Despite these worries, debates about the proper role of government regulation of AI have generally been lacking. There are a number of explanations for this: law is nearly always playing catch-up when it comes to technological advances; there is a decidedly anti-government libertarian bent to some of the leading thinkers and developers of AI; and the technology itself would seem to elude traditional regulatory structures.").

[75] Richard Waters, *Artificial Intelligence: Machine v. Man*, FIN. TIMES (Oct. 31, 2015), http://goo.gl/8gaWQn ("Their effort is prompted by a fear of what will happen when computers match humans in intelligence. At that point, humans would cede leadership in technological development, since the machines would be capable of improving their own designs by themselves. And with the accelerating pace of technological change, it wouldn't be long before the capabilities – and goals – of the computers would far surpass human understanding.").

[76] Harry Surden, *Machine Learning and Law*, 89 WASH. L. REV. 87, 88 (2014) ("In the last few decades, researchers have successfully used machine learning to automate a variety of sophisticated tasks that were previously presumed to require human cognition. These applications range from autonomous (i.e., self-driving) cars, to automated language translation, prediction, speech recognition, and computer vision. Researchers have also begun to apply these techniques in the context of law.").

[77] Benjamin G. Edelman & Damien Geradin, *Efficiencies and Regulatory Shortcuts: How Should We Regulate Companies like Airbnb and Uber?* (Harv. Bus. Sch. Working Paper 16-026) at 2, http://goo.gl/a0taVA ("We note that many platform operators advertise their services as "sharing." For example, short-term property rental service Airbnb says its service lets hosts "share . . . homes with guests" while transportation service Lyft says it offers "ridesharing." The term "sharing" partially captures some aspects of these companies' activities, e.g., employing a single resource for multiple purposes, such as using a vehicle both for an owner's personal needs and to transport paying passengers. Nonetheless, the key efficiencies generally do not come from "sharing" but from the market structure that platforms facilitate, including casual service providers who avoid the fixed cost and, often, regulation associated with traditional service."); Andy Kessler, *The Weekend Interview with Brian Chesky: The 'Sharing Economy'*

with existing rules or create their own exemptions because the existing regulatory framework does not apply and appropriate rules are not available, public policy goals including consumer protection and public safety can be undermined and incumbent firms that continue to be subject to existing rules encounter often severe competitive disadvantages[78]. To counteract such disadvantages, incumbent firms that are exposed to a perceived threat of disruptive innovation from disruptive firms may attempt to use the existing regulatory process to create obstacles for disruptive firms to compete.

The anticipated level of innovation in the next thirty years[79] makes it increasingly less likely that rulemakers will be able to effectively protect the public while harnessing innovation for the benefit of society. The combination of harm and possible benefits that are associated with disruptive innovation can either equally affect both consumers and providers or it can benefit a subset of consumers and providers while another subset suffers adverse consequences; it can also create tradeoffs for subsets of providers and consumers. As accelerating disruptive technology creates new complexity for society at a rapidly accelerating pace, especially in significant growth areas such as robotics, nanotechnology, and biotechnology,[80] society increasingly struggles with analyzing the wealth of new, beneficial, and ever more detailed information received from disruptive technologies.[81] The negative and positive impact of disruptive innovation will trigger political and policy pressures for and against various regulatory responses to change. The political system is, however, less likely to be able to deal with the challenges of disruptive innovation because the increasing complexity of innovation-driven regulatory issues causes political and policy makers' confusion over rapidly-emerging disruptive change, making a coherent political and policy solution to these challenges less likely.

The existing regulatory infrastructure cannot sufficiently distinguish and harness beneficial innovation. Rulemakers' inability to address regulatory issues associated with disruptive innovation will likely generate high levels of legal uncertainty and inconsistency[82] that inhibit innovation during technological transition periods; and

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and Its Enemies, WALL ST. J. (Jan. 17, 2014), http://www.wsj.com/articles/SB10001424052702304049704579321001856708992 ([Uber cofounder Brain Chesky said of the current regulatory structure]: "There were laws created for businesses, and there were laws for people. What the sharing economy did was create a third category: people as businesses," to which the application of existing laws is often unclear.").

[78] See Edelman & Geradin, *supra* note 77, at 23 ("Most regulatory regimes require full service to disfavored groups, including racial minorities, low-income users, and low-income regions. Software platforms tend to circumvent these requirements, either through decentralized decision-making that favors individual preferences over government mandates, or through software implementations that otherwise do not require compliance.").

[79] *See supra* Fn. [_]-[_] and accompanying text.

[80] *See supra* Fn. [_]-[_] and accompanying text.

[81] John O. McGinnis, *Accelerating Ai*, 104 NW. U. L. REV. 1253, 1269 (2010) ("The problem now is that the information available to be processed may be swelling beyond human capacity to achieve sound social decisionmaking without the aid of AI.").

[82] *Id*. at 18 ("[United States has] five federal agencies that directly examine and supervise financial institutions (Comptroller of the Currency, FDIC, Federal Reserve Board, CFPB, and National Credit Union Administration (NCUA)). At least 20 federal agencies regulate some aspect of financial products, from mortgages and student loans to retirement funds, and/or have enforcement mandates that include financial services, as with the Department of Justice (DOJ) and the FTC. Much of this complexity is multiplied by fifty at the state level, plus insurance products are almost entirely regulated by the states. . . . All or most of these regulatory bodies have at least fragmentary responsibility relating to the broad, overarching consumer

technological transition is likely going to be a permanent state in the age of disruptive innovation, which exacerbates the uncertainty and inconsistency created by rulemakers' inability to react timely and adequately to disruptive innovation. In the existing regulatory framework, regulators and commenters are engaged in a long, drawn out feedback process that involves hearings, proposed rules, the submission of comment letters, and finally agency lawyers finalizing a rule after considering the comments. The current regulatory framework lacks a mechanism that succinctly and anticipatorily informs rulemakers of beneficial innovative ideas. In fact, the existing rulemaking process prohibits ex parte communications and insufficiently integrates brainstorming and ideas across industries, and therefore may actually undermine innovation.

1. Ex Post Trial-and-Error Rulemaking

The ex-post trial-and-error-rulemaking in the existing regulatory framework[83] often produces suboptimal regulatory outcomes that may no longer be sustainable as disruptive innovation accelerates and causes unprecedented societal change. The ex-post trial-and-error approach to rulemaking has functioned in the existing regulatory framework because optimal rule requirements for rules do become clear when stable and presumptively optimal rules emerge as suboptimal. A prerequisite for ex-post trial-and-error rulemaking is thus the availability of the information on optimized rule requirements. In an age of exponential innovation, that information may not materialize at all or may not materialize in time for the trial-and-error rulemaking to be effective. In other words, because trial-and-error rulemaking did not anticipate regulatory issues created by innovation, rulemakers may not at all or much too late realize what new regulatory demands apply to a given innovation and associated regulatory issue.

2. Stable and Presumptively Optimal Rules

The existing regulatory infrastructure, including Congress, regulatory agencies, self-regulatory bodies, and the literature on regulation, relies almost exclusively on stable and presumptively optimal rules.[84] Such stable and presumptively optimal rules are created to address perceived regulatory issues identified by lawmakers through centralized information in the then existing economic and market conditions. Stable and presumptively optimal rules are tailored and drafted to attain permanent solutions for perceived regulatory issues that can be addressed with sufficient political support at the time of drafting.[85] The underlying conditions for rulemaking and the corresponding requirements for optimal and stable rules are, however, subject to constant and ever

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protection themes discussed above, such as privacy, data security, UDAP, fair lending, and the like. As these and other regulatory standards shift and escalate under pressure from fast-changing technology, it seems inevitable that the complexity of this structure will exacerbate uncertainty and inconsistency in regulatory expectations, and will militate against modernization that might address problems efficiently and serve consumers well.").

[83] Popper, *supra* note 8*;* Kirchner, *supra* note 11.

[84] See Kaal in FS Kirchner, *supra* note 7, at 2 ("[T]he institutional infrastructure for rulemaking was geared towards the creation of rules for governing a relatively stable society with less upward mobility and relatively stable economic and market environments."); Kaal Wake Forest, *supra* note 7; Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal & Lacine 2014, *supra* note 7.

[85] Kaal in FS Kirchner, *supra* note 7, at 8, 13.

increasing amounts of change.[86] The exponential growth of technology, the associated exponential growth of innovation, and the resulting growth in the complexity of regulatory issues will likely require ever increasing numbers of governance adjustments via stable and presumptively optimal rules,[87] making it increasingly less likely that rulemakers will be able to effectively protect the public via stable and presumptively optimal rules. If rulemakers cannot adequately protect their constituents, regulatory supplements facilitating anticipatory rulemaking may be justified.

The existing regulatory infrastructure with stable rules and stable rulemaking processes is subject to significant systemic constraints and path dependencies. Historically, a comparatively small, stable, and less interconnected society with limited upward mobility and relatively stable economic and market environments for rulemaking created an institutional infrastructure for rulemaking that produces stable and presumptively optimal rules to address a limited set of readily identifiable regulatory issues.[88] Because of the limited scope of regulatory issues and the need for consensus driven institutional designs, the historically evolved infrastructure for rulemaking could cope with its inherent collective action problems,[89] regulatory cycles,[90] and trial-and-error rulemaking,[91] without major disruptions. The exponential growth of technology and its associated disruptive innovation[92] are likely to expose the depth of issues related to the path dependencies in the existing regulatory infrastructure and the associated design flaws of the institutional infrastructure.

3. Timing

Timing of regulation in an environment of disruptive innovation should be a primary concern for policy makers. If policy makers regulate too early, they risk inhibiting innovation; if they withhold regulation too long, they may harm consumers and markets if regulatory inertia has set in around the disruptive product or service. The time frame for rulemaking in the existing regulatory infrastructure may be inadequate to address regulatory challenges associated with disruptive innovation. In the existing regulatory

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[86] *Id.*

[87] MAEVE P. CAREY, R43056, COUNTING REGULATIONS: AN OVERVIEW OF RULEMAKING, TYPES OF FEDERAL REGULATIONS, AND PAGES IN THE FEDERAL REGISTER 17 (2015) ("As the data show, the number of pages has increased since publication of the Federal Register began. The number of pages reached a peak in 1980 at 87,012 pages; decreased to 47,418 pages in 1986; then increased again and has been approximately between 65,000 and 85,000 pages for the past two decades.").

[88] Kaal in FS Kirchner, *supra* note 7, at 2-3 ("[T]he institutional infrastructure for rulemaking was geared towards the creation of rules for governing a relatively stable society with less upward mobility and relatively stable economic and market environments.").

[89] Coffee, *supra* note 9, at 1019-1082; Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal Wake Forest, *supra* note 7; Kaal in FS Kirchner, *supra* note 7; Ostrom, *supra* note 9 (The predominance of special interest groups in the rulemaking process can be temporarily overcome during and after crises when political entrepreneurs assume the transaction costs of organizing the otherwise disinterested latent groups); Olson, *supra* note 9 (Smaller and better-organized special interest groups typically control dispersed investors and other dominant latent groups in the competition to influence the rulemaking process).

[90] Coffee, *supra* note 9; Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal in FS Kirchner, *supra* note 7.

[91] Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal in FS Kirchner, *supra* note 7; Kirchner, *supra* note 11 at 161-172; Popper, *supra* note 8.

[92] *See supra* Fn. [_]-[_] and accompanying text.

framework, regulators and commenters are engaged in a long, drawn out feedback process that involves hearings, proposed rules, the submission of comment letters, and finally agency lawyers finalizing a rule after considering the comments[93]. This existing rulemaking process often prohibits ex parte communications,[94] involves very little brainstorming, and undermines innovation.[95] While rulemakers may be able to update regulations and regulatory guidance to address regulatory issues created by disruptive innovation, given the exponential nature of disruptive innovation,[96] they are less able to *adequately* update existing rules in the present regulatory framework. The speed of product innovation alone makes formal rulemaking in the existing regulatory infrastructure challenging. Formal rulemaking is simply too time-consuming.[97] The speed of product innovation makes it possible to bring a new product to market while formal rulemaking in the existing regulatory infrastructure, taking months and often years of regulatory procedure, is still dealing with the last product launch. New regulations pertaining to an innovative product could be obsolete before they are finalized.[98]

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[93] Lynn E. Blais & Wendy E. Wagner, *Emerging Science, Adaptive Regulation, and the Problem of Rulemaking Ruts*, 86 TEX. L. REV. 1701, 1706 (2008) ("[A]gencies systematically engage in excess data gathering, protracted analysis of the data and associated public comments, and extraordinarily detailed explanation of the bases and purposes of their final rules in an attempt to insulate their policies from judicial reversal. . . . This hyperformalization of notice-and-comment rulemaking has several consequences. The most obvious is the increase in time and resources required to promulgate each rule . . .").

[94] 5 U.S.C. § 557(d)(1) (2012); *Ex Parte Communications in Informal Rulemaking Proceedings (Recommendation 77-3*), 1 C.F.R. § 305.77 (2014) (listing other advantages associated with restraining ex parte communications, including reducing possibility of unfair influence over decision makers and affording interested parties opportunity to respond to information relied upon in decisionmaking process).

[95] Peter H. Schuck, *When the Exception Becomes the Rule: Regulatory Equity and the Formulation of Energy Policy Through an Exceptions Process*, 1984 DUKE L.J. 163, 197 (1984) ("Hastily prepared, overbroad rules can be disastrous for those who technically are covered by the rules but to whom the rules should not, in justice or sound policy, be applied. Inflexible application of such rules may quickly create grave competitive distortions, perhaps even driving firms out of business before the rules can be refined or eliminated."); Blais & Wagner, *supra* note 93, at 1705 ("Important statutory directives remain unimplemented years after the deadline for implementation has passed. Agencies are increasingly turning to even more informal methods-- which lack adequate opportunities for public participation and evade meaningful judicial oversight--to promulgate important policies. And, not surprisingly, agencies are increasingly reluctant to revisit rules after enactment, even if the factual or policy predicates underlying them have changed.").

[96] *See supra* Fn. [_]-[_] and accompanying text.

[97] Cass R. Sunstein, *Is the Clean Air Act Unconstitutional*?, 98 MICH. L. REV. 303, 371 (1999) ("With respect to systematic effects: A great deal of attention has been paid to the phenomenon of the "ossification" of notice-and-comment rulemaking, and indeed a high priority, for the future of administrative law, is to devise means to overcome the problem. Originally intended as a quick and effective alternative to formal, on-the-record rulemaking, executive and especially judicial innovations have converted notice-and-comment rulemaking into an exceptionally time-consuming affair, often consuming many years, frequently half a decade and more. In fact EPA estimates that informal rulemaking typically takes five years."); Thomas O. McGarity, *Some Thoughts on "Deossifying" the Rulemaking Process*, 41 DUKE L.J. 1385, 1385 (1992) ("Although informal rulemaking is still an exceedingly effective tool for eliciting public participation in administrative policymaking, it has not evolved into the flexible and efficient process that its early supporters originally envisioned. During the last fifteen years the rulemaking process has become increasingly rigid and burdensome.").

[98] Barefoot, *supra* note 52, at 10.

4. Unknown Future Contingencies

The existing regulatory infrastructure with stable and presumptively optimal rules is largely incapable of addressing the ever increasing unknown future contingencies associated with disruptive innovation. Because it lacks anticipatory rulemaking capabilities, the existing regulatory system addresses regulatory issues only ex-post, if and when they materialize and if core constituents are sufficiently burdened to precipitate enough political pressure for lawmakers to act.[99] Evidence exists that the suboptimal ex-post timing of rulemaking in the existing regulatory infrastructure regularly requires expedited rulemaking that results in suboptimal regulatory outcomes.[100] Rulemakers often discount or willingly accept the suboptimalities of rules associated with unknown future contingencies. Temporary acceptance of suboptimal rules increases temporary rule certainty and predictability, but it also precipitates the inevitable need for rule revision, amendments, and repeals[101] In the existing regulatory framework, if and when the inevitable future contingencies materialize, unveiling suboptimal sets of existing rules, rulemakers perpetuate a costly and uncertainty-increasing process of rule revisions, amendments, and repeals to address such shortcomings. Despite its insufficient anticipatory capabilities and all the downsides that are associated with it, stable and presumptively optimal rules remain the uniform response to perceived regulatory issues.[102]

Given the pace of innovation,[103] future contingencies in rulemaking are likely to substantially increase, making the dynamic anticipation of future contingencies more important for rulemaking. The current process of rule revisions, amendments, and repeals to address inevitable shortcomings of stable rules is costly, time-consuming, and cannot in our estimation keep track of future innovations and corresponding regulatory needs. Exponential innovation has the potential to overwhelm the existing regulatory process because rulemakers are still attempting to comprehend the regulatory demands of the last wave of innovative solutions, technologies, and applications while the next wave of

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[99] *Id.*; *see also supra* note 3.

[100] Kaal Wake Forest, *supra* note 7; Coffee, *supra* note 9; Roberta Romano, *Regulating in the Dark* 1 (Yale Law & Econ. Research Paper No. 442, 2012), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1974148 ("Foundational financial legislation is typically adopted in the midst or aftermath of financial crises, when an informed understanding of the causes of the crisis is not yet available. Moreover, financial institutions operate in a dynamic environment of considerable uncertainty, such that legislation enacted even under the best of circumstances can have perverse unintended consequences, and regulatory requirements correct for an initial set of conditions can become inappropriate as economic and technological circumstances change. Furthermore, the stickiness of the status quo in the U.S. political system renders it difficult to revise legislation, even though there may be a consensus to do so."); STEPHEN M. BAINBRIDGE, CORPORATE GOVERNANCE AFTER THE FINANCIAL CRISIS 269 (2012) ("Just as a ratchet wrench works only in one direction, the size and scope of government tends to move in only one direction—upwards—because the interest groups that favored the changes now have an incentive to preserve the new status quo, as do the bureaucrats who gained new powers and prestige. Hence, each crisis has the effect of ratcheting up the long-term size and scope of government.").

[101] Kaal in FS Kirchner, *supra* note 7, at 13 (describing "*ex-ante* experimentation" in rulemaking).

[102] *See* Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal Wake Forest, *supra* note 7; Kaal and Lacine 2014, *supra* note 7; Kaal in FS Kirchner, *supra* note 7.

[103] *See supra* Fn. [_]-[_] and accompanying text.

innovation is already in full force.[104] In effect, exponential innovation is likely to intensify the frequencies of the regulatory sine curve that is recognized by the literature.[105]

V. Dynamic Regulation as a Regulatory Supplement

Economists have used the concept of dynamic regulation in the context of innovation and learning by doing,[106] regulation of quality,[107] principal-agent and adverse selection problems,[108] and continuing regulatory relationships.[109] Dynamic elements in regulation have previously also been described as "dynamic games,"[110] "regulatory dialectic," and as a "dynamic adjustment process."[111] The rapid pace of technological developments in the telecommunications industry necessitated the use of dynamic elements in regulation.[112]

The theory of dynamic regulation conceptualizes the study of regulatory phenomena in relation to preceding and succeeding events, using institution-specific and decentralized information to facilitate feedback effects for anticipatory rulemaking.[113] The dynamic regulatory framework allows rulemaking to overcome its historic constraints and path dependencies that traditionally focused the rulemaking process on stable and presumptively optimal rules. Evolving from a historically reactive process based only on preceding events and driven by the agency- and collective-action problem of rulemaking, rulemaking in a dynamic framework allows for the anticipation of future

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[104] Romano, *supra* note 100, at 1 ("Moreover, financial institutions operate in a dynamic environment of considerable uncertainty, such that legislation enacted even under the best of circumstances can have perverse unintended consequences, and regulatory requirements correct for an initial set of conditions can become inappropriate as economic and technological circumstances change"); Shrupti Shah, Rachel Brody & Nick Olson*, The Regulatory of Tomorrow: Rulemaking and Enforcement in an Era of Exponential Change*, (Deloitte GovLab Report (2015)), http://dupress.com/articles/us-regulatory-agencies-and-technology/ ("Regulators are on the front lines of nearly every controversy resulting from a new technology—either being told to get out of the way or being called upon for solutions when incidents arise. Data breaches, 3D-printed guns, clashes between taxis and ridesharing services, and many other events that make news headlines also pose real challenges to regulators. In a fast-moving and increasingly complex world, regulators are finding it harder and harder to balance the need to protect citizens and fair markets with the need to avoid impeding innovation.").

[105] Kaal Wake Forest, *supra* note 7; Coffee, *supra* note 9.

[106] *See* Tracy R. Lewis & Huseyin Yildirim, *Learning by Doing and Dynamic Regulation*, 33 RAND J. ECON. 22, 23–24 (2002) ("Innovation is more rapid when current service is increased, enabling the supplier to accelerate his rate of learning.").

[107] Stephane Auray et al., *Dynamic Regulation of Quality*, 42 RAND J. ECON. 246, 246 (2011).

[108] JOHN M. LITWACK, DYNAMIC REGULATION, DEMAND INFORMATION AND MARKET PRICES (1992).

[109] David P. Baron & David Besanko*, Commitment and Fairness in a Dynamic Regulatory Relationship,* 54 REV. ECON. STUD. 413, 413 (1987); David P. Baron & David Besanko, *Regulation and Information in a Continuing Relationship,* 1 INFO. ECON. & POL'Y 267, 267 (1984).

[110] Edward J. Kane, *Extracting Nontransparent Safety Net Subsidies by Strategically Expanding and Contracting a Financial Institution's Accounting Balance Sheet*, 36 J. FIN. SERV. RES. 161, 161 (2009).

[111] Edward J. Kane, *Interaction of Financial and Regulatory Innovation,* 78 AM. ECON. REV. 328, 333 (1988) ("The regulatory dialectic posits a dynamic adjustment process that in the long run enforces a "law of one regulatory burden." Precisely because inefficient patterns of regulation impose excessively burdensome costs either on regulatees, their customers, or the general taxpayer, the burdened parties must be expected sooner or later to develop avoidance strategies by which to throw these burdens aside.").

[112] *See supra* note 16.

[113] *See* Kaal in FS Kirchner, *supra* note 7; Kaal in Liber Amicorum Peter Nobel, *supra* note 7; Kaal Wake Forest, *supra* note 7; Kaal and Lacine 2014, *supra* note 7.

innovation trends and associated contingencies.

Shortcomings in the existing rulemaking process[114] can be addressed with dynamic and anticipatory elements in rulemaking.[115] The collective action problem of rulemaking, problems associated with trial-and-error rulemaking, and problems associated with regulatory cycles derive largely from the nature of stable and presumptively optimal rules.[116] Rulemaking with dynamic elements increases the use of institution specific, decentralized, and timely information[117] to allow for adaptive rulemaking. Adaptive rulemaking helps overcome the collective action problem of rulemaking because with fewer stable rules latent majority groups and dominant minority groups have fewer opportunities to influence the continuously and timely adapting rulemaking process. Similarly, regulatory cycles and trial-and-error rulemaking become less prevalent because adaptive rulemaking processes supplement stable rules with adaptive capabilities that make rule revisions less prevalent and minimize trial-and error rulemaking.

Feedback effects are an integral part of dynamic forms of regulation.[118] Feedback effects are described in the theory of lawmaking as rulemakers' reactions to institutional change[119] or private actors' reactions and counteractivities to institutional constraints.[120] A dynamic regulatory framework facilitates feedback effects that help enhance the availability of institution-specific and decentralized information to support the rulemaking process.[121] Feedback effects can occur in several settings including intra- and interjurisdictional feedback processes, feedback processes between outcomes and institutions, feedback processes between different public and private rulemakers, and feedback processes between rules and rulemaking processes.[122] Competition between

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[114] *See supra* notes 49-55.

[115] Kaal Wake Forest, *supra* 7; Kaal in FS Kirchner, *supra* 7.

[116] The collective action problem of rulemaking, inherent in smaller and better-organized interest groups and dominant latent groups competing to influence the rulemaking process, pervades when regulatory outcomes are stable. Regulatory cycles, inherent in existing rule adoption, revisions, and revocations, derive from stable and presumptively optimal rules that cannot timely adapt to future contingencies and corresponding regulatory needs. Trial-and-error-rulemaking is necessitated if rules are presumptively optimal and stable. Trial-and-error-rulemaking could become obsolete if dynamic elements in rulemaking processes systematically anticipated future contingencies and corresponding regulatory needs.

[117] Including information on the functioning of financial institutions, information pertaining to how financial institutions, or decision makers in financial institutions, actually act and how they are expected to react to unforeseen contingencies in the future helps incorporate dynamic elements into financial regulation. Several mechanisms can increase the information for rulemaking in a more timely fashion, including but not limited to: 1. Contingent Capital, 2. Governmental Contracts in the form of Non-and Deferred Prosecution Agreements, 3. Venture Capital finance allocation, and 4. Crowdfunding. *See supra* note 7.

[118] *See supra* note 7.

[119] Jean-Jacques Dethier*, Governance and Economic Performance: A Survey* 49 (Discussion Papers on Development Policy No. 5, Center for Development Research, Bonn, April 1999), http://goo.gl/xzHwxK.

[120] Christian Kirchner, *Market Organizations: A New-Institutional Perspective*, 151 J. INST. THEORETICAL & ECON. 260, 265 (1995) ("By introducing various examples of the way in which private actors have tried to escape the onerous results of regulation, and showing that law courts often have favoured such "inventions," the paper developed a hypothesis of how public and private actors act and react in the complex process of forming the institutional arrangements of market.").

[121] Kaal in FS Kirchner, *supra* note 7, at 4 ("Rules can be adaptable if institutions and rulemaking processes integrate dynamic elements that produce timely, relevant, and decentralized information for rulemaking.").

[122] Rules as outcomes are the result of the institutional design of rulemaking and reinforce the institutional design. Existing rules create a feedback effect for the rulemaking process itself. Rules with suboptimal

legislators and regulators from different jurisdictions can facilitate interjurisdictional feedback processes.[123] The unrestricted exchange of information between public- and private rulemakers can create regulatory synergies that increase the availability of relevant, decentralized, and timely information for rulemaking[124] and facilitate feedback effects.[125] Existing rules can provide feedback effects for the rulemaking process itself.[126] Through feedback effects, rulemakers in a dynamic regulatory framework can adopt rules that are adaptable to future states of the world.

Feedback processes in a dynamic regulatory framework facilitates the enhancement of information for regulation. Dynamic regulatory tools as a regulatory supplement enable rulemakers to adapt to regulatory contingencies if and when they arise because feedback effect provides relevant, timely, decentralized, and institution-specific information ex-ante. By increasing the availability of information ex-ante, dynamic regulatory tools help lower unforeseen contingencies in the rulemaking process. Improved information for rulemaking also helps maintaining certainty in the rulemaking process.

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characteristics are the results of institutional arrangements and reinforce suboptimal institutional arrangements and rulemaking processes. Stable and presumptively optimal rules reinforce a rulemaking process with an institutional structure that perpetuates stable elements in rules.

[123] Including synergies and exchanges between public rulemakers and public regulators as well as intrajurisdictional feedback processes between private and public rulemakers in a given jurisdiction. Christian Kirchner et al., *Regulatory Competition in EU Corporate Law After Inspire Art: Unbundling Delaware's Product For Europe*, 2 EURO. COMPANY & FIN. L. REV. 159 (2015)*;* Kirchner et al*., Europäischer vs. US-amerikanischer Wettbewerb der Gesellschaftsrechte - Abschied vom alten Delaware-Verbundprodukt. Die Aktiengesellschaf*, 13 DIE AKTIENGESELLSCHAFT 469 (2012).

[124] Private rulemakers can have a comparative advantage over public rulemakers because, unlike their public counterparts, they often can produce necessary, comparable, decentralized, and institution-specific information for rulemaking. Unlike public rulemakers, private rulemakers often have access to decentralized information and can more readily react to emerging, decentralized, and institution-specific information. Interaction between public rulemakers and private rulemakers, including the exchange of emerging information, creates a feedback process between them that increases the availability, timeliness, and quality of information available to the public rulemaker. Based on the optimized information for rulemaking, the public rulemaker can take regulatory action when the relevant information for rulemaking becomes available. The interplay between public and private rulemakers and the associated feedback process enables a learning process and optimization process for the public rulemaker.

[125] *Id.* The rulemaking process is enhanced through the competition between private- and public rulemakers. Competition between different public rulemakers can require public rulemakers to meet consumers' and legal addressees' quality expectations and preferences. Consumer choice can add a dynamic element to the rulemaking process because public rulemakers in a given jurisdiction can adjust rulemaking to consumer choice once consumers have opted out of a suboptimal regulatory regime in that jurisdiction. Consumer choice creates a feedback effect for the public rulemaker. Consumer choice can thus facilitate appropriate information for rulemaking and enable anticipation and modification of the public rulemaker's next action in the rulemaking process. Feedback effects may exist between public rulemakers and parties who are subject to informal rules if public rulemakers observe the preferences and efficient solutions of parties who are subject to informal rules. In effect, parties who are subject to informal rules are signaling their preferences and efficient solutions to the public rulemaker. Public rulemakers can benefit from the additional insights such signaling may produce for the public rulemaking process.

[126] The existing regulatory framework for optimal rules reinforces rulemaking processes that perpetuate optimal rules, necessitating costly rule revision, updating, and revocation. Because of this feedback loop, suboptimal existing rules and rulemaking processes rulemaking processes and institutions that produce suboptimal outcomes.

Dynamic elements in rulemaking can help optimize the timing of rule enactment. A core problem for most regulation is its inaccurate and delayed timing. Because of the collective action problem of regulation, path dependencies, and political inertia, among many other reasons, regulation is mostly reactive, following business cycles and not preemptive, e.g. enacted before crises when governance improvements are most needed.[127] Instead of the traditional rule revisions ex-post after rules have emerged as suboptimal, feedback effects in dynamic regulatory processes can increase the availability of relevant information for rulemaking ex-ante and anticipate necessary revisions before rules emerge as suboptimal.[128] By identifying possible contingencies and necessary rule revisions with optimized information ex-ante, dynamic regulatory supplements make adaptive rulemaking the focal point for rulemaking in a dynamic framework.[129]

Industries and regulatory agencies can benefit from dynamic regulation as a regulatory supplement, an informal and flexible approach to regulatory issues. While the Administrative Procedure Act (APA)[130] institutes regulatory procedures to protect regulated industries[131] by requiring the full lawmaking process to apply,[132] industries and regulatory agencies often prefer unenforceable rules and no judicial involvement.[133] Both industries and regulators are affected by costly, untimely, overextended, and ossified rulemaking or adjudicative procedures and the associated regulatory uncertainty.[134] Dynamic regulatory supplements would not violate mandated regulatory procedures in the APA[135] as the full lawmaking process still applies.[136] Dynamic regulation functions as a regulatory supplement to help optimize the existing rulemaking process.

VI. Data

Venture capital's assessment of innovative products and initiatives generates institution- and industry specific decentralized information on innovation trends. To illustrate venture capital's ability to identify innovation trends, we use a PitchBook Data, Inc. dataset on venture capital deals in the United States with 77,508 deals involving 37,298 companies from 2005 to 2015. The dataset comprises all VC deals including all VC stages from 2005-2015 in the United States.

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[127] *See supra* text accompanying notes 70–72

[128] Kaal Wake Forest, *supra* note 7; Kaal in FS Kirchner, *supra* note 7.

[129] *Id*.

[130] Administrative Procedure Act, 5 U.S.C. §§ 551-559, 701-706 (2012).

[131] See 5 U.S.C. §§ 551-559 (2012).

[132] The APA requires that for a rule to become effective, the proposed rule must go through what is known as a notice-comment rulemaking, often a lengthy process in which the public is given an opportunity to comment on the proposed rule and the agency must consider such comments before promulgating a final regulation. 5 U.S.C. § 553(b)(A) (2012).

[133] Wu, *supra* note 22, at 1843 ("Both agency and industry will sometimes share an interest in an informal and flexible regime that resembles an unenforceable "letter of intent" in the world of private contracts. The costs of a slow-moving, ossified rulemaking or adjudicatory procedure, with its accompanying uncertainty and litigation costs, fall on both industry and agency.").

[134] McGarity, *supra* note 97, at 1387-96.

[135] Administrative Procedure Act, 5 U.S.C. §§ 551-559, 701-706 (2012).

[136] The APA requires that for a rule to become effective, the proposed rule must go through what is known as a notice-comment rulemaking, often a lengthy process in which the public is given an opportunity to comment on the proposed rule and the agency must consider such comments before promulgating a final regulation. 5 U.S.C. § 553(b)(A) (2012).

1. Capital Invested and Deal Count

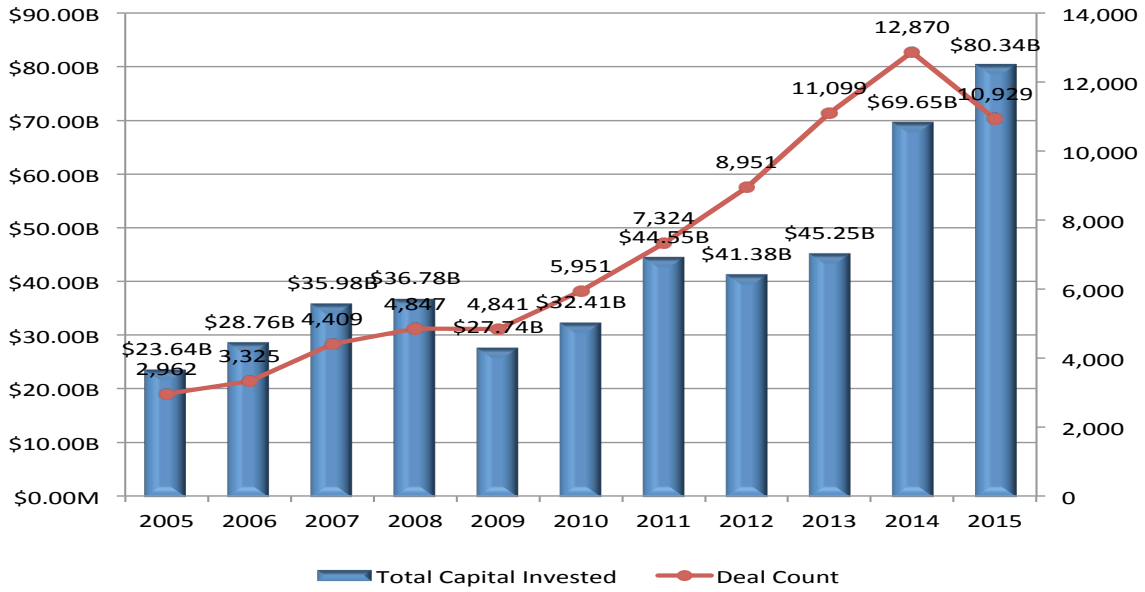

Figure [__]: VC Capital Invested and Deal Count United States 2005-2015. Dataset comprises 77,508 deals involving 37,298 companies.

2. VC Investors

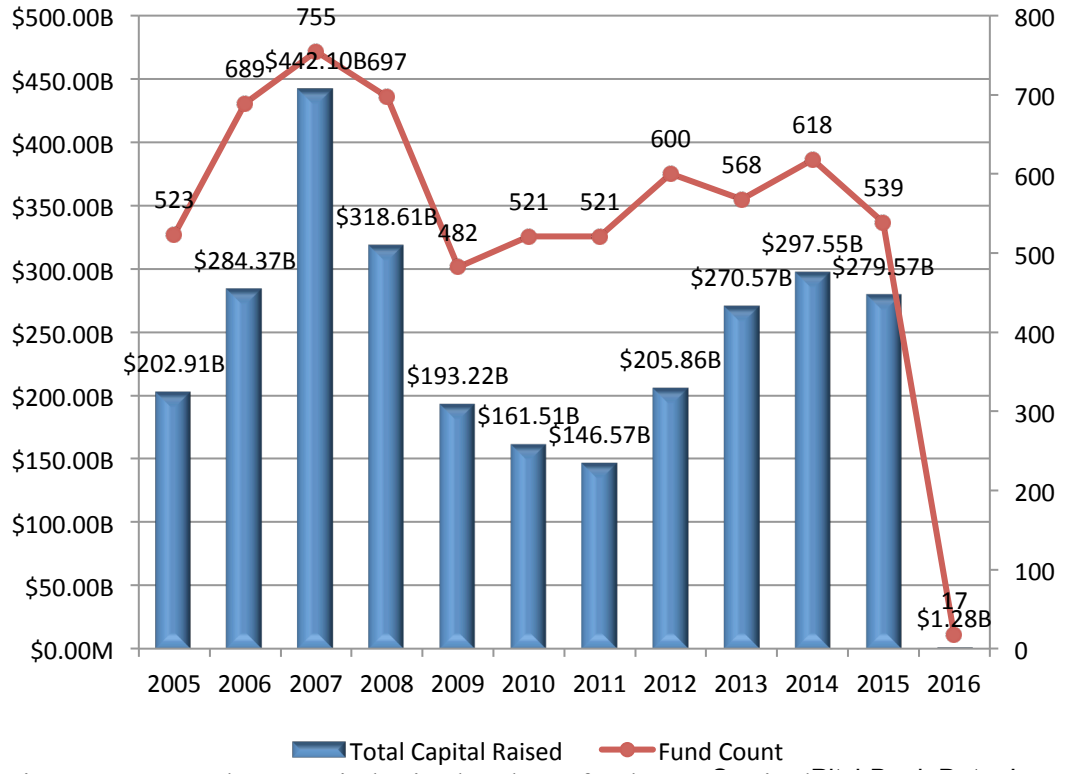

Figure [__]: Total VC capital raised and VC fund count United States 2005-2015. Dataset comprises 77,508 deals involving 37,298 companies.

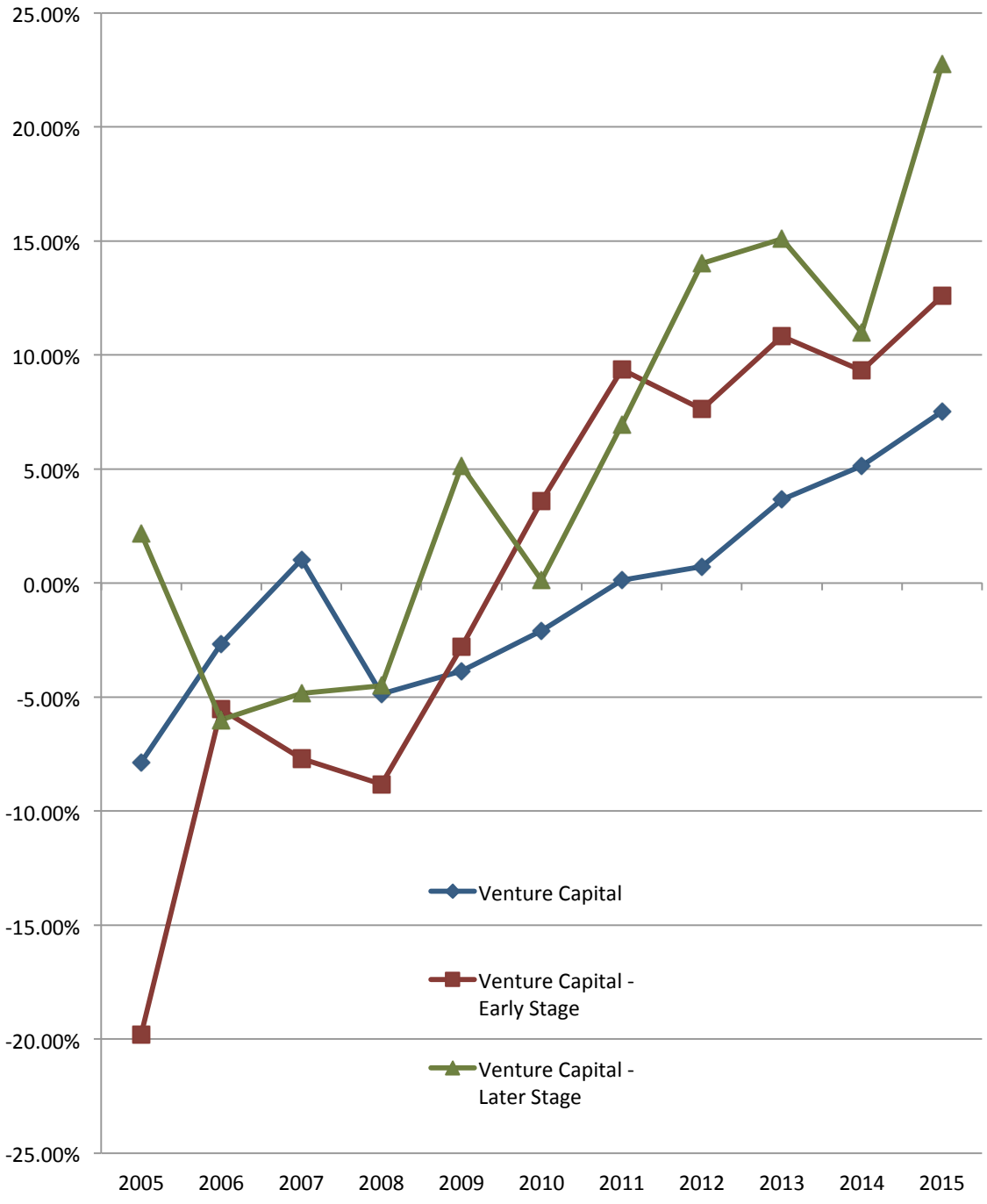

Figure [__]: VC Fund IRR by VC Fund Type 2005-2015. Dataset consists of 6,157 VC funds from 2005-2015.

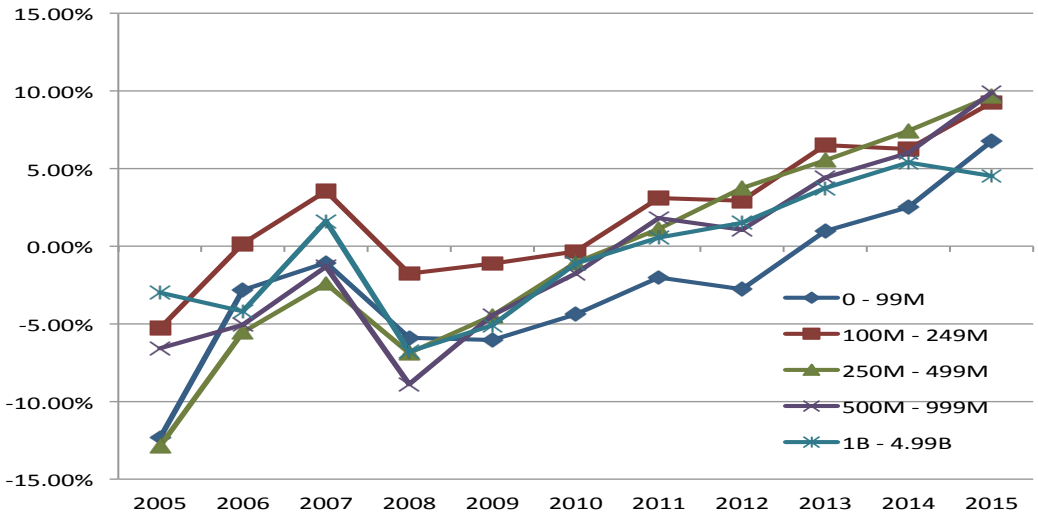

Figure [__]: VC Fund IRR by VC Fund Size 2005-2015. Dataset consists of 6,157 VC funds from 2005-2015.

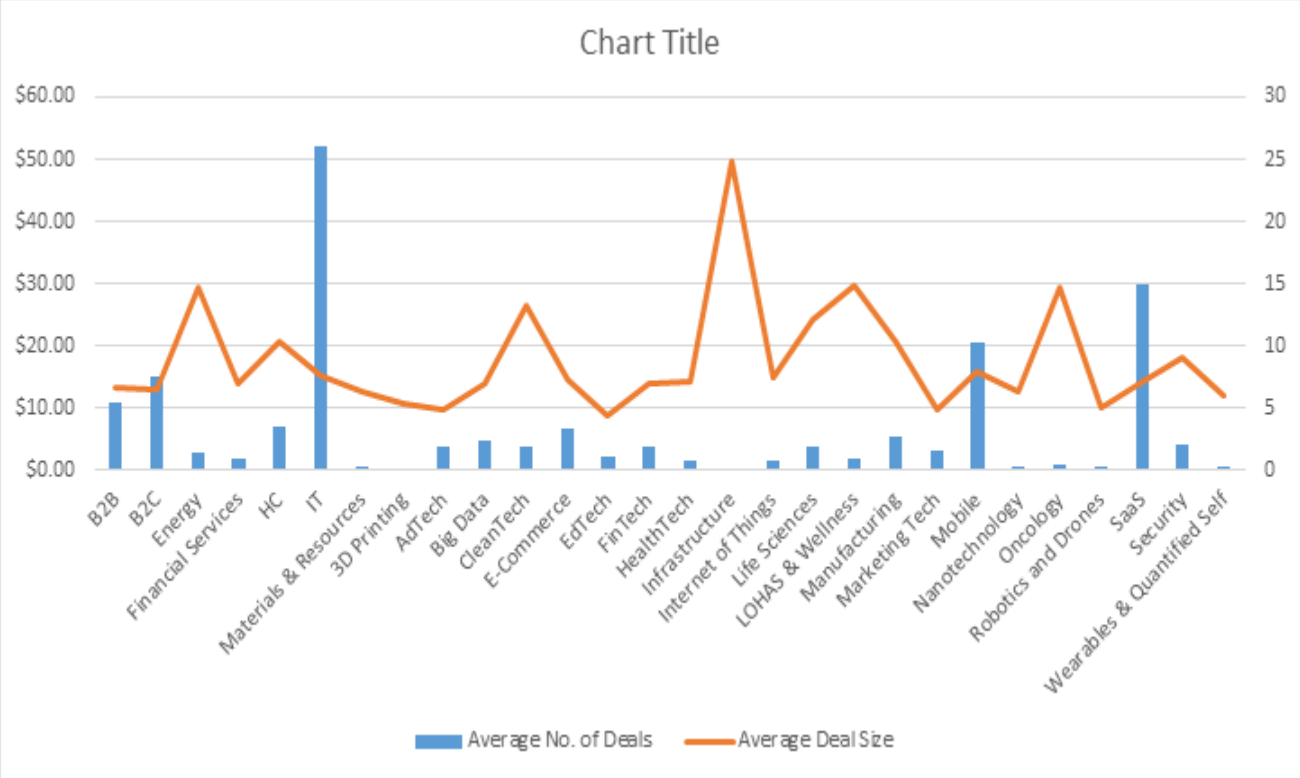

Table []: Contains the sector/industry allocations (both number of deals and deal size) for the top 25 united states venture capital investors between years 2005 and 2015. Investors include the following: Y Combinator, 500 Startups, Techstars, SV Angel, New Enterprise Associates, Western Technology Investment, Intel Capital, Kleiner Perkins Caufield & Byers, Sequoia Capital, Andreessen Horowitz, GV, Plug and Play Ventures, First Round Capital, Accel Partners, Khosla Ventures, Draper Fisher Jurvetson, Individual Investors, David McClure, Greylock Partners, MassChallenge, General Catalyst Partners, Lerer Hippeau Ventures, Bessemer Venture Partners, National Science Foundations, Lightspeed Venture Partners. Data provided by Pitchbook.

Add charts on LPs and Fund Types

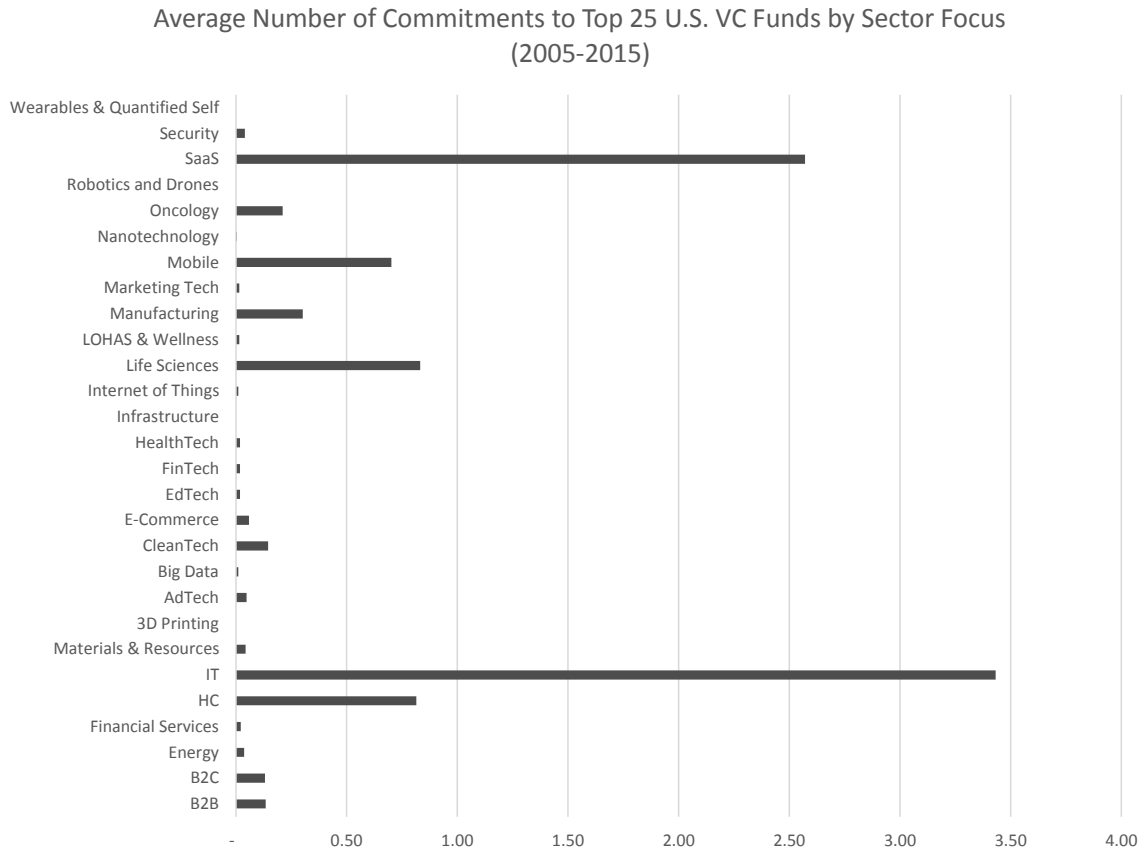

Table []: Contains the average number of commitments to the Top 25 U.S. VC funds by sector focus (Years 2005-2015). LPs in this dataset include the following: Adams Street Partners, California Public Employees Retirement System, HarbourVest Partners, New York State Common Retirement Fund, SBC Master Pension Trust, Pennsylvania State Employees' Retirement System, University of Texas Investment Management Company, Pension Benefit Guaranty Corporation, University of Michigan Endowment, Massachusetts Pension Reserves Investment Trust, San Francisco Employees' Retirement System, Hewlett-Packard Master Trust, Alaska Retirement Management Board, Los Angeles Fire and Police pension System, Alaska Permanent Fund, The Regents of the University of California Endowment, Employees' Retirement Plan of Duke University, Iowa Public Employees' Retirement System, Rockefeller Foundation, Mayo Pension Plan, Andrew W. Mellon Foundation, Employees' Retirement System of the State of Hawaii, BSS retirement Plan for Bargained Employees, Knightsbridge Advisers, BP Master Trust for Employee Pension Plans.

3. Deal Characteristics

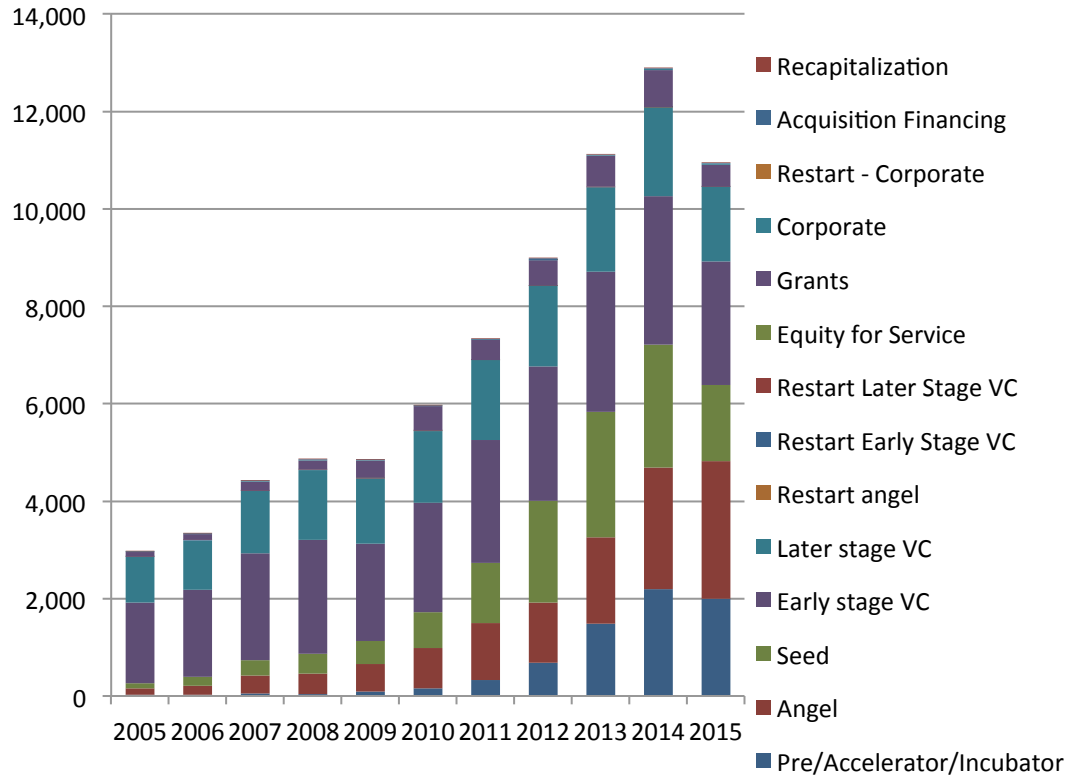

Figure [___]: VC deal count and deal type United States 2005-2015. Dataset comprises 77,508 deals involving 37,298 companies.

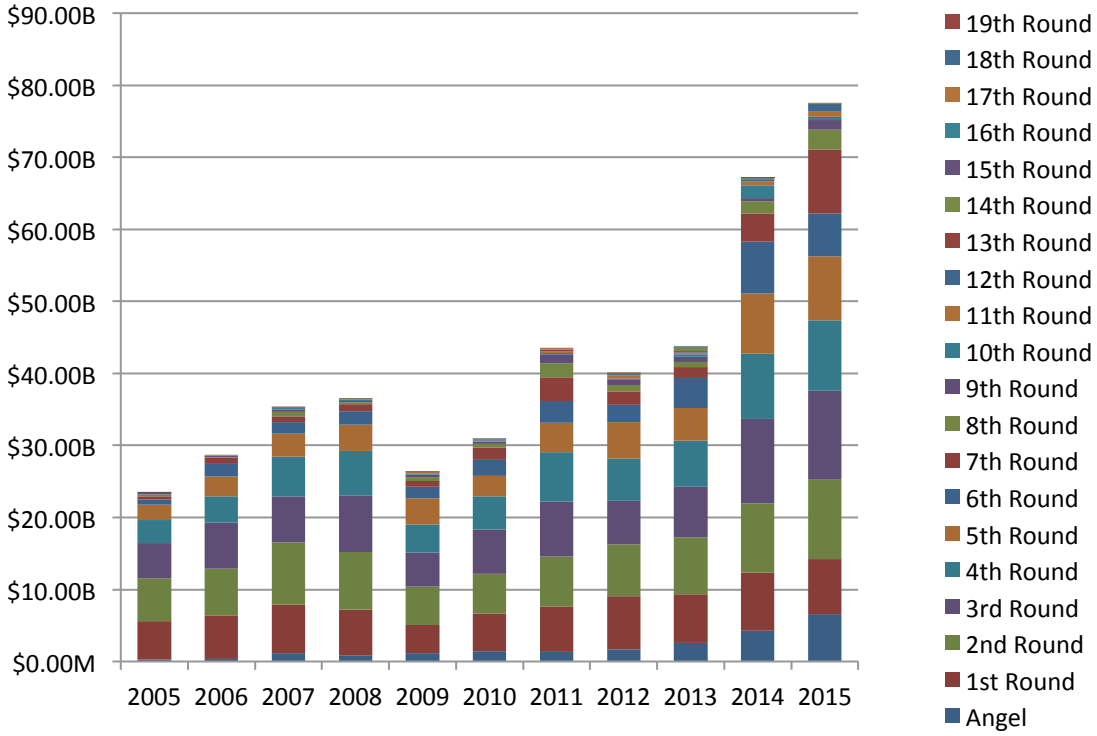

Figure [__]: VC capital invested by VC round United States 2005-2015. Dataset comprises 77,508 deals involving 37,298 companies.

4. Industries Represented

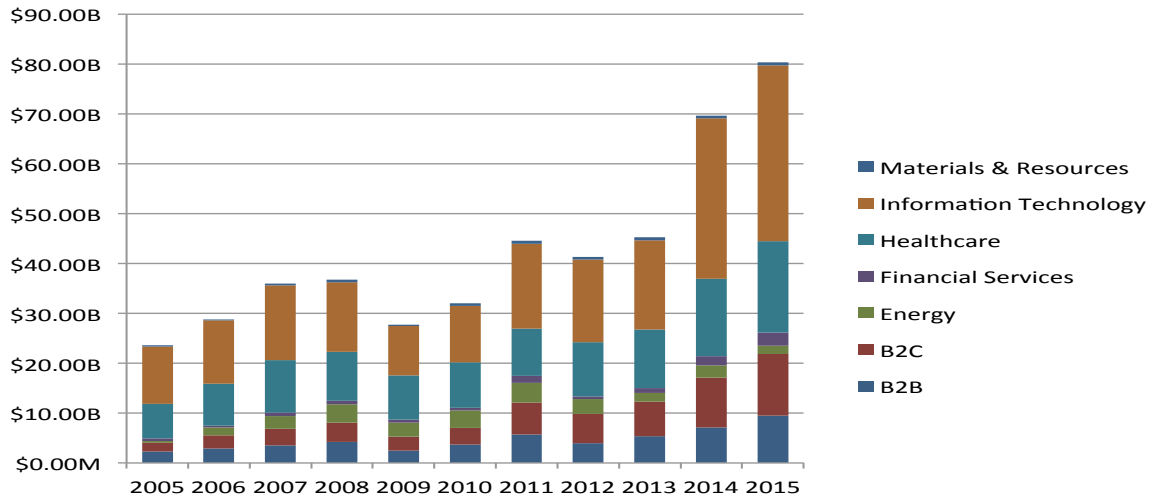

Figure [___]: VC capital invested by primary industry United States 2005-2015. Dataset comprises 77,508 deals involving 37,298 companies.

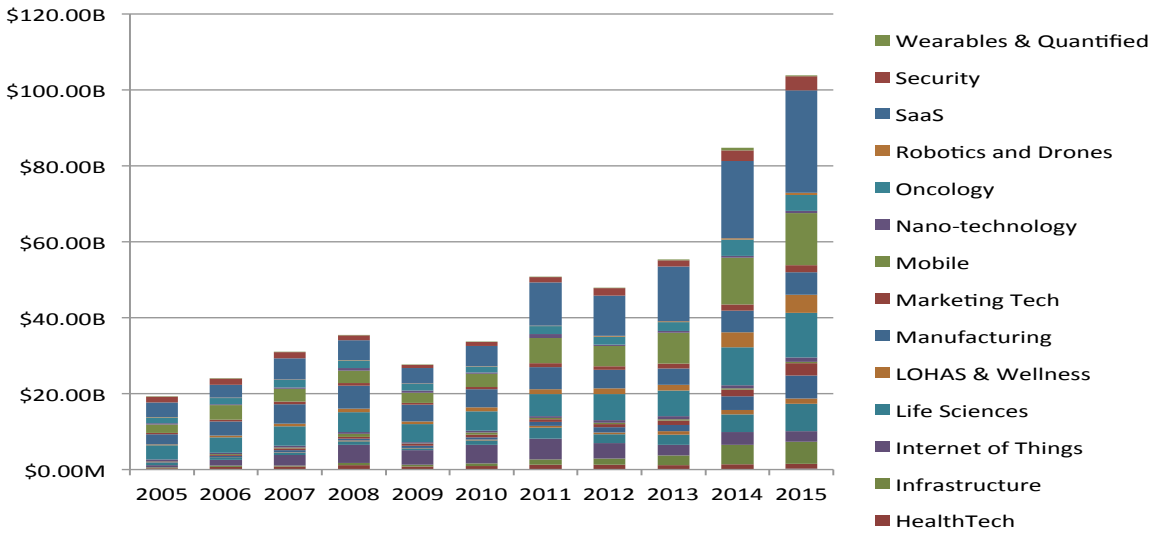

Figure [__]: VC capital invested by industry vertical United States 2005-2015. Dataset comprises 77,508 deals involving 37,298 companies.

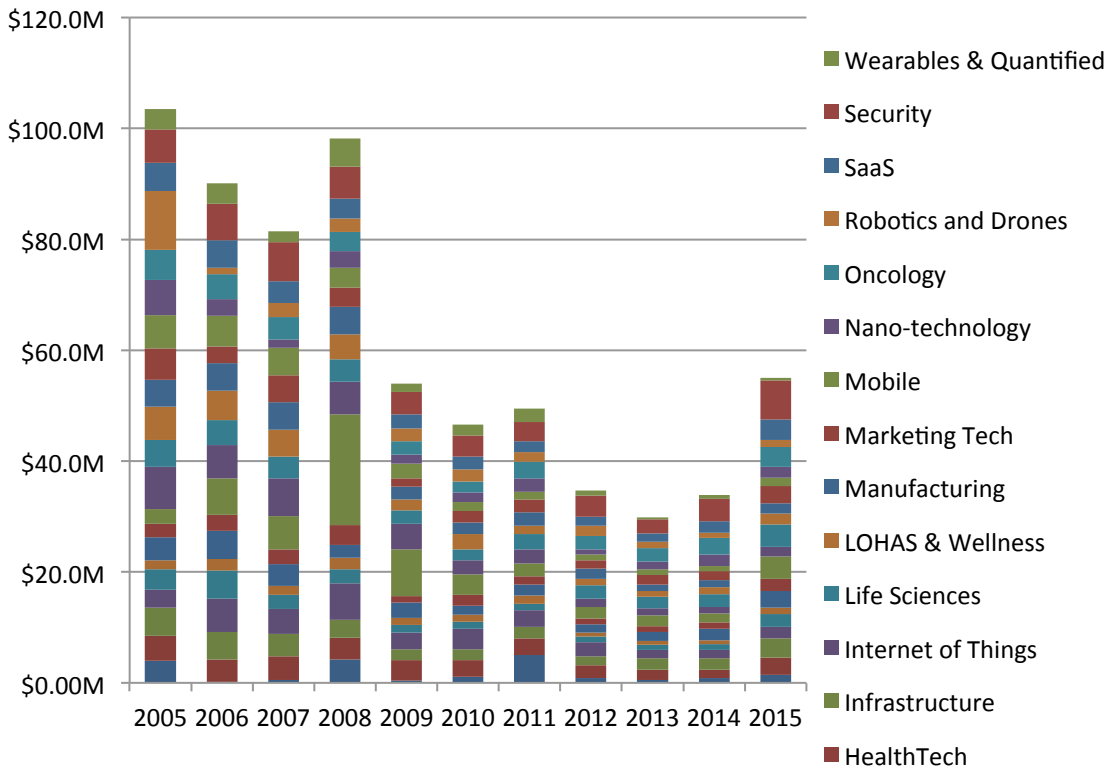

Figure [___]: Median VC deal size by industry vertical United State 2005-2015. Dataset comprises 77,508 deals involving 37,298 companies.

5. Investment Ratio by Industry

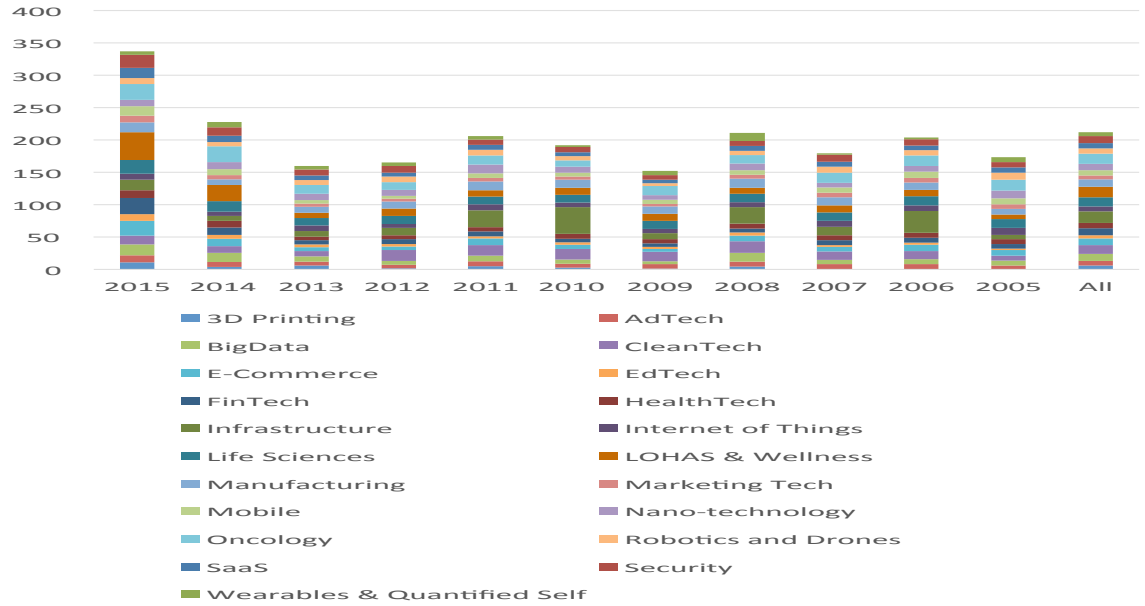

Figure [__]: VC Investment ratio by industry. The investment ratio is calculated as VC investment amount divided by VC deals per year and industry. Dataset comprises 77,508 deals involving 37,298 companies.

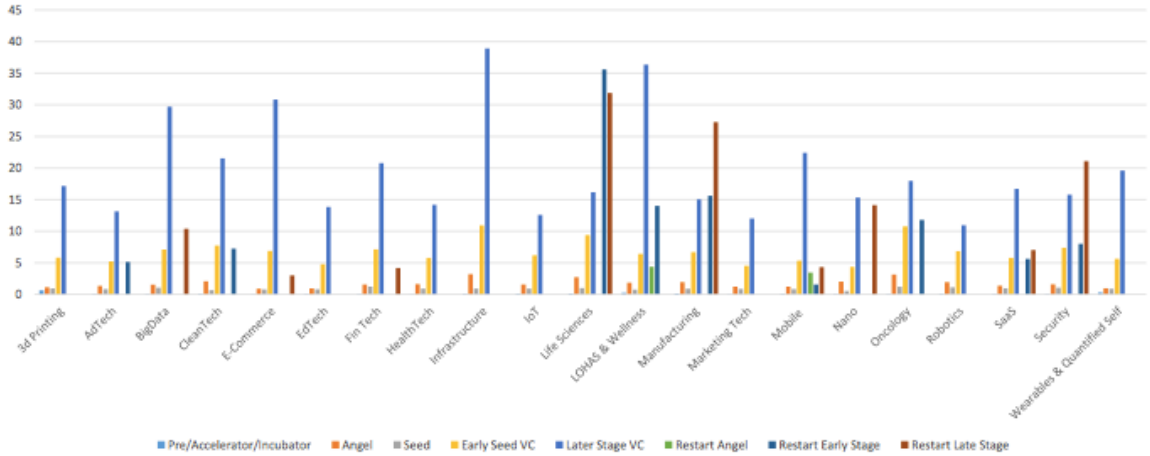

Figure [___]: VC deal type ratios by industry 2005-2015. Data provided by PitchBook. PitchBook provides the VC investments for the following periods/stages: Pre/Accelerator/Incubator, Angel, Seed, Early Seed VC, Later Stage VC, Restart Angel, Restart Early Stage, and Restart Late Stage. Pitchbook provides data for the following industries: 3d Printing, AdTech, Big Data, CleanTech, E-Commerce, EdTech, Fin Tech, Health Tech, Infrastructure, Internet of Things, Life Sciences, LOHAS and Wellness, Manufacturing, Marketing, Mobile, Nano, Oncology, Robotics, SaaS, Security and Wearables. The data runs from 2005 through 2015. The following ratios are calculated by dividing capital invested sum by the deal count for the cumulative deals between 2005 through 2015.

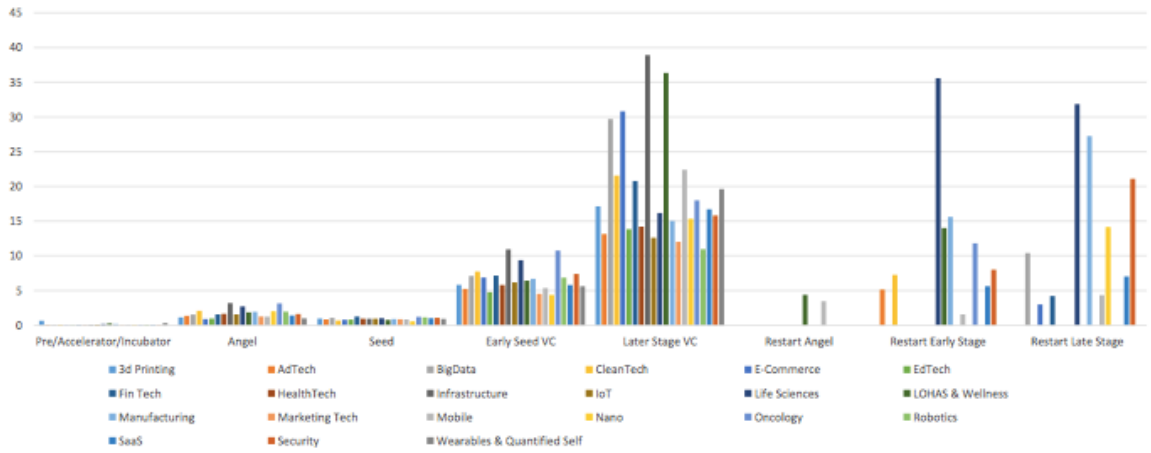

Figure [__]: VC Deal type ratios by industry vertical 2005-2015. Data provided by PitchBook. PitchBook provides the VC investments for the following periods/stages: Pre/Accelerator/Incubator, Angel, Seed, Early Seed VC, Later Stage VC, Restart Angel, Restart Early Stage, and Restart Late Stage. Pitchbook provides data for the following industries: 3d Printing, AdTech, Big Data, CleanTech, E-Commerce, EdTech, Fin Tech, Health Tech, Infrastructure, Internet of Things, Life Sciences, LOHAS and Wellness, Manufacturing, Marketing, Mobile, Nano, Oncology, Robotics, SaaS, Security and Wearables. The data runs from 2005 through 2015. The following ratios are calculated by dividing capital invested sum by the deal count for the cumulative deals between 2005 through 2015.

6. Innovation Sustainability

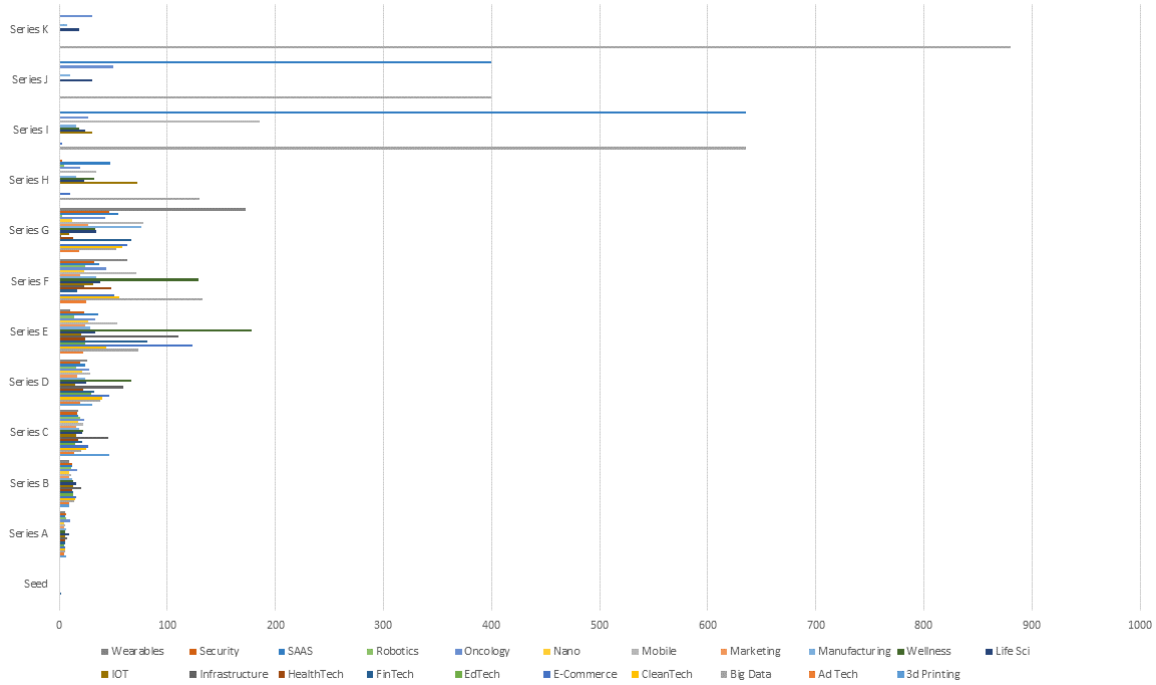

Figure [__]: Data provided by PitchBook. PitchBook provides the VC investments for the following periods/stages: Seed, Series A, Series B, Series C, Series D, Series E, Series F, Series G, Series H, Series I, Series J, and Series K. Pitchbook provides data for the following industries: 3d Printing, AdTech, Big Data, CleanTech, E-Commerce, EdTech, Fin Tech, Health Tech, Infrastructure, Internet of Things, Life Sciences, LOHAS and Wellness, Manufacturing, Marketing, Mobile, Nano, Oncology, Robotics, SaaS, Security and Wearables. The data runs from 2005 through 2015. The following ratios are calculated by dividing capital invested sum by the deal count for the cumulative deals between 2005 through 2015.

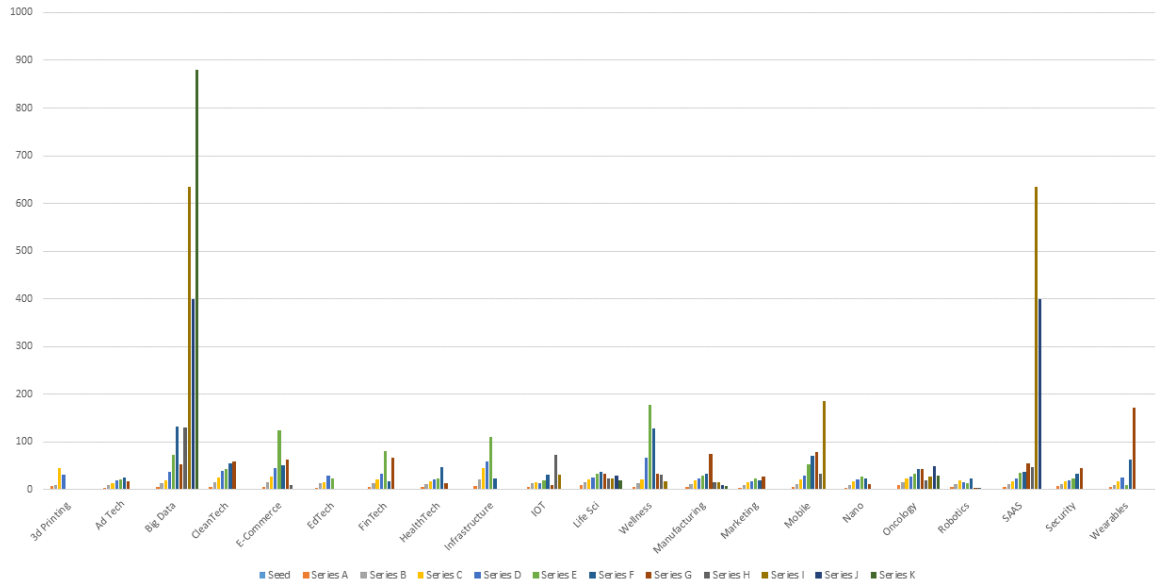

Figure [_]: Data provided by PitchBook. PitchBook provides the VC investments for the following periods/stages: Seed, Series A, Series B, Series C, Series D, Series E, Series F, Series G, Series H, Series I, Series J, and Series K. Pitchbook provides data for the following industries: 3d Printing, AdTech, Big Data, CleanTech, E-Commerce, EdTech, Fin Tech, Health Tech, Infrastructure, Internet of Things, Life Sciences, LOHAS and Wellness, Manufacturing, Marketing, Mobile, Nano, Oncology, Robotics, SaaS, Security and Wearables. The data runs from 2005 through 2015. The following ratios are calculated by dividing capital invested sum by the deal count for the cumulative deals between 2005 through 2015.

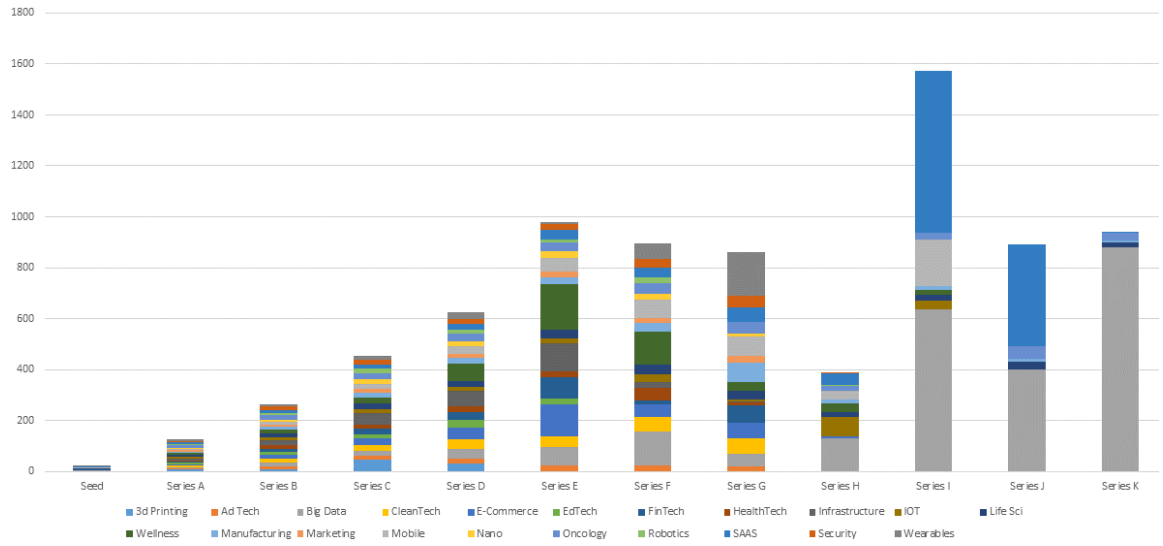

Figure [__]: VC deal / dollar investment ratios stage/series by industry vertical from 2005-2015. Data provided by PitchBook. PitchBook provides the VC investments for the following periods/stages: Seed, Series A, Series B, Series C, Series D, Series E, Series F, Series G, Series H, Series I, Series J, and Series K. Pitchbook provides data for the

following industries: 3d Printing, AdTech, Big Data, CleanTech, E-Commerce, EdTech, Fin Tech, Health Tech, Infrastructure, Internet of Things, Life Sciences, LOHAS and Wellness, Manufacturing, Marketing, Mobile, Nano, Oncology, Robotics, SaaS, Security and Wearables. The data runs from 2005 through 2015. The following ratios are calculated by dividing capital invested sum by the deal count for the cumulative deals between 2005 through 2015.

Company Name	Industry Vertical	Current Financing Status	Deal Date	% Acquired	VC Round	Series	Total Invested Equity	Year Founded
Palantir Technologies	Big Data, SaaS	Venture Capital-Backed	12/13/2015	4.29	12th Round	Series K	880	2004
Palantir Technologies	Big Data, SaaS	Venture Capital-Backed	11/3/2014	6.91	10th Round	Series I	635.71	2004
Palantir Technologies	Big Data, SaaS	Venture Capital-Backed	11/26/2014	0.33	11th Round	Series J	400	2004
Motricity	Mobile	Corporate Backed or Acquired	12/31/2007	20.11	9th Round	Series I	185	2001
Onconova Therapeutics (ONTX)	Life Sciences, Oncology	Private Equity-Backed	8/10/2012		10th Round	Series J	50	1998
Tocagen	Life Sciences, Oncology	Venture Capital-Backed	10/21/2015	12.98	9th Round	Series H	46.2	2007
TherOx	Life Sciences	Venture Capital-Backed	7/21/2005	58.68	9th Round	Series I	40.8	1994
Revolution Foods		Venture Capital-Backed	11/19/2015	11.85	12th Round	Series I	35.22	2006
Alien Technology	Internet of Things, Manufacturing	Venture Capital-Backed	3/12/2007	15.55	12th Round	Series I	33	1994
OptiScan Biomedical		Venture Capital-Backed	4/14/2010		11th Round	Series I	31.5	1994
BioNumerik Pharmaceuticals	Life Sciences, Oncology	Private Equity-Backed	3/12/2009		10th Round	Series K	30	1995
TherOx	Life Sciences	Venture Capital-Backed	2/20/2008	28.33	10th Round	Series J	29.99	1994
Alien Technology	Internet of Things, Manufacturing	Venture Capital-Backed	3/12/2007	15.89	11th Round	Series I	28.47	1994
Onconova Therapeutics (ONTX)	Life Sciences, Oncology	Private Equity-Backed	7/18/2012		9th Round	Series I	26.44	1998
Allconnect		Venture Capital-Backed	2/21/2007	10.08	11th Round	Series I	20	1998
NeuroPace	Life Sciences, LOHAS & Wellness	Venture Capital-Backed	7/8/2013	3.91	6th Round	Series I	18.05	1997
AFS Technologies		Private Equity-Backed	8/29/2008		3rd Round	Series I	13	1985
Agraquest	Life Sciences, Manufacturing	Formerly VC-Backed	1/1/2009	11.32	13th Round	Series J	10.2	1995
Agraquest	Life Sciences, Manufacturing	Formerly VC-Backed	6/18/2009	6.56	12th Round	Series I	10.13	1995
CafePress (PRSS)	E-Commerce	Venture Capital-Backed	11/24/2008	1.39	3rd Round	Series I	8.3	1999
Agraquest	Life Sciences, Manufacturing	Formerly VC-Backed	3/25/2011	6.89	14th Round	Series K	7.5	1995
Exa (EXA)		Formerly VC-Backed	5/21/2008	5.79	8th Round	Series I	6	1991
Iconix Biosciences	Manufacturing	Venture Capital-Backed	1/24/2007	3.95	10th Round	Series I	4	1997
Iconix Biosciences	Manufacturing	Venture Capital-Backed	12/18/2006	2.06	9th Round	Series I	2	1997
OptiScan Biomedical		Venture Capital-Backed	7/2/2010		12th Round	Series J	0.7	1994

Table 1: Top 25 companies by highest VC series investment.

7. Exit

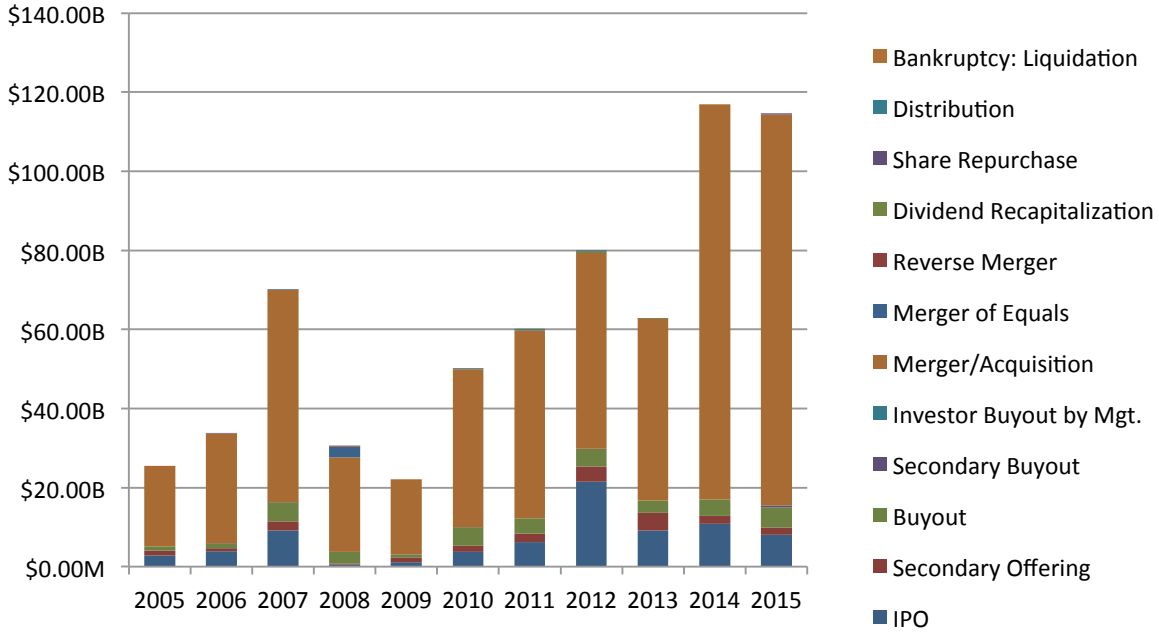

Figure [__]: VC capital invested by exit type. Database comprises 9,526 United States companies that exited after VC capital investment from 2005-2015.

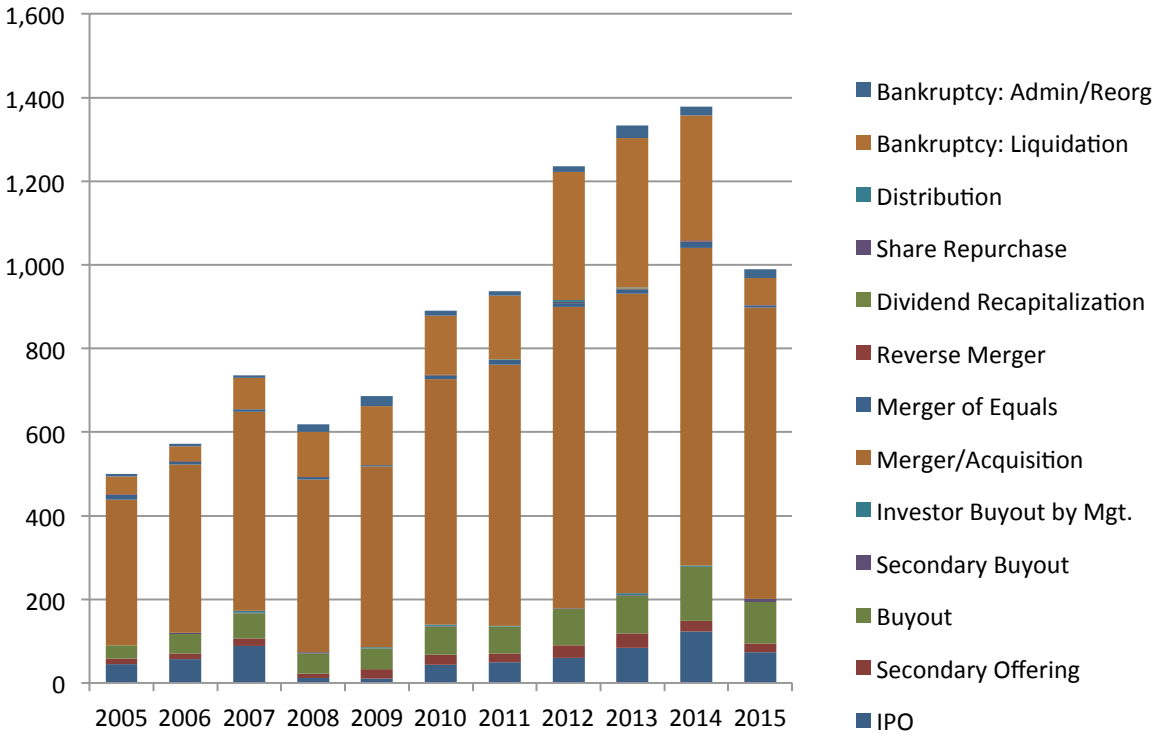

Figure [__]: VC deal count by exit type. Database comprises 9,526 United States companies that exited after VC deals from 2005-2015.

identify:
Ipo exit by industry by year (which industries have seen the most IPO exits from 2005-2015?)

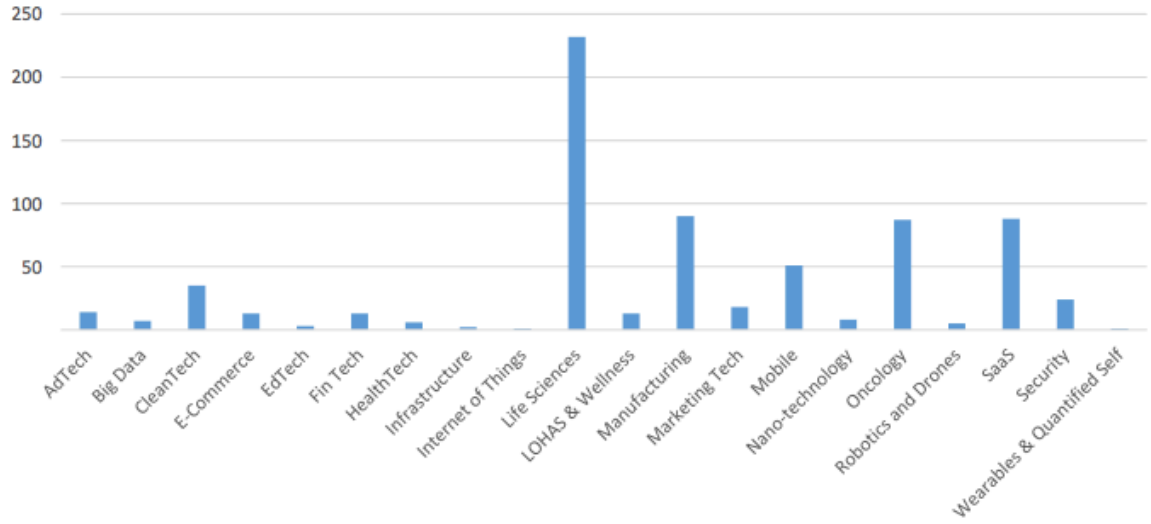

Figure [__]: VC deals 2005-2015 with IPO exit by industry vertical. 647 VC deals ended in IPO exit from 2005-2015.

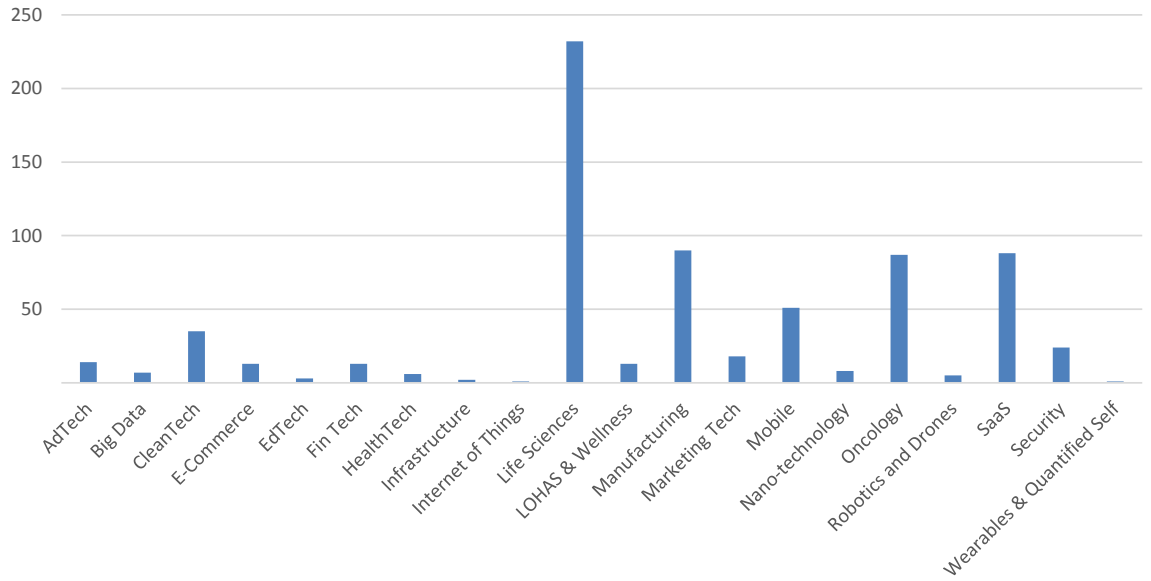

Figure [__]: Top 20 Industries by IPO exit. 647 VC deals ended in IPO exit from 2005-2015.

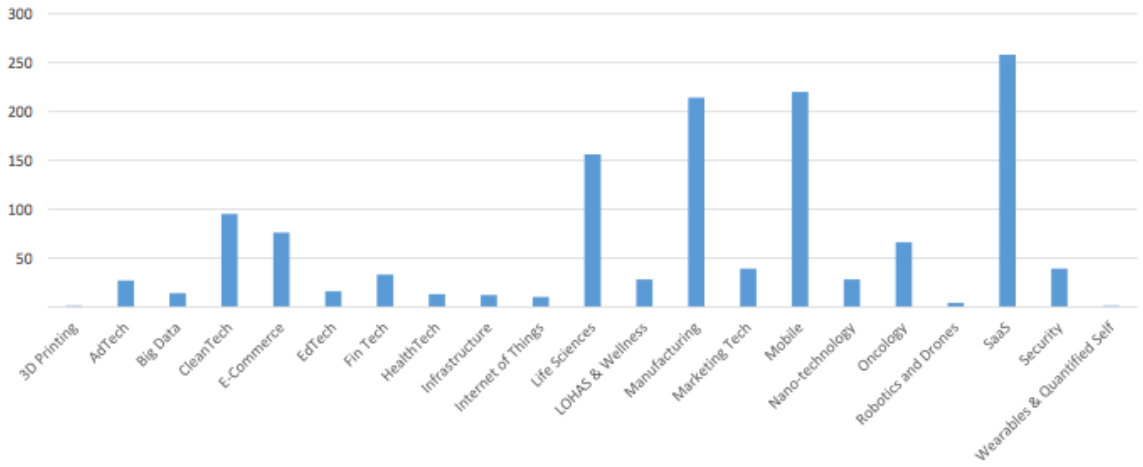

Figure [__]: VC deals 2005-2015 with Bankruptcy exit by industry vertical. 1890 VC deals ended in Bankruptcy exit from 2005-2015.

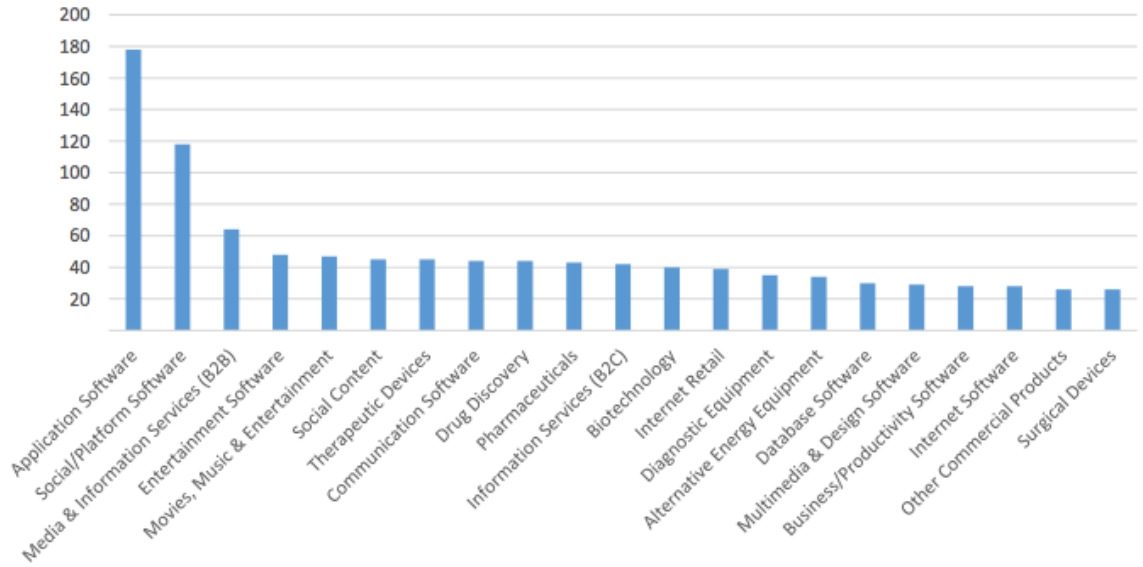

Figure [__]: Top 20 Industries by VC bankruptcy exit. 1890 VC deals total ended in Bankruptcy exit from 2005-2015.

Company Name	Industry Vertical	Deal Date	Deal Size	Pre Valuation	Post Valuation	Total Invested Equity	Year Founded
Facebook (FB)	SaaS	5/12	16006.88	72080.35	81247.23	6764.76	2004
Twitter (TWTR)	Mobile	11/13	1820	12342.12	14162.12	1760.85	2007
Interactive Brokers Group		5/07	1200.4	6.03	1206.43	1177.89	1977
Zynga	Mobile	12/11	1000	5993.43	6993.43	967.5	2007
VMware	SaaS	8/07	957	9921.48	1087.85	904.37	1998
Lending Club (LC)	E-Commerce, FinTech	12/14	870	4551.09	5421.09	711.12	2007
WEX		2/05	720	4.84	724.84	684	1983
Groupon (GRPN)		11/11	700	12056.07	12756.07	658	2008
Blue Buffalo Pet Products (BUFF)	Manufacturing	7/15	677.35	3244.06	3921.41	641.11	2002
Workday (WDAY)	FinTech, SaaS	10/12	637	3851.12	4488.12	598.78	2005
ClearWire	Mobile	3/07	600	3448.05	4048.05	564	1998
Vonage (VG)		5/06	531.25	2116.2	2647.45	499.38	2001
Fitbit (FIT)	LOHAS & Wellness, Mobile, Wearables & Quantified Self	6/15	731.5	3382.94	4114.44	447.75	2007
WhiteWave Foods	Manufacturing	10/12	391	2550	2941	367.54	
A123 Systems	CleanTech, Manufacturing, Nanotechnology	9/09	380.44	954.19	1325.44	345.26	2001
Wayfair (W)	E-Commerce, SaaS	10/14	366.85	2080.97	2399.97	286.23	2002
FireEye (FEYE)	SaaS, Security	9/13	349		2394.92	282.26	2004
SunRun (RUN)	CleanTech, LOHAS & Wellness	8/15	251	1107.03	1357.63	251	2007
Juno Therapeutics (JUNO)	Life Sciences, Oncology	12/14	264.55	1605.99	1870.54	246.03	2013
Square (SQ)	FinTech, Mobile, SaaS	11/15	243	2708.5	2951.5	218.15	2009
Arista Networks (ANET)		6/14	225.75	2508.29	2734.04	212.21	2004
Masimo	Manufacturing	8/07	202.58	695.3	897.89	202.58	1989
Hudson Pacific Properties (HPP)		6/10	217.6	127.45	345.05	202.37	2009
LinkedIn	Mobile	5/11	352.8	4035.19	4252.44	202.04	2003
GoPro (GPRO)	Manufacturing	6/14	427	2528.37	2955.37	200.78	2003
Etsy (ETSY)	E-Commerce	4/15	266.67	1508.73	1775.4	199.47	2005

Table 2: Top 25 companies by IPO exit.

Limited partners by industry by year (which are the most active/highest investment limited partners by industry from 2005-2015?)
Most active investors by industry by year (which are the most active/highest investment for investors/funds by industry from 2005-2015?)
For this dataset: https://my.pitchbook.com/?pcc=14688-37

Narrower description:
1) IPO exits by industry by year 2) Bankruptcy by industry by year 3) Top LPs commiting to Funds by Industry Preferences (of the funds) by year (number of commitments 4) Top Investors by industry by year (number of deals)

Discuss particular companies and products once we see which industries got the most series.

Pending:
1) Averages of LP commitments by industry and by industry vertical for the top 25 LPs from 2005-2015. Graph for each industry and vertical + overall, as you requested. 2) Averages (both number of deals and by dollar investments) for the top 25 Investors by industry and industry vertical from 2005-2015. Graph for each industry and vertical + overall, as you requested.

VII. Venture Capital as Dynamic Regulation of Disruptive Innovation

The data analysis shows that venture capitalists' finance allocation and the implicit assessment of innovative products, businesses, and initiatives generates highly relevant institution- and industry-specific decentralized information on innovation trends. As such, venture capitalists' innovation driven finance allocation can provide feedback on innovation trends for rulemakers, optimize the timing of regulation, and facilitate anticipatory rulemaking. Venture capitalists' investment allocations can provide rulemakers with a measure of risks associated with innovative developments as well as the economic opportunities associated with such innovation.

VC finance allocation can create feedback effects for dynamic regulation of innovation. The theory of lawmaking describes feedback effects as rulemakers' reactions to institutional change or private actors' reactions and counteractivities to institutional constraints. Kaal & Vermeulen show that data on VC finance allocation can distill institutional changes of companies that received VC financing in minute details. As such, the regulators' reaction to institutional change could be informed by VC financing allocations. VC feedback effects provide relevant, timely, decentralized, and institution-specific information ex-ante.

VC's finance allocation can help optimize the timing of rule enactment. A core problem for regulation of disruptive innovation is inaccurate and delayed timing. Regulation is mostly reactive, following business cycles, and not preemptive. Data on VC investments allows regulators to see where innovation trends exist and what possible risks are entailed before disruptive innovation materializes. Should regulators take such data on VC investments and their possible implications for disruptive innovation seriously and integrate them in rulemaking processes or legislative proposals, it is conceivable that the identification of disruptive innovation and associated legal concerns

could be addressed in a more timely fashion. By identifying possible contingencies and necessary rule revisions with optimized information from VC investments ex-ante, before disruptive innovation creates problems, regulators could anticipate regulatory needs.

Venture capitalists' innovation driven finance allocation can facilitate anticipatory rulemaking. Through the feedback effects that are facilitated by venture capitalists' finance allocation towards innovative products, rulemakers can obtain timely and decentralized industry specific and entity specific information that allows them to adapt rules to anticipate regulatory issues. For instance, information on industry-specific VC investments allows regulators to anticipate regulatory needs in certain industries that are associated with the highest levels of disruptive innovation. Disruptive innovation may here be quantified with the VC dollar investment in such industries. Kaal & Vermeulen are examining multiple metrics with VC investment information. The broad data on VC investments allows for a detailed analysis of innovation trends with anticipatory qualities that could be directly utilized by regulators.

Venture capitalists' investment allocations can provide rulemakers with a measure of risks associated with innovative developments. [_____]

Venture capitalists' investment allocations can provide rulemakers with a measure of the economic opportunities associated with such innovation. [_____]

Venture capitalists' investment allocations can provide rulemakers with a measure of risks associated with innovative developments as well as the economic opportunities associated with such innovation.

Critics may suggest that the market often undervalues venture capital financed innovation in products and ideas. The authors realize that a trend for venture capital financed technology companies, among others, to stay private[137] and market undervaluation of formerly venture capital financed companies[138] suggest that the innovation potential identified by venture capital finance allocation may not always be shared by the market at large. However, our objective in this article is not to discuss the long-term potential of venture capital financed innovation. Rather, we suggest that venture capitalists' innovation driven finance allocation can provide feedback for rulemakers, optimize the timing of regulation, and facilitate anticipatory rulemaking.

Critics may also suggest that venture capital financed innovation is not a reliable measure of innovation that requires regulatory action. [____]

VIII. Conclusion

VC has outrun regulation and regulation is too slow to react, hurting the process. [Just like drone regulation is too slow] The notice and comment procedures of the APA and

[137] Nicole Bullock, Gavin Jackson & Jennifer Hughes, Global Listings Drop as Tech Groups Stay Private, Financial Times, 2/3 January 2016 at 9.
[138] CITE Examples.

SEC are too slow; moreover the micromanagement of the markets is overdone by the SEC and, being outdated, is slowing down vc.