

# TRADING IN THE CLOUDS

By: Colleen M. Baker<sup>1</sup>

## Introduction

In 2017, three childhood friends with a mere \$10,000 of seed capital founded Grao Directo,<sup>2</sup> now “the largest digital platform for grain trading in Latin America.”<sup>3</sup> Grao Directo, through its 2020 partnership with the Chicago Mercantile Exchange (“CME”), provides cloud-based access to real time data on grain markets, and it also matches grain market participants via a smart phone app.<sup>4</sup> In 2019, CME through its CME Smart Stream service became the first derivatives exchange to supply real-time market data via the cloud.<sup>5</sup> As a result, Brazilian farmers—even in the remotest of regions—can now access such market data.<sup>6</sup> Previously, they relied upon “static snapshot[s]” of such markets curated from phone calls and weather patterns.<sup>7</sup> Grao Directo’s CEO, Alexandre Borges, shared: “[i]magine, being in Brazil, we were getting access to state-of-the-art

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<sup>2</sup> Russell Blinch, *Powered by the Cloud: The New Era for Market Data*, INSTITUTIONAL INVESTOR (Feb. 14, 2022), <https://www.institutionalinvestor.com/article/b1wp6n1z514x17/powered-by-the-cloud-the-new-era-for-market-data>.

<sup>3</sup> *Grão Directo Drives Innovation with CME Group’s Real-Time Market Data*, CME GROUP (July 12, 2022), <https://www.cmegroup.com/articles/videos/2022/grao-drieto-drives-innovation-with-cme-groups-real-time-market-data.html>.

<sup>4</sup> In 2019, CME through its CME Smart Stream service became the first derivatives exchange to supply real-time market data via the cloud. Blinch, *supra* note 2.

<sup>5</sup> *Id.*

<sup>6</sup> *Id.*

<sup>7</sup> *Id.*

infrastructure.”<sup>8</sup> This is merely one example of the transformative potential on a global scale of trading exchange groups’ increasing migration to the cloud, which is the focus of this Article.

Both trading exchange groups (“exchanges”) and cloud service providers (“CSPs”) are systemically important economic infrastructure.<sup>9</sup> Without doubt, the interconnections between them are rapidly increasing.<sup>10</sup> Indeed, not only are exchanges migrating to the cloud, but they are also entering into transformative partnerships with CSPs, moving toward the creation of “super super systemic”<sup>11</sup> entities. For example, Microsoft recently announced a commitment to purchase 4% of the London Stock Exchange Group Plc (“LSEG”), a “deal that pushes big

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<sup>8</sup> *Id.*

<sup>9</sup> See generally Colleen Baker et al., *Banking on the Cloud*, 21 TRANSACTIONS: TENN. J. OF BUS. L. 381, 381 (2020) (arguing that cloud service providers should be designated as systemically important under Dodd-Frank’s Title VIII); Nizan Geslevich Packin, *Too-Big-to-Fail 2.0? Digital Service Providers as Cyber-Social Systems*, 93 IND. L.J. 1211, 1215–16 (2018) (arguing for the designation of key digital service providers as “Critical Service Providers”).

<sup>10</sup> See, e.g., Magnus Haglind, *Cloud Computing Is the Exchange Infrastructure of the Future*, FIN. NEWS (Nov. 14, 2017, 11:48 AM), <https://www.fn.london.com/articles/cloud-computing-is-the-exchange-infrastructure-of-the-future-20171114>.

<sup>11</sup> Paul Tucker, Chair of the Systemic Risk Council, has used the word “super-systemic” in reference to clearinghouses. See, e.g. Symposium, Paul Tucker, Harvard Kennedy School and Business School, *Over-the-Counter Derivatives at the Over-the-Counter Derivatives Symposium*, Chicago (April 11, 2014) <https://www.chicagofed.org/~media/others/events/2014/annual-over-the-counter-derivatives-symposium/tucker-clearinghouses-new-central-banks-tucker-2014-pdf..> As clearinghouses are generally part of trading exchange groups, the combination of exchange groups and CSPs should arguably be considered “super super systemic.”

tech further into financial markets.”<sup>12</sup> Microsoft’s cloud computing service, Azure, is one of the three largest<sup>13</sup> CSPs, which in combination account for about 66% of the global market.<sup>14</sup> Its 10-year deal with LSEG – Microsoft’s financial investment and LSEG’s commitment to spend \$2.8 billion on Microsoft cloud services<sup>15</sup> – is not an anomaly. In fact, Microsoft and LSEG were arguably late to the party. In 2021 the Chicago Mercantile Exchange (CME) announced a 10-year partnership with Google Cloud<sup>16</sup> and the Nasdaq publicized a multi-year partnership with Amazon Web Services.<sup>17</sup>

Exchanges’ growing reliance on and partnerships with CSPs are a critical, understudied issue in the legal literature. Indeed, this is the first

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<sup>12</sup> William Shaw & Amy Thomson, *Microsoft to Buy 4% of London Stock Exchange Group on Cloud Deal*, BLOOMBERG (Dec. 12, 2022, 2:17 AM), <https://www.bloomberg.com/news/articles/2022-12-12/microsoft-agrees-to-buy-4-stake-in-lseg-on-cloud-partnership>.

<sup>13</sup> Felix Richter, *Amazon, Microsoft & Google Dominate Cloud Market*, STATISTA (Dec. 23, 2022), <https://www.statista.com/chart/18819/worldwide-market-share-of-leading-cloud-infrastructure-service-providers/>.

<sup>14</sup> Nikou Asgari et al., *Why Has Big Tech Fallen in Love with Exchanges?*, FIN. TIMES (Dec. 16, 2022), <https://www.ft.com/content/b8ffa049-cf19-45ec-aaf6-36adc613412e>.

<sup>15</sup> Shaw & Thomson, *supra* note 12.

<sup>16</sup> Nicholas Fearn, *Cloud Computing Powers the World’s Financial Exchanges*, FIN. TIMES (May 9, 2022), <https://www.ft.com/content/40e51620-3da6-4bc6-9d43-05236c7daa93>; *see also* Jon Watkins, *Google Invests \$1 Billion into CME Group as the Two Strike 10-Year Cloud Deal*, THE TRADE (Nov. 5, 2021, 11:26 AM), <https://www.thetradenews.com/google-invests-1-billion-into-cme-group-as-the-two-strike-10-year-cloud-deal/>.

<sup>17</sup> Fearn, *supra* note 16.

law review Article to focus on the topic. In doing so, it extends prior work by the author examining banks' increasing use of the cloud.<sup>18</sup> As this Article explores, the growing integration of exchanges and CSPs creates both benefits and risks. However, this Article concludes that whether the current collaborative trend between CSPs and exchanges will continue indefinitely or culminate in fierce competition remains unclear.<sup>19</sup> This Article posits that the continued intertwining of exchanges and CSPs will generate a new type of financial intermediary platform<sup>20</sup> and formidable market actor, in addition to a host of related regulatory issues the author plans to explore in future research. As a Nasdaq executive remarked regarding exchanges' migration to the cloud: "It opens up a new era for everyone prepared to realise that cloud is not just a cost-saving exercise, it is an opportunity to fundamentally change how the system is designed."<sup>21</sup>

This Article proceeds as follows. Part I provides a brief overview of trading exchanges and cloud computing, including current regulatory considerations. Part II explores benefits and risks of exchanges' increasing

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<sup>18</sup> See generally Baker et. al, *supra* note 9.

<sup>19</sup> The author's prediction of an eventual change in the competitive landscape is a perspective also shared by others. See, e.g., Asgari et. al, *supra* note 14 (quoting Niki Beattie, CEO of Market Structure Partners, "Right now they need each other but long term, the friendly supplier could become a very big threat[.]").

<sup>20</sup> Legal scholars have explored digital financial platforms in the context of the asset management industry. See Dirk A. Zetsche et. al, *Digital Finance Platforms: Toward a New Regulatory Paradigm*, 23 U. PA. J. BUS. L. 273, 306–10 (2020).

<sup>21</sup> Haglind, *supra* note 10.

migration to the cloud. The Article concludes by positing that this migratory trend is likely to culminate in the rise of a new type of financial intermediary platform and highlights that issues in this area are ripe for additional research.

### **Part I: An Overview of Trading Exchange Groups and Cloud Computing**

This Part provides a cursory overview of exchanges, the evolution of their business models, and their regulation. An introduction to cloud computing, the limited applicability of existing regulatory frameworks in this area, and to recent partnerships between CSPs and significant exchanges follows.

#### **A. Trading Exchange Groups**

Trading exchange groups – many of which house markets for securities and derivatives trading – are vital actors in capital markets,<sup>22</sup> a fundamental building block of a robust economy.<sup>23</sup> Indeed, “[t]he U.S. capital markets are the largest, deepest, and most vibrant in the world and

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<sup>22</sup> See generally, U.S. DEP’T OF THE TREASURY, A FINANCIAL SYSTEM THAT CREATES ECONOMIC OPPORTUNITIES: CAPITAL MARKETS (Oct. 2017), <https://home.treasury.gov/system/files/136/A-Financial-System-Capital-Markets-FINAL-FINAL.pdf>, [hereinafter Treasury Market Report] (describing capital markets including markets for equity, bonds (government and private), derivatives, and securitization).

<sup>23</sup> *Id.* at 4.

of critical importance in supporting the U.S. economy.”<sup>24</sup> The trading exchange group market is highly concentrated, and a record amount of M&A activity transpired in 2019 (\$28 billion) and 2020 (\$21 billion).<sup>25</sup> In 2020, a mere handful of exchange operators produced more than half of the industry’s revenues.<sup>26</sup>

Exchanges have now evolved far beyond their early beginnings in which they were member-owned and focused on providing a trading venue and member regulation.<sup>27</sup> In the early 1990s, a combination of technology, globalization, and competition led to most significant exchanges becoming publicly-traded institutions and large corporate structures.<sup>28</sup> Indeed, today’s major trading “exchanges groups are global behemoths.”<sup>29</sup> For example, Intercontinental Exchange Group houses thirteen exchanges and six clearinghouses worldwide.<sup>30</sup>

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<sup>24</sup> *Id.*

<sup>25</sup> The 2020 number of \$21 billion was as of November 30, 2020. Philip Stafford, *Exchanges M&A Returns as Holding Companies Diversify*, FIN. TIMES (Nov. 30, 2020), <https://www.ft.com/content/fda081bd-fc91-4a33-adfc-79ade3ef1a08>.

<sup>26</sup> Phillip Stafford, *How Exchange Operators Have Grown Bigger and Bigger*, FIN. TIMES (Dec. 11, 2020), <https://www.ft.com/content/fb6b14bb-9af6-46a9-9fbf-78a6a02dbce0>; see also *CME/Cboe: Logical Exchange Consolidation But the Timing Might be Tardy*, FIN. TIMES (Aug. 19, 2021), <https://www.ft.com/content/cf278cc4-958a-4648-95f1-55c990a95254>.

<sup>27</sup> Colleen Baker, *Derivatives and ESG*, 59 AM. BUS. L.J. 725, 748 (2022).

<sup>28</sup> *Id.* at 750.

<sup>29</sup> *Id.* at 763; see generally Stafford, *supra* note 26.

<sup>30</sup> Intercontinental Exchange, Inc., Annual Report (Form 10-K), at 5 (Dec. 31, 2021).

Most importantly, the business models of significant exchanges groups have transformed “from utility-like trading centres to hubs of financial data and technology.”<sup>31</sup> For example, Nasdaq’s CEO stated “Nasdaq is a global technology company focused on the capital markets.”<sup>32</sup> Similarly, Intercontinental Exchange, Inc. has termed itself a “global data and technology company.”<sup>33</sup> In this environment, data has become “the oil of the 21<sup>st</sup> century” for the financial industry<sup>34</sup> as “capital markets run on data.”<sup>35</sup> Exchanges have clearly embraced this perspective. In fact, several recent acquisitions by exchanges have primarily been data driven.<sup>36</sup>

In their metamorphosis, exchanges have also become “powerful market actors in their own right.”<sup>37</sup> Indeed, “[t]he biggest players have set their sights on owning more of the building blocks on which investors

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<sup>31</sup> Nicole Bullock & Phillip Stafford, *Nasdaq Chief Doubles Down on Data as NYSE Fight Intensifies*, FIN. TIMES (May 2, 2019), <https://www.ft.com/content/e45bc7ee-6bf3-11e9-a9a5-351eeaf6d84>.

<sup>32</sup> Nicole Bullock & Phillip Stafford, *Nasdaq’s Future Lies in Tech, Data and Analytics, Says Chief*, FIN. TIMES (Oct. 12, 2017), <https://www.ft.com/content/6d72548a-af30-11e7-beba-5521c713abf4>.

<sup>33</sup> INTERCONTINENTAL EXCHANGE, 2020 SUSTAINABILITY REPORT 6 (2021).

<sup>34</sup> Robin Wigglesworth & Eric Platt, *S&P Global’s \$44Bn Deal Shows Data Is the Oil of the 21<sup>st</sup> Century*, FIN. TIMES (Dec. 1, 2020), <https://www.ft.com/content/cd99579c-e01f-4a71-a124-e9c03598e5b9>.

<sup>35</sup> Judson Althoff, *Empowering the Future of Financial Markets with London Stock Exchange Group*, MICROSOFT (Dec. 11, 2022), <https://blogs.microsoft.com/blog/2022/12/11/empowering-the-future-of-financial-markets-with-london-stock-exchange-group/>.

<sup>36</sup> See Baker, *supra* note 27, at 751.

<sup>37</sup> Stafford, *supra* note 26.

rely, including data, analytics, indices, the venues on which trades are executed and the businesses that subsequently settle them.”<sup>38</sup> In sum, exchanges are becoming financial technology platforms, and are increasingly reliant on CSPs to assist in powering their transformation.

Yet despite the evolution of exchanges’ business models, they still provide critical financial market infrastructure, and their substantial framework of regulation has remained relatively constant. In the U.S., both securities<sup>39</sup> and derivatives exchanges<sup>40</sup> began historically as private, self-regulatory organizations (SROs), and they retain this designation - now codified in securities and derivatives laws – to this day. However, both securities exchanges and derivatives exchanges have also now outsourced many of their SRO obligations to the Financial Industry Regulatory Authority (FINRA)<sup>41</sup> and to the National Futures Association (NFA),<sup>42</sup> respectively. The Securities Exchange Commission (SEC) has regulatory authority over securities markets, securities exchanges, and

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<sup>38</sup> *Id.*

<sup>39</sup> See, e.g., Lori Richards, Dir., Off. of Compliance Inspections and Examinations, U.S. Secs. & Exch. Comm’n, Speech by SEC Staff: Self-Regulation in the New Era (Sept. 11, 2000), <https://www.sec.gov/news/speech/spch398.htm>.

<sup>40</sup> See, e.g., Heath P. Tarbert, *Self-Regulation in the Derivatives Markets: Stability Through Collaboration*, 41 NW. J. INT’L L. & BUS. 175, 179–83 (2021).

<sup>41</sup> See *About FINRA*, Financial Industry Regulatory Authority, <https://www.finra.org/about/what-we-do> (last visited March 5, 2022).

<sup>42</sup> See *About NFA*, NAT’L FUTURES ASS’N, <https://www.nfa.futures.org/about/index.html> (last visited March 5, 2022).



FINRA.<sup>43</sup> The Commodity Futures Trading Commission (CFTC) has regulatory oversight of derivatives markets, derivatives exchanges, and the NFA.<sup>44</sup> The SEC and CFTC also have a shared regulatory interest in a limited number of areas.<sup>45</sup>

Surprisingly, however, the systemic risk posed by today's significant exchanges to financial market stability has received little attention by policymakers or legal scholars. To be sure, the systemic risk posed by clearinghouses – either financial market utilities that are housed within exchanges or can standalone entities – has been in the regulatory spotlight, especially since the financial crisis of 2007-09.<sup>46</sup> However, a clearinghouse<sup>47</sup> disruption is not the only possible source of systemic risk posed by significant exchanges. Other facets of exchange operations are

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<sup>43</sup> See generally Securities Act of 1933, 15 U.S.C. § 77a–77aa.; Securities Exchange Act of 1934, 15 U.S.C. § 78a–78qq..

<sup>44</sup> See generally Commodities Exchange Act, 7 U.S.C. §§ 1–27f..

<sup>45</sup> For example, these agencies share regulatory jurisdiction over “mixed swaps” and security futures. See *Derivatives*, SEC (May 4, 2015), <https://www.sec.gov/spotlight/dodd-frank/derivatives.shtml>; *Security Futures Product*, CFTC, <https://www.cftc.gov/IndustryOversight/ContractsProducts/SecurityFuturesProduct/index.htm> (last visited Apr. 13, 2023).

<sup>46</sup> See generally Colleen Baker, *Incomplete Clearinghouse Mandates*, 56 AM. BUS. L.J. 507 (2019); Paolo Saguato, *The Ownership of Clearinghouses: When “Skin in the Game” Is Not Enough, the Remutualization of Clearinghouses*, 34 YALE J. ON REG. 601 (2017).

<sup>47</sup> For simplicity, this Article uses the word “clearinghouse” to refer to a central counterparty clearinghouse; however, there are several different types of clearinghouses.

also systemically critical. For example, the robustness of an exchange’s matching engine – which is core to the exchange, matches buyers and sellers, and facilitates price discovery<sup>48</sup> – is fundamental to market integrity. Over the past decade, significant problems at a number of exchanges have disrupted trading markets,<sup>49</sup> and this trend continues. For example, in January 2023, a glitch at the New York Stock Exchange resulted in “wild price swings that affected over 250 stocks . . . which added or wiped out billions of dollars of market value.”<sup>50</sup>

The next section provides an overview of CSPs, whose outages have also caused significant market disruptions, before discussing their recent partnerships with significant exchanges and regulatory considerations.

## B. Cloud Computing

Use of cloud computing has exploded in the past two decades for a number of reasons, including “advancements in virtualization and other technologies, networking, connectivity, and reduction in costs of hardware

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<sup>48</sup> See *All About Trading and Matching Technology*, NASDAQ, <https://www.nasdaq.com/about-matching-engines> (last visited Sept. 12, 2022) (describing exchange matching engines).

<sup>49</sup> John McCrank, *From Hungry Squirrels to Cyberattacks, Exchange Outages Roil Markets*, REUTERS (Oct. 1, 2020, 4:18 PM), <https://www.reuters.com/article/us-global-exchanges-outages/from-hungry-squirrels-to-cyberattacks-exchange-outages-roil-markets-idUSKBN26M7FA>.

<sup>50</sup> Joe Rennison, *N.Y.S.E. Glitch Leads to Wild Swings in Share Prices*, N.Y. TIMES (Jan. 24, 2023), <https://www.nytimes.com/2023/01/24/business/nyse-trading-glitch.html>.

and other components.”<sup>51</sup> Investment in public cloud services is projected to reach \$600 billion in 2023, an increase from \$220 billion in 2016.<sup>52</sup> The National Institute of Standards and Technology terms cloud computing “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.”<sup>53</sup>

Currently, five CSPs account for approximately 90% of the market, which experts estimate experience a significant outage each quarter.<sup>54</sup> In order of size, the three largest CSPs are Amazon Web Services (AWS), Microsoft Azure, and Google Cloud.<sup>55</sup> Amazon Web Services experienced a major outage in December 2021, impacting a broad expanse of businesses and industries, including trading platforms.<sup>56</sup> CSP

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<sup>51</sup> This report addresses the financial service sector in general, but it is not focused specifically on exchanges. U.S. TREASURY DEP’T, *THE FINANCIAL SERVICE SECTOR’S ADOPTION OF CLOUD SERVICES 15* (2023), <https://home.treasury.gov/system/files/136/Treasury-Cloud-Report.pdf> [hereinafter *Treasury Cloud Report*].

<sup>52</sup> *Id.* (citing findings by the research firm, Gartner).

<sup>53</sup> Peter Mell & Timothy Grace, *The NIST Definition of Cloud Computing*, NIST SPECIAL PUBLS., Sept. 2011, at 2. <https://www.govinfo.gov/app/details/GOVPUB-C13-74cdc274b1109a7e1ead7185dfec2ada>.

<sup>54</sup> Omar Abdel-Baqi & Aaron Tilley, *Amazon Web Services Outage Takes Businesses, Services Offline*, WALL ST. J.: TECH, Dec. 7, 2021, <https://www.wsj.com/articles/amazon-web-services-appears-to-be-down-for-many-users-11638898270>.

<sup>55</sup> Richter, *supra* note 13.

<sup>56</sup> Abdel-Baqi, *supra* note 54.

outages occurred in 2022<sup>57</sup> and “[a]t the current rate, experts predict at least 20 high-profile cloud outages each year.”<sup>58</sup> Hence, businesses, such as exchanges, that rely upon CSPs should anticipate potential outages and related losses.<sup>59</sup> At the same time, experts argue that “[c]ompared to on-site hardware, cloud-based infrastructure results in **more frequent downtime but with less severity.**”<sup>60</sup>

Several types of cloud computing arrangements are possible, including the use of a public cloud (a common, shared pool of computing resources), a private cloud (specific cloud resources dedicated to a single user and provided by the user or a third party), a community-based cloud (cloud resources dedicated to a specific community of users and provided by the users or a third party) and a hybrid arrangement (the use of a combination of public and private clouds).<sup>61</sup> Currently, hybrid arrangements are the most prevalent in the financial industry as institutions tend initially to migrate their less critical applications.<sup>62</sup> For example, exchanges using a public cloud tend to do so for “data

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<sup>57</sup> Wade T. Millward, *The Biggest Cloud Outages of 2022*, CRN (Dec. 19, 2022), <https://www.crn.com/news/cloud/the-15-biggest-cloud-outages-of-2022>.

<sup>58</sup> Andreja Velimirovic, *Cloud Outage: Why and How Does It Happen?*, PHOENIXNAP (Oct. 5, 2022), <https://phoenixnap.com/blog/cloud-outage> (included in the Must-Know Cloud Outage Statistics).

<sup>59</sup> *See generally id.* (noting that 60% of companies that use public cloud services reported losses due to outages in 2022).

<sup>60</sup> *Id.*

<sup>61</sup> Baker et al., *supra* note 9, at 385.

<sup>62</sup> Treasury Cloud Report, *supra* note 51, at 25.

transmission, processing, analysis, and long-term data storage,” and increasingly to leverage cloud-based data mining and analytics capabilities.<sup>63</sup> Some experts recommend that exchanges’ critical systems, such as matching engines, remain on their internal technology infrastructure given their importance and the risk of CSP outages.<sup>64</sup>

Similarly, several cloud service models are available. The three primary models—Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS)—each reflect a different balance of responsibility between the customer and the CSP for infrastructure, computer resources, and applications.<sup>65</sup> The SaaS service model comprises the largest segment of the market.<sup>66</sup> Figure 1 below, from a recent U.S. Treasury report, *The Financial Services Sector’s Adoption of Cloud Services*,<sup>67</sup> provides a comparison of potential cloud computing arrangements and service models.

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<sup>63</sup> Philip Moyer, *New Research from Google Cloud Reveals Five Innovation Trends for Market Data*, GOOGLE (Sept. 22, 2021), <https://cloud.google.com/blog/topics/financial-services/market-data-distribution--consumption-through-cloud--ai>; see also Karl Flinders, *Nasdaq Gives Customers Real-Time Data Through Cloud Platform*, COMPUTERWEEKLY (April 23, 2020), <https://www.computerweekly.com/news/252482062/Nasdaq-gives-customers-real-time-data-through-cloud-platform>.

<sup>64</sup> Fearn, *supra* note 16.

<sup>65</sup> See Baker et al., *supra* note 9, at 385.

<sup>66</sup> Treasury Cloud Report, *supra* note 51, at 16.

<sup>67</sup> *Id.*

Figure 1: NIST Definition of Cloud

<b>Essential characteristics</b>	On-Demand Self-Service	User can unilaterally provision server time, network storage, etc. as needed without involving service provider.
	Broad Network Access	Capabilities are available over the network and accessed through common mechanisms (e.g. a Web browser) and devices.
	Resource Pooling	Physical and virtual resources are shared across a large pool of users, allowing for dynamic assignment according to users' demands.
	Rapid Elasticity	Computing capabilities can be scaled rapidly up or down according to users' demands, such that any given user's demand is met without interruption.
	Measured Service	Users access capabilities as a service and pay only for resources used.
<b>Service models</b>	Software-as-a-Service (SaaS)	End-user applications provided as a service only. User cannot manage or control any underlying cloud infrastructure.*
	Platform-as-a-Service (PaaS)	Application platforms or middleware provided as a service on which users can build and deploy custom applications using programming languages, libraries and other tools supported by service provider.
	Infrastructure-as-a-Service (IaaS)	Broad and scalable computing capabilities provided as a service, including processing, storage, networks, and operating systems, enabling more control over deployed applications.
<b>Deployment models</b>	Public Cloud	The cloud infrastructure is available for open use by the general public. It generally is owned by and exists on the premises of the cloud service provider.
	Private Cloud	The cloud infrastructure is available for exclusive use by a single organization. It may exist on or off premises and may be owned by the organization, a third party, or both.
	Community Cloud	The cloud infrastructure is available for use only by a specific community of users that have shared needs or concerns. It may be owned by one or more of the community users, by a third party, or some combination.
	Hybrid Cloud	The cloud exists as a configuration of two or more distinct cloud infrastructures (public, private, or community) that enables data and application portability among the separate infrastructures.

\* Cloud infrastructure includes network, servers, data, middleware, operating systems, storage, etc.  
 Source: National Institute of Standards and Technology.

C. Exchange – CSP Partnerships

In 2020, Amazon Web Services (AWS), Singapore Exchange (SGX), and Aquis Exchange in London were pioneers of trading in the clouds, engaging in a “proof of concept to show that trading shares in the cloud can be sufficiently fast and reliable.”<sup>68</sup> In 2021, CME Group and Google Cloud announced a 10-year partnership, including a \$1 billion

<sup>68</sup> Huw Jones, *Amazon Pilot Lifts Stock Exchanges into the Cloud*, REUTERS (Nov. 20, 2020), <https://www.reuters.com/article/us-exchange-cloud-amazon-com-idCAKBN2801R5>.

equity investment by Google in CME Group,<sup>69</sup> and the eventual transfer of CME's market and information technology infrastructure to Google's cloud.<sup>70</sup> For CME, projected benefits of the partnership encompass enhanced automation, increased resiliency, efficiencies in onboarding new customers, and enhanced analytical and risk management offerings.<sup>71</sup> Terry Duffy, CME's CEO, commented that the partnership, "will transform derivatives markets."<sup>72</sup>

Nasdaq's multi-year partnership with Amazon Web Services anticipates the eventual transition of its North American markets to the cloud.<sup>73</sup> Their collaboration aims to develop a "co-designed" technology infrastructure solution to be used not only for the phased migration of Nasdaq's markets, but also for that of other exchange operators in the future.<sup>74</sup> The partnership also plans to seek innovative ways to harness the cloud's capabilities with Nasdaq data, analytics, and software

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<sup>69</sup> Nicholas Megaw, *Google Strikes \$1bn 'Cloud' Deal with Exchange Operator CME Group*, FIN. TIMES (Nov. 4, 2021), <https://www.ft.com/content/f120cd0d-73a9-4b0e-8e3e-e5449f33bbf5>.

<sup>70</sup> Fearn, *supra* note 16, at 2; *see also* Watkins, *supra* note 16, at 2.

<sup>71</sup> Megaw, *supra* note 69, at 10.

<sup>72</sup> *Id.* (quoting CME Group CEO Terry Duffy).

<sup>73</sup> Fearn, *supra* note 16, at 2.

<sup>74</sup> Annabel Smith, *Nasdaq Partners with AWS to Migrate North American Markets to the Cloud*, TRADE NEWS (Dec. 1, 2021), <https://www.thetradenews.com/nasdaq-partners-with-aws-to-migrate-north-american-markets-to-the-cloud/>.

solutions.<sup>75</sup> Nasdaq’s CEO Adena Friedman stated, “[t]his landmark partnership with AWS seeks to power a truly cloud-based market infrastructure that is more resilient, scalable, and accessible for all market participants.”<sup>76</sup>

As part of their 10-year strategic partnership, Microsoft plans to make a 4% equity investment in the London Stock Exchange Group (LSEG), and it projects future partnership-related revenues of \$5 billion.<sup>77</sup> For its part, the LSEG has committed to spend at least \$2.8 billion on Microsoft cloud services over the period.<sup>78</sup> A Microsoft blog comments that: “[f]oundational to the partnership will be the digital transformation of LSEG’s technology infrastructure and data and analytics platforms onto the Microsoft Cloud . . . we will co-create an open, centralized, financial data platform enabling seamless data democratization, collaboration and new monetization opportunities across the financial services ecosystem.”<sup>79</sup>

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<sup>75</sup> *Nasdaq and AWS Partner to Transform Capital Markets*, NASDAQ (Nov. 30, 2021, 11:44 AM), <https://www.nasdaq.com/press-release/nasdaq-and-aws-partner-to-transform-capital-markets-2021-12-01>.

<sup>76</sup> *Id.* (quoting Nasdaq President and CEO Adena Friedman).

<sup>77</sup> Althoff, *supra* note 35.

<sup>78</sup> Shaw & Thomson, *supra* note 12.

<sup>79</sup> Althoff, *supra* note 35.



In addition to these groundbreaking CSP-exchange partnerships, many exchanges such as Cboe Global Markets<sup>80</sup> and Intercontinental Exchange Group<sup>81</sup> use cloud computing for a number of reasons, including offering data and data services to clients.

#### D. General Regulatory Considerations

Exchanges' comparatively slower migration to the cloud likely reflects their substantial framework of regulation and associated regulatory requirements.<sup>82</sup> CSPs and their financial institution clients generally use a "shared responsibility" model for public cloud arrangements, meaning their respective responsibilities for security, performance, and resilience are contractually allocated based upon the selected service model.<sup>83</sup> However, financial institutions such as exchanges are themselves ultimately responsible for their operational resilience and compliance with legal and regulatory mandates, providing incentives for these institutions to integrate risk management mechanisms into the contract.<sup>84</sup>

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<sup>80</sup> *Cboe to Distribute Real-Time Data via AWS with Cboe Global Cloud*, CBOE (Oct. 27, 2021), <https://ir.cboe.com/news-and-events/2021/10-27-2021/cboe-distribute-real-time-data-aws-cboe-global-cloud>.

<sup>81</sup> See Intercontinental Exch. Grp., *Cloud Connect*, INTERCONTINENTAL EXCH. INC., <https://www.theice.com/market-data/connectivity-and-feeds/cloud-connect> (last visited March 5, 2022).

<sup>82</sup> See Megaw, *supra* note 69.

<sup>83</sup> See Treasury Cloud Report, *supra* note 51, at 5, 19.

<sup>84</sup> See *generally id.* at 20, 31.

Mechanisms for ensuring that CSPs meet the security, performance, and resilience requirements under the contract include risk evaluations and audits.<sup>85</sup>

Via the Bank Service Company Act,<sup>86</sup> federal banking regulators have limited examination and regulatory authority over banks' outsourcing of certain services to third-parties.<sup>87</sup> However, the SEC and the CFTC do not have an equivalent statutory authority.<sup>88</sup> The Federal Financial Institutions Examination Council,<sup>89</sup> a council of banking regulators, has also released a *Joint Statement on Risk Management for Cloud Computing Services*.<sup>90</sup> As of this writing, the SEC and the CFTC have not released a comparable statement to the best of the author's knowledge.

However, both the SEC and the CFTC have promulgated regulations that address regulated markets and entities' technology infrastructure. In 2014, the SEC adopted Regulation Systems Compliance and Integrity (Reg SCI)<sup>91</sup> to "strengthen the technology infrastructure of

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<sup>85</sup> See *id.* at 22.

<sup>86</sup> 12 U.S.C.A. §§ 1861-1867 (2022).

<sup>87</sup> Treasury Cloud Report, *supra* note 51, at 35.

<sup>88</sup> *Id.* at 36. Under Dodd-Frank's Title VIII, these agencies have limited examination authority of a third-party's provision of an "integral" operational service to a designated financial market utility.

<sup>89</sup> See FED. FIN. INST. EXAMINATION COUNCIL, <https://www.ffiec.gov/> (last visited March 6, 2023).

<sup>90</sup> See *FFIEC Joint Statement on Risk Management for Cloud Computing Services*, FED. FIN. INST. EXAMINATION COUNCIL (2020), <https://www.fdic.gov/news/financial-institution-letters/2020/fil20052a.pdf>.

<sup>91</sup> See 17 C.F.R. §§ 242.1000-1007 (2014).

U.S. securities markets.”<sup>92</sup> In general, it aims to decrease systems issues, increase systems resiliency, and improve the SEC’s oversight of relevant technology infrastructure.<sup>93</sup> Reg SCI “sets standards for systems that directly support trading, clearance and settlement, order routing, market data, market regulation, or market surveillance.”<sup>94</sup> These incorporate standards for business continuity and disaster recovery, including timeframes within which interrupted critical services must resume, and notification requirements for system changes.<sup>95</sup> The CFTC’s System Safeguards Regulations<sup>96</sup> sets risk analysis and oversight standards, business continuity requirements, mandated time frames for disaster recovery, notification obligations for system changes, and obligations surrounding outsourcing.<sup>97</sup>

The global legal and regulatory landscape for CSPs is fragmented and lacks uniformity.<sup>98</sup> Cloud services are global, but regulation is local. Therefore, multinational financial institutions such as significant

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<sup>92</sup> *Spotlight on Regulation SCI*, U.S. SEC. EXCH. COMM’N. (Dec. 9, 2016), <https://www.sec.gov/spotlight/regulation-sci>.

<sup>93</sup> *Id.*

<sup>94</sup> Treasury Cloud Report, *supra* note 51, at 33.

<sup>95</sup> *Id.* at 33, 35.

<sup>96</sup> See 17 C.F.R. § 39.18 (2016).

<sup>97</sup> *Id.*; see also Treasury Cloud Report, *supra* note 51, at 34–35.

<sup>98</sup> See Treasury Cloud Report, *supra* note 51, at 40–43.

exchanges must deploy their cloud strategy accordingly,<sup>99</sup> and be prepared to navigate different regulatory regimes. At the same time, “international regulatory frameworks, and specific requirements from foreign jurisdictions, can significantly influence the services CSPs provide and how they engage with financial institutions and authorities.”<sup>100</sup> Global regulatory fragmentation also means that international financial regulators’ insight into financial institutions’ overall use of cloud computing will be limited.<sup>101</sup>

Ultimately, the increasing partnerships between exchanges, which are subject to an extensive regulatory framework, and CSPs, which are subject to little (if any) direct regulation, treads a delicate balance that seems unlikely to continue indefinitely. A complicating factor in this area is that regulatory institutions themselves increasingly use cloud computing services.<sup>102</sup>

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<sup>99</sup> *See id.*

<sup>100</sup> *Id.* at 38; *see generally* Transcript of CFTC Technology Advisory Committee Meeting at 199, Oct. 3, 2019, [https://www.cftc.gov/sites/default/files/2020/06/1591390538/tac\\_100319\\_transcript.pdf](https://www.cftc.gov/sites/default/files/2020/06/1591390538/tac_100319_transcript.pdf).

<sup>101</sup> *See* Treasury Cloud Report, *supra* note 51, at 7.

<sup>102</sup> *See e.g.* Sec. Exch. Comm’n Office of Inspector General, *The SEC Can More Strategically and Securely Plan, Manage, and Implement Cloud Computing Services*, SEC. EXCH. COMM’N (2019), <https://www.sec.gov/files/SEC-Can-More-Strategically-and-Securely-Plan-Manage-and-Implement-Cloud-Computing-Service.pdf>; Annex A: The Department of Treasury’s Cloud Strategy of Treasury Cloud Report, *supra* note 51.

## Part II: Benefits and Risks of Trading in the Clouds<sup>103</sup>

This Part explores potential benefits, risks, and costs of financial institutions such as exchanges' reliance on cloud computing services, considerations ultimately impacted by how institutions "use, design, and implement"<sup>104</sup> such services. Global financial regulators are increasingly focused on the potential risks presented by critical third-party service providers, especially CSPs.<sup>105</sup> Any financial institution user will have to manage the risks associated with a CSP. However, an additional consideration for exchanges is that similar to CSPs, their market is highly-concentrated and systemically important.

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<sup>103</sup> In general, this Part applies benefits and risks/costs of cloud computing for financial institutions in general to the exchange context. There appear to be limited resources specifically addressing exchanges' use of cloud computing.

<sup>104</sup> Treasury Cloud Report, *supra* note 51, at 10. The quoted language is applied to financial institutions in general.

<sup>105</sup> See e.g., Stephen Morris & Laura Noonan, *UK financial regulators to step up scrutiny of cloud computing giants*, FIN. TIMES (Jan. 9, 2022), <https://www.ft.com/content/29405a47-586b-4c5a-b641-0f479b4cee1d>; See e.g. Treasury Cloud Report, *supra* note 51 U.K., *Operational Resilience: critical third parties to the U.K. financial sector* (2022) (examining the growing dependencies of its financial sector on technology services, including cloud computing services); FSB, *Big tech interdependencies – a key policy blind spot* (2022); FCA, *The Potential Competition Impacts of Big Tech Entry and Expansion in Retail Financial Services* (2022); IOSCO, *Principles on Outsourcing* (2021) (including an annex on *Outsourcing and Cloud Computing*); FINRA, *Cloud Computing in the Securities Industry* (2021); FSB, *Regulatory and Supervisory Issues Relating to Outsourcing and Third-Party Relationships* (2020); FSB, *Third-party dependencies in cloud services: Considerations on financial stability implications* (2019); and, FSB, *Fintech and Market Structure in Financial Services: Market Developments and Potential Financial Stability Implications* (2019).

Critical financial infrastructures such as exchanges usually begin their migration to the cloud slowly, moving non-core applications first and retaining critical operations onsite.<sup>106</sup> However, the three noted partnerships between significant exchanges and CSPs – Microsoft Azure and the LSEG, Google Cloud and CME, AWS and Nasdaq – all anticipate the eventual migration of at least some of the exchanges’ markets to the cloud. Indeed, the Options Clearing Corporation, a systemically important, standalone clearinghouse, has already announced its intention to migrate core operations to the cloud in the near future.<sup>107</sup>

#### A. Benefits

A primary advantage of cloud use for exchanges – and for other types of financial institutions – is that it offers flexible, dynamically scalable computing resources.<sup>108</sup> In such an environment, it should be easier to accommodate intermittent trading surges than it would be in an environment of static, limited computing resources onsite. Cloud use should also enable IT cost savings if exchanges do not need to ensure onsite resources sufficient to process such surges – that is, ensuring “burst

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<sup>106</sup> See generally Treasury Cloud Report, *supra* note 51, at 30.

<sup>107</sup> See *OCC Receives No Objection Notice from SEC on Cloud Infrastructure Proposal*, OPTIONS CLEARING CORP. (Nov. 7, 2022), <https://www.theocc.com/newsroom/views/2022/11-07-occ-receives-no-objection-notice-from-sec-on-cloud-infrastructure-proposal>.

<sup>108</sup> See Watkins, *supra* note 16.

capacity”<sup>109</sup> – and if they are able to reduce onsite IT upgrading and maintenance requirements.<sup>110</sup> Access to scalable computing resources should also aid with remote work arrangements and heightened fintech use in the post-pandemic world.<sup>111</sup> In sum, a core advantage of cloud computing is its technological agility;<sup>112</sup> potential for rapid, global resource deployment;<sup>113</sup> and, ability to provide superior systems testing environment.<sup>114</sup>

Other key benefits of cloud computing for exchanges include security, resilience, reliability, business process efficiencies, faster innovation, and machine learning and AI capabilities.<sup>115</sup> The cloud and AI applications will drive digital transformation in the exchange industry.<sup>116</sup> Customers want

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<sup>109</sup> Treasury Cloud Report, *supra* note 51, at 21.

<sup>110</sup> See *What Is Cloud Computing?*, AMAZON WEB SERVS. (last accessed March 6, 2023), <https://aws.amazon.com/what-is-cloud-computing/>.

<sup>111</sup> See Treasury Cloud Report, *supra* note 51, at 19.

<sup>112</sup> *What Is Cloud Computing?*, *supra* note 110. AWS explains this notion of agility: “The cloud gives you easy access to a broad range of technologies so that you can innovate faster and build nearly anything that you can imagine. You can quickly spin up resources as you need them—from infrastructure services, such as compute, storage, and databases, to Internet of Things, machine learning, data lakes and analytics, and much more.”

<sup>113</sup> See *id.*

<sup>114</sup> See Treasury Cloud Report, *supra* note 51, at 21.

<sup>115</sup> See *Nasdaq and AWS Partner to Transform Capital Markets*, NASDAQ (Dec. 1, 2021), <https://www.nasdaq.com/press-release/nasdaq-and-aws-partner-to-transform-capital-markets-2021-12-01>.

<sup>116</sup> See Althoff, *supra* note 35.

flexible access to data and data analytic capabilities<sup>117</sup> and cloud computing can aid exchanges in customizing their provision of data and services to clients.

Financial market participants have commented that it is an “age of resiliency,”<sup>118</sup> and financial regulators are increasingly focused on financial institutions’ operational resilience,<sup>119</sup> especially in the context of cloud computing. Indeed, this topic is at the center of a recent report by the U.S. Treasury Department, *The Financial Services Sector’s Adoption of Cloud Services*.<sup>120</sup> Operational resilience can be defined as “the practices and disciplines that enable firms to provide products and services to the marketplace in face of disruptive events, regardless of the nature and origin of those events, by anticipating, preventing, recovering and responding to such events.”<sup>121</sup>

Use of cloud computing can potentially increase exchanges’ operational resiliency, which should decrease their operational risk.

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<sup>117</sup> Blinch, *supra* note 2.

<sup>118</sup> CFTC Technology Advisory Committee Meeting Transcript at 191, Oct. 3, 2019 (words of Jason Harrell, Executive Director and Head of Business and Government Cybersecurity Partnerships, DTCC), [https://www.cftc.gov/sites/default/files/2020/06/1591390538/tac\\_100319\\_transcript.pdf](https://www.cftc.gov/sites/default/files/2020/06/1591390538/tac_100319_transcript.pdf).

<sup>119</sup> See generally Treasury Cloud Services Report, *supra* note 51, at 9.

<sup>120</sup> *Id.* at 14.

<sup>121</sup> CFTC Technology Advisory Committee Meeting Transcript, *supra* note 118, at 195.



Ironically, however, cloud computing can also present resiliency risks as noted below. CSPs can increase their resilience through redundancy practices, such as by using multiple data centers located in different geographic regions, and state of the art cybersecurity.<sup>122</sup> Of course, such measures would be too costly for many financial institutions to take on an individual basis.

- B. Similar to resiliency, cybersecurity protection is both a benefit and a potential risk for exchanges in using cloud computing. In general, public cloud security is equivalent or superior to most financial institutions onsite capabilities.<sup>123</sup> However, a cybersecurity risk of CSPs is that they are single points of entry and failure. Potential Risks/Costs

Operational resilience can be both a benefit and a risk of CSPs, especially given their outage risk, and clients' potentially limited knowledge about or control over such events. Relatedly, the risk of connectivity issues will rise when IT infrastructure is offsite.<sup>124</sup> Financial institutions such as exchanges could increase resiliency by using multiple CSPs, but

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<sup>122</sup> See Treasury Cloud Report, *supra* note 51, at 20.

<sup>123</sup> *Id.* at 21.

<sup>124</sup> *Id.* at 55.

this would likely be an imperfect solution. For example, simultaneous execution of applications across multiple cloud environments might be impractical: “[r]unning an application across multiple CSPs at the same time may also be less desirable, given the costs, staffing, and complexity involved in doing so, particularly given the complexity associated with identifying and managing risk across multiple cloud environments.”<sup>125</sup>

Another potential drawback/risk of cloud computing use is insufficient transparency of a CSP’s operations, which could adversely impact exchanges’ understanding of relevant risks and compliance with regulatory responsibilities.<sup>126</sup> Limited transparency also implies that exchanges are likely to have limited (if any) insight into third-party providers’ CSP reliance,<sup>127</sup> and its impact on concentration risk. Traditionally, third-party outsourcing has been a one-to-many arrangement, however, CSPs reverse that model with millions outsourcing to one.<sup>128</sup>

The multi-tenant environment of public clouds makes onsite audits of CSPs challenging, particularly given resource and security considerations.<sup>129</sup> Market participants are exploring solutions to this issue

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<sup>125</sup> *Id.* at 6.

<sup>126</sup> *See generally id* at 7.

<sup>127</sup> Treasury Cloud Report, *supra* note 51, at 49.

<sup>128</sup> Baker et. al, *supra* note 9, at 390–91.

<sup>129</sup> Treasury Cloud Report, *supra* note 51, at 5.

such as “pooled audits, certifications, or real-time updates to customers,”<sup>130</sup> and some have suggested an “industry certification” for vendors such as CSPs to improve current market approaches.<sup>131</sup>

CSPs also present concentration risk for financial institutions such as exchanges, and relatedly, CSPs market position affords them significant “contractual leverage.”<sup>132</sup> In fact, even significant financial institutions have purportedly struggled to negotiate certain contractual provisions, including for audit and termination rights.<sup>133</sup> Concerns about CSP lock-ins also exist, making data and application mobility important.<sup>134</sup> However, changing CSP providers or returning IT infrastructure in-house, can also be both a costly and lengthy process.<sup>135</sup> Recognizing the increasing use of multi-cloud environments, some CSPs are focusing on data commoditization and portability, and enhancing interoperability.<sup>136</sup>

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<sup>130</sup> *Id.*

<sup>131</sup> CFTC Technology Advisory Committee Meeting Transcript, *supra* note 118, at 202–03.

<sup>132</sup> *Id.* at 200; *see also* Treasury Cloud Report, *supra* note 51, at 7.

<sup>133</sup> Treasury Cloud Report, *supra* note 51, at 7.

<sup>134</sup> CFTC Technology Advisory Committee Meeting Transcript at 141, Mar. 27, 2019, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cftc.gov/sites/default/files/2019/08/1565287729/tac\_032719\_transcript.pdf.

<sup>135</sup> Treasury Cloud Report, *supra* note 51, at 26.

<sup>136</sup> *See* Steven Rosenbush, *Oracle and Microsoft Agree to Deepen Interoperability of Cloud Platforms*, WALL ST. J., (July 20, 2022) <https://www.wsj.com/articles/oracle-and-microsoft-agree-to-deepen-interoperability-of-cloud-platforms-11658318400>.

Others are also exploring distributed cloud arrangements or smaller, local cloud data centers.<sup>137</sup> However, relying upon multiple CSPs creates complexities,<sup>138</sup> and relying upon a single CSP has advantages—there is likely to be a greater understanding and management of the risks of one platform rather than having technology staff master the risks of multiple CSP platforms.<sup>139</sup> Finally, included within CSP's concentration risk is the potential risk to financial market stability, especially given the systemic importance of both CSPs and significant exchanges.

### Conclusion

Undoubtedly, exchange's increasing use of cloud computing presents both risks and benefits, such as promoting the global democratization of markets as seen in the case of Grao Directo. However, developments in this area are quickly exceeding traditional outsourcing relationships. Indeed, the author speculates that recent transformative partnerships between significant exchanges and CSPs are merely nascent steps toward the creation of a new type of financial platform and market actor. This

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<sup>137</sup> Richard Waters, *Google Bets on the Cloud Breaking Up*, FIN. TIMES (Oct. 14, 2021), <https://www.ft.com/content/ab36b9e2-00e0-469c-9388-fa034f9bfd63>.

<sup>138</sup> Treasury Cloud Report, *supra* note 51, at 25–26.

<sup>139</sup> CFTC Technology Advisory Committee Meeting Transcript, *supra* note 134, at 156.

metamorphosis will present a plethora of new regulatory and research issues ripe for investigation by the author and other legal scholars.



