RegTech*

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Abstract

Compliance-driven investments in technology—or "RegTech"—have grown rapidly in recent years. To understand these investments, we study how financial institutions respond to new internal control requirements. First, we show that affected firms make significant investments in enterprise resource planning, data management, and hardware. These investments then allow for complementary expenditures on customer relationship management tools that rely upon information quality. As a result, customer complaints and employee misconduct decline at affected firms. Additionally, market concentration increases. Our results illustrate how regulation can directly and indirectly affect technology adoption, which in turn affects noncompliance functions and market structure.

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1. Introduction

In their compliance efforts, financial institutions (FIs) are increasingly investing in information technology and hiring technological experts, a development industry participants refer to as "RegTech." In 2019, public U.S. FIs spent nearly $10 billion on RegTech investments, compared to just $2.2 billion on auditing, and RegTech expenditures are forecast to grow at 35% per year (Juniper 2021). RegTech is one of the fastest-growing segments based on global venture capital, private equity, and merger volume (Marlin & Associates 2021).

RegTech investments commonly involve sweeping improvements in data collection, data management, and information systems. While regulators may intend for these improvements to enhance investor protection, FIs report also using RegTech investments in their operations management and strategy (Thomson Reuters 2021). Additionally, interactions between regulation, big data, and market power are attracting attention from researchers and policymakers concerned with the elevated concentration in the financial sector (Philippon 2016).

Despite growing interest in FinTech (D'Acunto, Prabhala, and Rossi 2019; Goldstein, Jiang, and Karolyi 2019), we lack evidence on firms' RegTech investments and their effect on operations and market structure. Few settings permit researchers to observe technological investments at individual firms. When data are available, studying technology adoption is inherently difficult: adoption decisions are typically endogenous, and, in cases where adoption is driven by regulation, one must be able to observe both affected and unaffected firms.

In this paper, we examine regulation adding new internal control requirements for a subset of U.S. broker-dealers (BDs) to investigate firms' RegTech investment response, and explore how these investments affect operations and market structure. To do so, we assemble a novel dataset covering multiple aspects of technological investment and operations at both affected and unaffected BDs. We track software and hardware investments using the Aberdeen

Computer Intelligence Database (Bloom, Sadun, and Van Reenan 2012; Graetz and Michaels 2018), website technology adoption data using BuiltWith (Koning, Hasan, and Chatterji 2019), and technology-related labor demand using Burning Glass Technologies (BGT) (Hershbein and Kahn 2018; Acemoglu et al. 2020). For operations data, we examine customer complaints and misconduct involving individual employees, publicly reported on the BrokerCheck website. BDs with available data are responsible for the majority of the assets and employment in the industry and include both publicly and privately held FIs.

Our findings are threefold. First, the regulation had direct and indirect effects on technology adoption at affected BDs. These BDs increase their IT budgets, add enterprise resource planning (ERP) and data management software that directly aids compliance with the amendment, and add servers and computers. They also increase job postings for computer and information systems managers. We then show regulation indirectly affects technology adoption by requiring new data investments that can be leveraged for noncompliance purposes (e.g., enables adoption of communications and customer relationship management [CRM] tools that require high quality data). Second, as a result of these technological investments, affected BDs see fewer customer complaints and less employee misconduct. Third, labor market concentration increases.

The regulatory changes we study followed the discovery of large Ponzi schemes in the late 2000s, when the SEC sought to improve safeguards for BD custody of customer securities and funds. Accordingly, the 2014 amendments to Securities Exchange Act Rule 17a-5 (henceforth Rule 17a-5 or "the amendment") require certain BDs to report on their internal controls over compliance with rules concerning capitalization and separation of customer and firm assets (Kowaleski et al. 2018). Specifically, BDs must maintain controls for and documentation demonstrating *moment-to-moment* compliance with requirements to hold adequate net capital and segregate customer assets. While the amendment mandates internal

control attestation only for carrying BDs—those that maintain custody of customer assets—all BDs must publicly disclose financial statements, employee records, and complaint details, providing a control group for our analyses.

Before the amendment, many carrying BDs used "systems and technology that have been built in-house many years ago… and as a result, have found it difficult to provide report logic details and report parameters to their auditors for testing" (Deloitte 2015). After the amendment, carrying BDs began to "invest in shoring up technology or data architecture to alleviate data-related concerns, including rationalizing data sources and centralizing data into a single data source… [thus establishing] increased accuracy and completeness of source data" (EY 2019).

Our first analyses explore the direct channel of technology adoption by describing the nature and extent of compliance-driven investments in the eight years around the amendment. We compare investments across carrying and noncarrying BDs, while controlling for BD and location-by-year fixed effects as well as employees' tenure, registration status, complaint history, and cubic controls for BD size. These controls account for time-invariant BD features, local economic conditions, and the BD's scale, expertise, product offerings, and service quality.

We find that, after the amendment, carrying BDs increased their IT budgets by 40%. They employed 28% more ERP programs, 17% more data management programs, 39% more servers, and 21% more computers. We also find significant extensive margin expansion: carrying BDs were 13% (8%) more likely to add an ERP (data management) program for the first time. These extensive margin results are notable in their own right, as "implementing an ERP system is a major undertaking," consuming significant time and resources (CFO Magazine 2022). Carrying BDs also increased job postings for computer and information systems managers by over 14%.

We find parallel investment trends across affected and unaffected BDs beforehand. Additionally, we conduct a variety of matching and subsample analyses to confirm that our findings are not driven by differences in BD size, product offerings, or changes in regulation unrelated to the amendment.

Our second set of tests investigates the indirect channel of technology adoption by studying complementary investment. This analysis is motivated by the idea that data and information systems are nonrivalrous goods: multiple corporate functions can simultaneously use them without detracting from their compliance role (Jones and Tonetti 2020). Because of this nonrivalrous property, RegTech investments can increase the return on complementary assets (Teece 1986; Brynjolfsson and Hitt 2000; Hughes and Morton 2006). To illustrate, by enhancing the monitoring environment, communication and document management tools can help BDs improve customer service and reduce misconduct. However, adopting these tools requires having adequate information quality and availability. From this perspective, RegTech investments can render the necessary expenditures on these input factors sunk.

Consistent with this hypothesis, we find that carrying BDs increased the number of communication and document management programs by 13% following the amendment. In fact, we find that vendors commonly bundled these software programs with the RegTech offerings studied in our first tests. In placebo tests, we find no increase for other software programs less pertinent to the amendment, indicating our findings do not follow from confounding events driving technological investment of all types at carrying BDs. We also observe nearly 30% increases in CRM and premium website technologies commonly linked to internal analytics tools and data infrastructure.[1]

[1] As examples, ThreatMetrix provides real-time fraud detection and transaction security, Pardot automates marketing and sales engagement, and goMoxie allows live chat between the customer and BD.

To understand the operational effects of these technological investments, our third set of tests examines customer complaints and employee misconduct after the amendment. Common incidents relate to unsuitable investment recommendations, excessive trading, and commissions—grievances unrelated to the amendment itself but conceivably prevented by monitoring via the BD's internal information processes. At carrying BDs, the complaint (misconduct incident) likelihood declined by four (three) percentage points, and the number of complaints (misconduct incidents) fell by 9% (9%). These effects are meaningful, compared to regulatory and individual factors studied in the literature (Charoenwong, Kwan, and Umar 2019; Egan, Matvos, and Seru 2019; Kowaleski, Sutherland, and Vetter 2020), and we find no evidence that they are driven by business model differences or other regulation.[2]

Instrumental variable tests point to the complaint declines happening through the technological investments studied in our earlier analyses. In separate tests examining the onset of COVID-19 as a natural experiment, we further establish a role for technology in improving customer service. Intuitively, COVID-19 forced most BD employees to work remotely, and BDs with superior technology beforehand were better positioned to respond to customer concerns amid the significant market turmoil and better able to monitor employees in this new work environment. Comparing BDs in the same location-quarter, we find those with superior technology before the pandemic experienced fewer complaints during the pandemic.

Despite potentially benefitting from complaint declines, the damages BDs avoided are quite modest—in the low six figures—compared to the standard ERP implementation costs which can run into the millions (Momoh 2015). Additionally, before the amendment, carrying BDs faced customer pressure to strengthen controls in response to the late 2000s BD Ponzi schemes and bankruptcies. Then the additional investment we document could be viewed as

[2] More generally, we note that back office differences in carrying and noncarrying BDs have little to do with the customer complaints we study. Complaints involving individual advisers overwhelmingly relate to investment advice, and not to their firm's custody or capitalization status.

NPV-negative and beyond what BDs would have independently chosen, absent the amendment.[3] Reinforcing this, many late adopters adding technology only after the amendment had no complaint or misconduct history and were small—for them, compliance costs would have been onerous, with uncertain benefit to customers. Onerous compliance costs also raise questions about the market structure consequences of RegTech, which we explore in our final tests.

RegTech can affect market concentration through the relative burden of compliance costs and the differential benefits of additional data. SEC comment letters discuss how the amendment's compliance costs have a sizable fixed component and how larger BDs can more easily bear them (SEC 2013). In terms of benefits, large FIs make greater use of hard information in their operations (Stein 2002). Additionally, with cross-selling and statistical modelling, gains from additional customer information can increase with firm size. As one industry report explains: "Greater scale enables firms to increase these relatively fixed [technological] investments, and returns on those investments can increase significantly when they support a larger number of advisors and assets under management" (Martin 2021).

Consistent with this claim, we find that employees are 4% more likely to move from unaffected to affected BDs following the amendment. Accordingly, labor market concentration increases. While the welfare effects of concentration are complex (Carlton 2007; Covarrubias, Gutierrez, and Philippon 2020), our evidence illustrates how the consequences of regulation that compels technology-driven compliance can interact with firm size.

We make three contributions. By offering the first empirical analysis of RegTech, we add to the growing literature on technology adoption at FIs (D'Acunto, Prabhala, and Rossi 2019; Crouzet, Gupta, and Mezzanotti 2021; Liberti, Sturgess, and Sutherland 2021) as well as

[3] See also Labro and Stice-Lawrence (2020), who find evidence that regulation-compelled accounting system updates impose significant costs on U.S. hospitals.

the broader FinTech literature (Buchak et al. 2018; Fuster et al. 2019; Begenau, Farboodi, and Veldkamp 2018). FIs increasingly rely on technology to demonstrate compliance with reporting, capital, consumer protection, and risk management regulations (Deloitte 2021). We illustrate how regulation can both directly and indirectly affect technology adoption at FIs. The direct effect manifests as significant improvements in data collection, data management, and information systems made for compliance purposes at affected firms. The indirect effect stems from these improvements rendering sunk the data infrastructure and information quality required to adopt complementary software and CRM tools in noncompliance functions.

Second, we add to the literature on complaints and misconduct at BDs (Dimmock and Gerken 2012; Charoenwong et al. 2019; Egan et al. 2019, 2021; Kowaleski et al. 2020). Complaints are relevant to trust and participation in the financial system (Guiso, Sapienza, and Zingales 2008; Giannetti and Wang 2016; Gurun, Stoffman, and Yonker 2018), have resulted in billions of dollars of settlements over the past decade, and are a major focus of BDs' risk management. One challenge in monitoring complaints is that the advisory business is relationship based (Dimmock, Gerken, and Van Alfen 2021; Gurun, Stoffman and Yonker 2021), and individual employees have discretion in how they advise clients. We document a role for technology in improving financial service quality by facilitating employee monitoring. (See also Bachas et al. 2018; Higgins 2021; Heese and Pacelli 2022.)

Finally, we add to research exploring direct and indirect benefits from improving internal controls in response to regulation (e.g., Feng, Li, and McVay 2009; Ellul and Yeramilli 2013; Baxter et al. 2013; Feng, Li, McVay, and Skaife 2015; Gallemore and Labro 2015; Miller, Sheneman, and Williams 2021; Schoenfeld 2022). One implication of our findings is that technological advances creating new opportunities for data collection and monitoring will strengthen the linkages across compliance and noncompliance functions that depend upon customer and employee data.

2. Broker-Dealers and the Rule 17a-5 Amendments

2.1 U.S. Broker-Dealers

BDs trade securities for themselves and their customers. Their customers include individual households and institutions that invest in debt, equities, mortgage-backed securities, mutual funds, options, variable life insurance, and other securities. According to FINRA's latest industry snapshot (FINRA 2021), as of 2020, there were nearly 620,000 registered employees, with 182 (11) at the average (median) BD. There are 3,435 registered BDs with over 150,000 branches, generating over $360 billion in revenue and $77 billion in income.

A key characteristic distinguishing BDs is whether they maintain custody of (or "carry") customer assets. Carrying BDs face tighter regulation because their direct control over customer assets creates opportunities for misappropriation and loss. To avoid this regulation, a noncarrying BD (or an "introducing" BD) must promptly transmit any customer assets it receives to another BD. Carrying BDs typically maintain a back office custodial function that manages compliance and has its own employees separate from the customer-facing financial representatives and investment advisers involved in the complaints we study.[4] Figure 1 provides an illustration. Economies of scale and having compliance expertise are amenable to being a carrying BD: carrying BDs tend to be large, and switching between carrying and noncarrying status is exceedingly rare. Roughly five percent of BDs are carrying BDs.

Carrying and noncarrying BDs offer similar fee schedules to customers, typically based on the customer's portfolio size and trading frequency. Most customers are likely unaware of the distinction—it is difficult to find references to the BD's carrying status on their website or advertisements, for example. Instead, the websites typically promote the quality of advice provided, relationship building, and information about products and locations.

2.2 Rule 17a-5 amendments and technology adoption

[4] Maintaining custody and clearing trades allows a BD to keep more of the fees charged to their customer rather than outsourcing custodial requirements and sharing fees with another BD.

BD reporting is regulated under Rule 17a-5 of the 1934 Securities Exchange Act. Each year, BDs must furnish audited reports containing financial statements and accompanying regulatory schedules and reports. The SEC amended Rule 17a-5 in 2014 to increase focus on the regulatory schedules and reports. Specifically, the amendments newly require managers at carrying BDs to state that they have established and maintained internal controls that provide reasonable assurance that noncompliance with the Financial Responsibility Rules will be prevented or detected on a timely basis.[5] These Financial Responsibility Rules seek to manage the risk of customer losses from unexpected BD failures in three main ways. First, BDs must maintain a minimum level of safe and liquid assets to cover firm obligations.[6] Second, BDs must segregate customer from firm assets. Third, BDs must perform a periodic security count to affirm company records and send account statements to customers. Notably, the amendments require BDs to state that these controls are effective on a moment-to-moment basis throughout the reporting period and not just at the end.

BDs made significant investments to comply with the amendment (EY 2019). A prominent RegTech vendor noted that BDs have faced "robust review and scrutiny from both auditors and regulators following the amendment. As a result, investing in new technologies such as SaaS adoption, emphasizing strong controls around data quality as well as the soundness of the calculations has become the centerpiece of a thoughtful reporting solution" (Palaparthi and Sarda 2020).

2.3 Complaint and misconduct monitoring via technology

[5] See Kowaleski et al. (2018) and Kowaleski (2020) for a description of the BD audit environment, and a more comprehensive discussion on how the regulatory changes affect the audit.
[6] This requires BDs to document the investment haircuts and operational charges that reduce net assets when computing Net Capital, the aggregate indebtedness that raises the minimum required Net Capital, and the reliability of systems that produce the information.

BDs and their financial representatives and advisers (collectively "employees") must register with the Financial Industry Regulatory Authority (FINRA), a self-regulatory enforcement agency tasked with protecting investors. FINRA develops and enforces rules, conducts firm exams, oversees firm and employee licensing, and maintains a website, "BrokerCheck," with profiles for every registered employee. The website includes each employee's licenses, registration status, employer (current and past), and detailed records of customer complaints, civil proceedings, and regulatory sanctions. Complaints can be reported by customers, regulators, or the firm. The most common incidents involve unsuitable investment recommendations (21% of incidents), misrepresentation (18%), unauthorized activity (15%), omission of key facts (12%), commission-related issues (9%), and investment fraud (8%); these categories are not mutually exclusive (Egan et al. 2019). This means the complaints we study predominately can be traced to employee-customer interactions and not firm issues of custody, capitalization, and regulatory reporting affected by the amendments.[7]

Complaints alienate customers, can result in financial damages, and attract bad publicity. Serious violations (e.g., employee misconduct) can result in license revocation for individuals and firms. Therefore we expect BDs to evaluate and implement technologies that monitor employees' interactions with customers and identify problematic behavior. We note several applications of technology to employee-customer interactions oversight:

1. A leading software vendor described how its technology helps BDs "identify bad actors quickly and accurately, preventing massive fines and company-debilitating crises."[8]

2. A law firm specializing in cases involving BD misconduct stated: "In the vast majority of credible broker misconduct cases that we see, there is a direct line between the misconduct perpetrated by a broker and the failure to supervise on behalf of the brokerage firm." The firm further describes how some BDs rely on technology "to supervise their

[7] To confirm this, we reviewed LexisNexis for litigation against BD auditors. We found only two cases over the past 43 years involving the type of complaints we study.
[8] See https://www.behavox.com/products/compliance/asset-management

brokers' investments in order to ensure they are properly aligned with their clients' profiles, risk tolerances, and objectives."[9]

3. A FINRA white paper (FINRA 2018) reported the following:

   a. "Some [software] tools that seek to employ a more predictive risk-based surveillance model also focus on linking data streams previously viewed largely in isolation. For instance, the relationship between certain structured data (such as trade orders and cancels, market data, and customer portfolio) and unstructured data (such as emails, voice recordings, social media profiles and others communications) have historically been difficult to link together. However, [software] tools are being developed that would help to integrate these disparate data forms and then identify and track related anomalies that merit attention" (p. 4). To illustrate, Figure 2 provides a screenshot from a tool that allows BDs to track both investment activity and employee-customer communications.

   b. "In addition, some [software] tools monitor investor portfolios in changing market conditions and produce recommendations to better align the portfolio with the investor's risk profile" (p. 6).

   c. "The use of certain [software] tools could also assist in reducing the number of false alerts, thereby freeing up staff time to focus on alerts that warrant escalation. For example, during our research, one firm noted that false alerts of its employee surveillance system were reduced by 80% after the adoption of a [software] tool and that the escalation rate of its alerts went up significantly" (p. 7).

4. A Bloomberg article on BD compliance issues related to customer interactions explains:

   > "The dark ages of supervision are over. Contemporary compliance platforms are designed to provide transparency into the multifaced nature of modern collaboration applications and seamlessly analyze video and audio data in addition to traditional text content. As firms deploy collaboration tools like Zoom, Microsoft Teams, and Webex, supporting compliance technologies purpose built to manage the risks of these new interactive video, audio, and text features is critical."[10]

5. More broadly, survey evidence summarized in Figure 3 highlights that firms use RegTech output in operations and that RegTech adoption relies on both investment budgets and employee skillsets.

[9] See https://broker-misconduct.com/investor-fraud-failure-to-supervise

[10] See https://news.bloomberglaw.com/us-law-week/insight-compliance-officers-must-ensure-collaboration-platforms-meet-finra-sec-rules?context=search&index=3

While these applications emphasize how technology helps BDs monitor employees, technology also helps customers track their investments and identify problems with the services BDs provide them. As both firm and customer monitoring can reduce complaints and misconduct, our analyses do not determine the type of monitoring most affected by technology. For both, better monitoring reduces employees' incentives to misbehave because the detection likelihood is greater (Becker 1968). Additionally, more detailed and timely information about employee-customer interactions provides supervisors and customers with an early warning.

2.4 Timing

Acquiring and implementing the technology to comply with the amendment and achieve complaint reductions, however, takes time. Industry publications and consulting guides suggest a typical ERP adoption spans approximately a year, and delays are common (McKinsey 2012; CFO Magazine 2019). During implementation, the systems are not fully functional. Accordingly, because the amendment passed in 2013 and took effect for carrying BDs with fiscal years ending on or after June 1, 2014 (most BDs have December 31 fiscal year ends), we expect investments to begin in 2013 or 2014 and any complaint decline to appear a year later.

3. Empirical Methodology

3.1. Data and measures

We construct our sample from the intersection of several datasets. Firm-level registration data (Form BD) come from FINRA, and BD customer complaints and employee data come from BrokerCheck. We obtain our baseline BD-year panel using the Audit Analytics Broker-Dealer module, which assembles all annual Rule 17a-5 reports filed with the SEC. Into this dataset, we merge the BrokerCheck complaint and employee data. The sample for our complaint analysis includes 4,663 unique BDs and 26,721 BD-year observations between 2010 and 2017. Our technology adoption analysis samples contain fewer observations, depending on variable coverage in Aberdeen, BGT, and BuiltWith. (See Appendix A.1 for details.)

To identify treated firms, we follow Schnader et al. (2019) and ensure that the BD reports a required minimum level of Net Capital of at least $250,000 in all sample years.[11] We then review registration data filed under Form BD to identify BDs that report clearing trades for other BDs as well as those that report introducing arrangements.[12] We use this information to distinguish between treated and control BDs, and validate our approach using public and administrative sources.

Table 1, Panel A reports summary statistics for all BDs in our sample. The mean (median) BD has $1.3 billion ($707,000) of assets and $648 million ($293,000) of net capital. Carrying BDs comprise 5.4% of our sample, and 47.4% of our observations are from the *Post* period. The mean (median) BD has 211 (11) adviser and representative employees, with an average tenure of 6.2 years. On average, 29.4% of employees are dually registered as investment advisers, and 4.5% of employees have a complaint on their record. Nearly five percent of affirmers in 2011 are Chief Compliance Officers.

The probability of a BD receiving any complaints in a year is 9.9%, while the average number of complaints is 1.45. The probability of a misconduct incident is 10.0%, and the average number of incidents is 0.87. Not all complaints are serious enough to be deemed misconduct, and not all misconduct incidents originate from a customer complaint.

3.2. Research design

Our empirical analyses use the following OLS specification:

[11] We cannot retrieve Form Custody filings through the Freedom of Information Act, due to the form being deemed confidential and protected from release pursuant to FOIA Exemption 4, 5 U.S.C. § 552(b)(4).

[12] For each BD that reports minimum required Net Capital of $250,000 in all sample years, we check the following. If a BD reports that it "Clears for other BDs," we code *Treated* as one. If not, we only code *Treated* as one when the BD reports that it does not engage in any of the following introducing arrangements: 1) refers or introduces customers to any other broker or dealer; 2) has an arrangement with any other person, firm, or organization under which any books or records of applicant are kept or maintained by such other person, firm or organization; 3) has an arrangement with any other person, firm, or organization under which accounts, funds, or securities of the applicant are held or maintained by such other person, firm, or organization; or 4) has an arrangement with any other person, firm, or organization under which accounts, funds, or securities of customers of the applicant are held or maintained by such other person, firm or organization.

$$y_{i,t} = \alpha_i + \alpha_{f(i,t),t} + \beta \times Post_t \times Treated_i + \Gamma' \times X_{i,t} + \varepsilon_{i,t}, \quad (1)$$

where i indexes BDs, t indexes years, and $f(i,t)$ is the FINRA district for BD i during year t. The sample period spans 2010 to 2017. The dependent variable measures RegTech investments, complementary investments, customer complaints, or employee misconduct as described in subsequent sections. To facilitate interpretation, we measure 100 times either an indicator variable or the inverse hyperbolic sine (similar to the log of one plus the value).

$Post$ is an indicator variable equal to one beginning in 2014. $Treated$ is an indicator variable equal to one for carrying BDs and is static within each BD. The coefficient of interest β captures the difference between carrying and noncarrying BDs after the amendment. α_i are BD firm fixed effects that account for time-invariant BD features, including the business model and customer base. $\alpha_{f(i,t),t}$ are FINRA district-by-year fixed effects that account for local economic conditions as well as time-location level enforcement variation.[13] The BD firm and FINRA district-by-year fixed effects absorb the *Treated* and *Post* main effects, respectively. Our control variables $X_{i,t}$ consist of the log total assets, the fraction of employees with a previous complaint, the lagged log average BD employee tenure, and cubic controls for lag number of employees, and the fraction of employees that are dually registered as investment advisers. We also include a separate linear time trend for investment advisers, given they offer different services than brokers (they are licensed to sell investment advice) and face additional regulation (Charoenwong et al. 2019). We winsorize all continuous dependent and independent variables at the 1% level, and cluster standard errors by BD.

4. Empirical Results

4.1 Technology adoption

4.1.1 RegTech

[13] There are 11 FINRA districts, named for the location of their primary office: San Francisco, Los Angeles, Denver, Kansas City, New Orleans, Dallas, Atlanta/Boca Raton, Chicago, Philadelphia/Woodbridge, Long Island/New York, and Boston.

We study BDs' RegTech investments in software, hardware, and personnel. We access Aberdeen's Computer Intelligence Database ("CiTDB"), which has been used to study digitization and technology adoption (Bloom et al. 2012, 2014; Graetz and Michaels 2018; He et al. 2021; Tuzel and Zhang 2021; Heese and Pacelli 2022). Aberdeen collects data from several sources. Each year, they survey senior IT executives about software and hardware usage. Additionally, they conduct systematic data collection efforts, including web-scraping job postings and purchasing customer lists from vendors to identify software choices.

Our analyses use two CiTDB datasets. One reports firm-level software usage categorized by type, allowing us to study specific software investments around the amendment, as proxied by the adoption of a new software type. A second dataset tracks and estimates the total IT budget for software, hardware, and staff as well as the number of personal computers, laptops, and servers at over three million establishments. Specifically, Aberdeen combines survey responses on budgets and hardware with imputed values based on Dun & Bradstreet figures on firm age, industry, revenue, employment, and location.[14] During our sample window, we can match 5,238 BD-year observations to the software dataset and 11,352 BD-year observations to the hardware dataset.

To study personnel decisions, we gather data on BD labor demand from Burning Glass Technologies ("BGT") (Hershbein and Kahn 2018; Acemoglu et al. 2020; Bloom et al. 2021). BGT provides comprehensive coverage of job boards and company job listings since 2007. From these job postings, it extracts an employer name, location, and title, as well as any required job skills. Our matched BD-BGT sample includes 1,307 BD-year observations.

The RegTech software investments that we consider include ERP and data management tools that enable the firm to develop, maintain, and report the information required to

[14] Unfortunately, the dataset does not separate survey from estimated values. While we are not aware of reasons why estimation errors would be correlated with the amendment, we interpret our results with caution and study other datasets (CiTDB software and BGT) that do not rely on imputation.

demonstrate moment-to-moment compliance with Rule 17a-5. Specifically, ERP allows for automation and better audit trails. Firms with ERP systems can quickly generate financial reports, monitor and control which employees access data, and reduce or eliminate reliance on manual work that leads to delays, errors, and fraud. ERP software also integrates a company's financials, reporting, operations, and human resource activities. For this reason, ERP is often referred to as the central nervous system of a business.

Data management software centralizes, consolidates, and helps maintain proper version histories of information pertaining to customer accounts and transactions—thus helping demonstrate compliance with customer asset segregation requirements under the amendment. Associated application development tools help link data sources, automate workflows, and create dashboards to demonstrate compliance.

We count the number of unique software programs in a given category (ERP or data management). In addition, we study labor demand relevant to RegTech. We measure the number of BD job postings referencing "compliance" or involving computer and information systems managers (Standard Occupational Classification code 11-3021).

Summary statistics for these variables are reported in Table 1, Panel B. For context, note that the median BD with nonmissing data in the software (IT budget and hardware) sample has 125 (30) employees. On average, BDs have 1.1 types of ERP program and 3.3 types of data management program. The median BD has four servers, 31 personal computers and laptops, and an IT budget of approximately $330,000. On average, each year there are 42 job postings mentioning compliance (ERP) skill requirements and 0.4 postings for computer and information systems managers.

Table 2 models RegTech software investments using equation (1). In column 1 (2) of Panel A, we find a 28% (17%) greater increase in software related to ERP (data management)

for carrying than noncarrying BDs. Column 3 studies the number of both types of software programs, and finds a 24% increase.

To understand how many BDs adopt this software for the first time (i.e., the extensive margin), Panel B studies an indicator for having these software types. We find 13% (8%) greater extensive margin adoption of ERP (data management) software for carrying BDs. Column 3 shows 7% greater adoption for carrying BDs when we consider whether the BD has either software type.

Table 3 studies RegTech hardware and labor demand. Panel A, Column 1 shows a 39% increase in the number of servers, and column 2 shows a 21% increase in personal computers and laptops. Column 3 studies IT budgets and finds a 40% increase. As for labor demand, in Panel B, we find that carrying BDs increase job postings with compliance skill requirements by 35% more (column 1) and postings for computer and information systems managers by 15% more (column 2) than noncarrying BDs. Thus our evidence corroborates claims from RegTech vendors, regulators, auditors, and BDs that the amendments compelled significant technological investments and hiring.[15]

Next we assess the robustness of our technology adoption findings. For parsimony, we focus on the number of ERP and data management software tools (i.e., the dependent variable in column 3 of Table 2, Panel A), but this choice is not important to our inferences.

First, to more closely link the amendment to investment increases, Figure 4, Panel A models software investments in event time. The gray area marks the amendment's implementation period. The plotted coefficients are the difference between carrying and noncarrying BD investments yearly. We find a significant investment increase after the amendment, and parallel trends across treatment and control BDs before. This suggests that

[15] For example, survey evidence presented in Figure 3 illustrates that many FIs have had to "widen the skillset" within the risk and compliance functions to accommodate developments in FinTech and RegTech.

pre-trends or developments unrelated to the amendment do not explain the differential software adoption we document.

Second, carrying and noncarrying BDs may differ, for example, in their size or product offerings, and therefore their investments may have evolved differently, even absent the amendment. Thus, although we include a range of business model controls in equation (1), the functional form may not fully account for the differences. Therefore we develop a coarsened exact matched sample based on all control variables plus the number of product offerings, splitting continuous variables into 100 subclasses. Figure A.1 illustrates the raw and adjusted differences between treatment and control samples; the largest raw differences relate to assets and headcount, but the adjusted differences are small. Table 4 shows that we find similar results, regardless of whether we retain all matches and only focus on within-subclass variation (column 1) or drop those with high treatment-control imbalances, defined as those with more than 100 control BDs for each treated BD (column 2).

Third, in light of the numerous regulatory developments banks faced over the past decade (e.g., Dodd-Frank), column 3 drops bank affiliates without diminishing the effect. Our results also remain if we begin our sample in 2012 (Dodd Frank passed in 2011); if we drop BDs whose majority of employees are dually registered (Dodd-Frank had provisions affected registered investment advisers); and if we exclude BDs reporting they are conflicted on Form ADV, due to having multiple business lines.

Finally, although we include cubic size controls, we further evaluate the possibility that size differences between carrying and noncarrying BDs could explain our results. Column 4 includes size-specific trends by interacting an indicator variable for BDs with above-median headcount with our *Post* variable. Not only do our results remain but also this interaction term is statistically and economically insignificant, suggesting that our results cannot be explained by larger BDs more aggressively adding software during our sample period.

4.1.2 Complementary investments

We study two types of complementary technology adoption: software and website technologies. For software, we examine Aberdeen's "communication and document management" field. Useful for our purposes of tracking complaint- and misconduct-relevant technologies, these tools support behavioral detection models for employee conduct. Damages and sanctions resulting from customer complaints are increasingly issued based on email or other communications initiated by employees (e.g., phone, video, social media).[16] To avoid costly customer complaints, BDs can adopt communication programs that digitize records of employee communications, and document management tools that allow AI-based analysis of unstructured data. Not only do these tools improve the information environment, but they also interface with and benefit from the more foundational software examined in our RegTech tests. ERP systems allow supervisors to access and monitor employee communications, and data management programs provide security and version control for digitized information.

For website technologies, we access data from BuiltWith, a competitive intelligence firm that tracks technology adoption patterns (Koning et al. 2019). BuiltWith regularly scrapes a substantial fraction of the internet, and, each time it visits a webpage, it logs the presence of a technology or tool. For example, BuiltWith may track whether a website uses a cookie to track visitors, has a chat function or transaction fraud prevention tool, or has integrated social media, such as Twitter or Facebook.

FIs commonly employ CRM website technologies to track user patterns and collect information about customers. These website technologies are often linked to internal software programs like SalesForce or Hubspot that help track communications, and other tools that perform risk and profitability analysis. CRM tools are also a key part of online portals, which

[16] See https://www.smarsh.com/blog/must-know-finra-trends-the-impact-on-compliance/

are used by advisers to communicate with customers (see Figure 2 for an example). In turn, the portals can help customers identify issues with, for example, securities they own, advice they have received, or commissions they are charged. Accordingly, we count the number of CRM website technologies for each BD. We also count the number of premium (i.e., paid for) website technologies. Premium website technologies commonly have a marketing focus but can require richer databases and better cybersecurity, webpage development, and overall infrastructure. Collectively, these software tools and website technologies facilitate employee monitoring by both BDs and customers.

Table 5, Panel A reports summary statistics for these variables. On average, BDs have 1.5 types of communication and document management software, 1.6 CRM website technologies, and 1.3 premium website technologies.

Table 5, Panel B studies complementary investments using equation (1). Column 1 finds that finds that, following the amendment, carrying BDs expand their communication and document management tools by 13%. Similarly, column 2 finds a 27% increase in the number of CRM website technologies, and column 3 finds a 29% increase in premium website technologies.

Panel C conducts placebo tests to evaluate the possibility that we are merely capturing an investment expansion unrelated to the amendment. Specifically, we study investments in anti-virus and other technologies (i.e., we exclude the ERP and data management tools we studied previously). Columns 1 and 2 find no difference in carrying and noncarrying BD investments for these software types.

Further supporting a complementary investment interpretation, we find that individual software providers commonly bundle various tools with the RegTech software studied in Table 2: for BDs with both RegTech and complementary software, over two-thirds of the time, the software is from the same vendor. Table 6 empirically links the RegTech and complementary

investments. Column 1 (2) shows BDs making data management or ERP investments are 5% (7%) more likely to have an above-average number of CRM (premium website) technologies.

4.2. Customer complaints and employee misconduct

To understand the effects of technology adoption on operations, we study complaints and employee misconduct using equation (1). Our measures are 100 times (a) an indicator variable for whether the BD's employees receive a customer complaint or have a misconduct incident recorded that year, and (b) the inverse hyperbolic sine of the number of complaints or misconduct incidents. For complaints, following Charoenwong et al. (2019), we consider all types regardless of ultimate resolution, as a measure for financial service quality. For misconduct, we follow Egan et al. (2019) and identify resolved incidents. Misconduct incidents need not be reported by customers; regulators, firms, and others can also initiate.

Column 1 in Panel A of Table 7 shows that after the amendment, carrying BDs have a four percentage point lower probability of having a registered complaint, compared to noncarrying BDs. Economically, this decline represents 14% of a standard deviation in the probability of receiving complaints. Column 2 studies the number of complaints and finds a 9% decline. The next two columns study employee misconduct. Column 3 shows a three percentage point decline in the probability of a misconduct incident, and column 4 shows a 9% decline in the number of incidents. Thus, technology not only improves customer service (as proxied by a decline in customer complaints), but also reduces costly misconduct. Reinforcing this, column 5 shows a significant decline in complaints seeking $5,000 or more in damages.

Figure 4, Panel B presents event time plots based on column 1. Complaints evolve similarly for the two types of BDs in the pre-amendment period and drop for carrying BDs starting in 2014. Recall from Figure 4, Panel A that carrying BDs' RegTech investments begin in 2013 and, from Section 2.4, that these types of investments take many months. Thus a

sustained complaint decline beginning in 2014 is consistent with the amendment causing major technological investments that ultimately aid complaint monitoring.

We then trace the complaint decline to technological investments using an instrumental variables analysis. Specifically, we construct an index, *Tech Index*, that encompasses the technological investments examined in our prior tests. First, we take the inverse hyperbolic sine of each of the number of servers, ERP software types, and CRM website technologies. Second, we take the Z-score of each of these three measures. Third, we average the Z-scores across the available measures for each BD. For example, a BD with a Z-score of 1 for the transformed server variable and 0.5 for the transformed CRM website technology variable but no available software data will have an index value of (1+0.5)/2 = 0.75.

The benefit of our approach is that it is holistic: it considers multiple aspects of BDs' technological expenditure response, while allowing us to develop a sufficient sample for an instrumental variables analysis. (Our Aberdeen and BuiltWith samples do not fully overlap, and as the example above illustrates, our approach allows us to include BDs with partial coverage.) Nevertheless, we find similar results under a range of alternative approaches, including studying servers, CRM technologies, or the IT budget alone.

Panel B presents the results. In the first stage, we find a significantly positive relation between *Treated* × *Post* and *Tech Index*, and the first-stage clustered F-statistic is 50.9. Column 2 then finds that BDs making larger technology investments are significantly less likely to have complaints.

4.2.1 Additional evidence on complaints and technological investment

To bolster our instrumental variables analysis, we conduct several additional tests to link technology adoption to complaints. First, we use the onset of COVID-19 as a natural experiment that disrupted BDs' interactions with customers. The assumptions underlying this analysis are twofold. First, COVID-19 forced most BD employees to work remotely,

effectively shifting customer communications from the office (where they can be more easily monitored) to employees' homes. Second, as Section 2.3 illustrates, technology aids complaint oversight. As one RegTech blog explains, "Under the new working conditions forced by the COVID-19 pandemic, collaboration tools have become increasingly important."[17]

We use the following OLS specification to study complaints:

$$y_{i,t} = \alpha_i + \alpha_{f(i,t),t} + \beta \times Tech\ Index_{i,2017} \times COVID_t + \Gamma' \times X_{i,t} + \varepsilon_{i,t}, \quad (2)$$

where i indexes BDs, t indexes quarters, and $f(i,t)$ is the FINRA district for BD i during quarter t. The dependent variable is 100 times an indicator for whether the BD has a registered customer complaint that quarter. $COVID$ is an indicator variable equal to one starting in Q2 2020. *Tech Index*$_{2017}$, defined above, is measured in 2017 to capture the BD's technological capabilities before the event window. α_i are BD fixed effects and $\alpha_{f(i,t),t}$ are FINRA district-by-year fixed effects. We include cubic controls for the number of employees. The sample period runs from Q3 2018 to Q3 2021 and omits Q1 2020 (during which the World Health Organization declared a global pandemic). We cluster standard errors by BD.

Table 8 presents the results. Column 1 shows that, in the post-COVID-19 period, BDs with better technology are significantly less likely to experience a complaint. Column 2 studies variation in the extent of work from home using the log number of COVID-19 cases in each county. We find technological investments reduce complaints more in counties with more cases. For context, the standard deviation of log cases is 5.1, so a one standard deviation increase in cases corresponds to a 0.83% (5.1 x 0.162) increase in the probability of a complaint. By comparison, a one standard deviation increase in *Tech Index* is 0.9, so a one standard deviation increase in the index corresponds to a nearly one-half reduction of this effect (-0.080 x 0.9/.162= -44%).

[17] See https://a-teaminsight.com/shield-integrates-with-zoom-to-ensure-communications-compliance/?brand=rti

Second, we use Form BD filings accessed in 2015 to identify BD product offerings. We classify BDs as retail-focused if they offer investment advice, mutual funds, variable life insurance, or debt products. Retail investors are less sophisticated than institutional investors and are more prone to file complaints. For example, retail investors rely on BDs for advice, and their lack of sophistication leads to disagreements about suitability and misrepresentation. Our assumption is that the scope for reducing complaints via technological monitoring is greater for retail investors. Table 9, column 1 shows the complaint decline is statistically greater for retail-focused BDs.

Third, for BDs whose business model already requires superior controls and strict oversight, the amendment should have less effect on complaints. To proxy for this, we measure whether the BD had a Chief Compliance Officer (CCO) that affirmed the financial statements in 2011, before the amendment was even proposed. BDs not operating in 2011 are excluded. Table 9, column 2 shows the complaint decline is concentrated among BDs without a CCO in 2011. Those with a CCO in 2011 experienced no incremental complaint change. (*Treated* × *Post* + *Treated* × *Post* × *CCO in 2011* is indistinguishable from zero.) Overall this evidence reinforces our Table 7 results linking technological investment to complaint reductions.

4.2.2 Robustness and alternative explanations

4.2.2.1 Business model differences

Carrying and noncarrying BD business model differences could generate distinct complaint trends. Therefore we repeat our tests using our coarsened exact matched sample, as summarized in Figure A.1. Column 1 in Table A.2 shows our results are the same using the matched sample. Column 2 drops matched pairs with more than 100 control BDs for each treated BD and finds similar results. We also model size trends directly by introducing an interaction term *Size* × *Post* in column 3. We find a lower incidence of complaints at larger BDs in the post-period. However, the amendment has an effect distinct from this size trend.

A related concern is that selection into the carrying or noncarrying type explains the complaint declines we document. However, switching from one status to the other is quite rare and requires a costly transition from proprietary back-office infrastructure to that of a new custodian, with whom the BD must now share fees. Figure A.2 further suggests that BDs did not switch type to avoid the new regulation as we find the distribution of BDs' Net Capital changes little after the amendment. Additionally, our discussions with regulators and market participants and our review of industry publications finds that switching between carrying and noncarrying status is quite rare in general.

4.2.2.2 Auditor and regulator attention

Some complaints involve employee behavior that might draw scrutiny from auditors and plausibly relate to their work. To investigate this, we follow Cook et al. (2020) and identify complaints with references to "forgery," "fraud," "theft," and variants of these phrases (*Auditor-Related Complaints*). Approximately 10% of all complaints in our sample are *Auditor-Related Complaints*. Our assumption is that the amendment leads to more involved audits for affected BDs, and the nature and seriousness of complaints referencing forgery, fraud, and theft will draw extra auditor attention. Thus, under an auditor attention-based explanation, we should see starker declines in *Auditor-Related Complaints* than those involving behavior less relevant to auditors (e.g., unsuitable investment advice or misrepresentation). However, Columns 4 and 5 of Table A.2 show the opposite pattern: we find no economic or statistical change in *Auditor-Related Complaints* and a significant decline in *Non-Auditor-Related Complaints*.

Next we consider regulator attention. Although the amendment focused on internal controls over compliance, it may have been enacted as part of a larger effort to improve customer protection, tighten enforcement, and reform BD-customer interactions. Under this explanation, however, we should find a common complaint decline across carrying and

noncarrying BDs, contradicting our findings. We also note that equation (1) controls for FINRA district-by-year fixed effects, which account for time-varying unobservable enforcement differences within a region.

A more nuanced explanation involves regulator attention focusing on carrying BDs affected by the amendment. To investigate this, we study the party filing the complaint (customer, regulator, or firm). Column 6 in Table A.2 shows no change in regulator-reported complaints.

We also consider whether changes in regulation unrelated to Rule 17a-5 could explain the complaint declines we find. For example, banks had staggered deadlines for adopting different provisions of Basel III. In column 7, we drop all BDs that are affiliates or subsidiaries of banks. Our results remain. Likewise, Dodd-Frank affects only a subset of our BDs, and our main specification controls for differential trends for them. Taken together, the evidence in this section does not support auditor or regulator attention-based interpretations for our complaint results.

5. RegTech and Market Concentration

Our final analyses investigate the interaction between the amendment and the BD competitive environment, focusing on market concentration. Our motivation is threefold. First, because technological investments have a large fixed component, the amendment's burden falls more heavily on smaller BDs. The SEC's summary of and response to public comment letters on the amendment illustrate this concern, describing how "the costs could disproportionately impact smaller broker-dealers due to the fixed cost components … of compliance with these requirements" (SEC 2013).

Second, research illustrates how large FIs make greater use of hard information in their operations (Stein 2002; Berger, Minnis, and Sutherland 2017). Relatedly, RegTech can create additional hard information, both by hardening soft information and enabling measurement of

previously unrecorded activity. Third, to the extent that RegTech investment complementarities are scalable, larger BDs may disproportionately gain. For example, larger firms have more customers and therefore more data to construct profitability, risk, and fraud prediction models. As a result, their models will be more accurate and can incorporate more nuances than those of smaller rivals with less data. Similarly, in virtue of their scale and scope, larger firms will have more investment, cross-selling, and synergistic opportunities.[18]

Increasing compliance costs can lead to industry consolidation. For example, a post-Dodd-Frank survey of small banks reports that 26% are contemplating mergers as a response to the increasing regulatory burden and 95% anticipate industry consolidation (Peirce, Robinson, and Stratmann 2014). While our event window contains too few mergers to study using equation (1), we note the post-amendment period saw MassMutual acquire MetLife Premier Client Group (over 4,000 advisers and financial representatives).

Beyond consolidation, firm size can also increase through hiring. To illustrate, a recent industry report explains: "Greater scale enables firms to increase these relatively fixed investments and returns on those investments can increase significantly when they support a larger number of advisors and assets under management … in one of (our) most recent surveys, *technology was tied for the top spot among the factors most frequently cited by advisors as influencing their decision to join a BD*" (Martin 2021; emphasis added). Then, because the amendment compels technological investment at carrying BDs, it can lead to more advisers leaving noncarrying BDs for (larger) carrying BDs. Given the importance of advisers to BD size (advisers are the primary employee type, and employee-client relationships drive assets under management), such turnover has direct implications for market concentration.

We use the following OLS specification to study turnover:

[18] Routledge (2018) discusses Amazon's acquisition of Whole Foods as an example: "The data Amazon extracts from Whole Foods has more value the larger is Amazon … Big data (and related processing) has larger impacts on large companies" (p. 90).

$$y_{i,j,t} = \alpha_{i,j} + \alpha_t + \beta \times PairType_{i,j} \times Post_t + \varepsilon_{i,j,t}, \quad (3)$$

where i indexes origin BDs (where the employee leaves), j indexes destination BDs (where the employee joins), and t indexes years. Thus the unit of observation is BD firm pair-year. The dependent variable is 100 times an indicator for whether an employee left BD i for BD j during the year or the inverse hyperbolic sine of the number of switchers. $PairType$ refers to indicator variables for each combination of origin and destination BD type (leaves noncarrying, joins carrying; leaves carrying, joins noncarrying; and leaves carrying, joins carrying; the holdout pair is leaves noncarrying, joins noncarrying). $Post$ is an indicator variable equal to one beginning in 2014. $\alpha_{i,j}$ are BD firm pair fixed effects, and α_t are year fixed effects. We cluster standard errors by destination BD. Intuitively, our specification compares switching from one BD type to another across the pre- and post-amendment periods, while holding both BD firm-pair-level and year-level heterogeneity constant.

Table 10, Column 1 shows that, after the amendment, the likelihood of an employee switching from a noncarrying to a carrying BD increases. The 0.535 coefficient on *Leaves Noncarrying, Joins Carrying x Post* represents 4% of the unconditional mean switch rate. By contrast, we find no change in other switch types in the post amendment period. Column 2 studies the number of switches and again finds a significant increase in turnover from noncarrying to carrying BDs and no change in other switch types.

Figure 4, Panel C examines the *cumulative change* in the probability of switches from noncarrying to carrying BDs throughout our event window. We find little movement in the pre-amendment period, indicating pre-trends are not responsible for our Table 10 findings. Then switching ramps up in 2014 and 2015, before levelling off (i.e., the amendment appears to have induced a one-time shift from noncarrying to carrying BDs).

Finally, to combine the effects of consolidation and hiring, Table 11 studies market concentration at the MSA-year level. Following Gelman et al. (2021), we measure each BD's

market share as the ratio of the total headcount across their branches in the MSA to total headcount across all branches from all BDs in the MSA. Studying the full set of BDs within an MSA allows us to measure concentration changes within a local market where households choose BDs, regardless of carrying status. We find nontrivial concentration increases in the post-amendment period. The column 1 coefficient of 32.168 for *Post* indicates the Herfindahl-Hirschman Index increases by 4% in the post-amendment period, relative to the unconditional mean of 740. (The maximum possible value is 10,000.) Columns 2 and 3 study the aggregate market share of the largest four and eight firms, respectively. We arrive at a similar inference: shares for the largest BDs increase post amendment by between 0.9% and 1.9%. While we view this analysis as descriptive and cannot observe other dimensions of the competitive environment such as prices or profitability, our evidence at least suggests that the regulatory amendments affected labor market structure.

6. Conclusion

Using amendments to internal control requirements at U.S. BDs, we show regulation has direct and indirect effects on technology adoption. The direct effect relates to data collection, data management, and hardware investments aimed at improving controls and record-keeping. The indirect effect stems from these investments rendering sunk the information quality expenditures required to adopt complementary software and CRM tools. We then explore the operational effects of this technology adoption. We find carrying BDs subject to the amendment experience significant declines in customer complaints and employee misconduct. Our results cannot be explained by differences in size, product offerings, or changes in regulation unrelated to the amendment.

Though the BD setting has unique features, the nature of the regulation (internal control attestation) and response (technological investment) that we examine are common to other FIs. Our results point to two potential implications of the growth in RegTech investments in the

financial sector. First, technological advances will strengthen the linkages between compliance and operating functions, especially as FIs increasingly rely upon RegTech solutions for compliance and more customer information is digitized. As our results illustrate, such linkages can have important effects on FI service quality and employee misconduct. Second, when combined with large fixed compliance costs, complementarities of the type we document could increase the optimal size of FIs and lead to greater market concentration. Analyses of concentration are attracting significant attention (Philippon 2016), and our study motivates additional research on RegTech investments and market structure.

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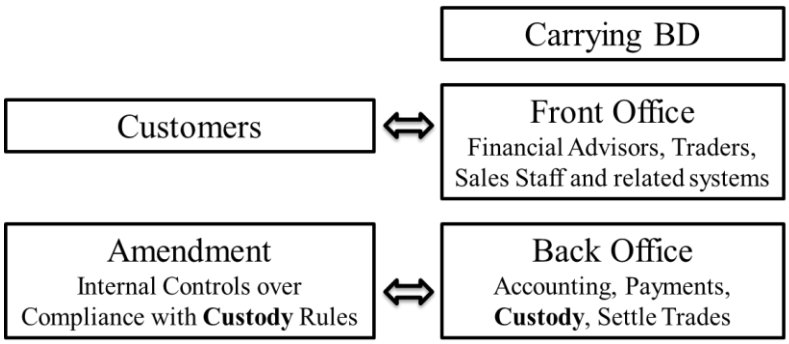
Figure 1: Organizational Structure

This figure illustrates the organizational structure of carrying (Panel A) and noncarrying (Panel B) BDs. Both panels show that customers interact with a BD's front office employees in executing transactions and obtaining financial advice. Panel A maps the amendment's direct effect to the BD's back office. Panel B shows that noncarrying BDs, who need not comply with the amendment, must promptly transmit client assets to a carrying BD subject to the amendment.

Panel A: Carrying BDs, Amendment



Panel B: Introducing Arrangement of Noncarrying BDs

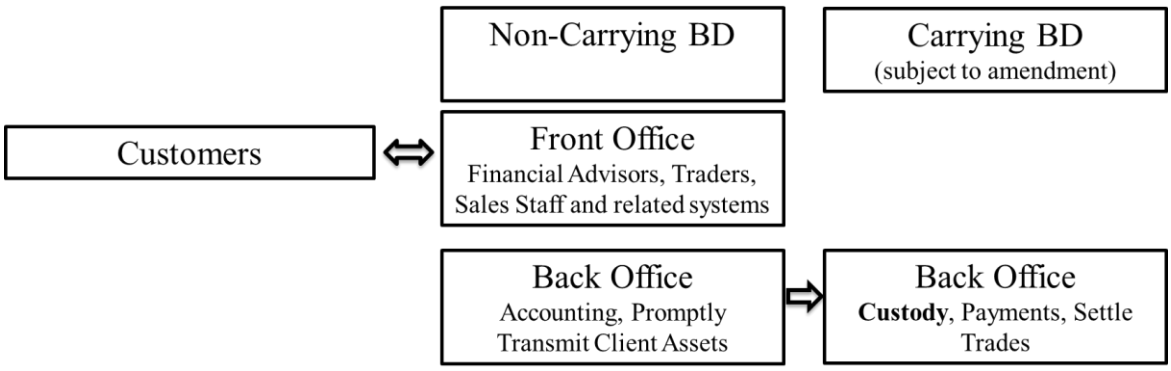


Figure 2: Example Customer Relationship Management Web Portal

This figure presents a screenshot from a CRM web portal. Emphasis added (in yellow) for items referencing account activity tracking, notes and communications, and audit trail.

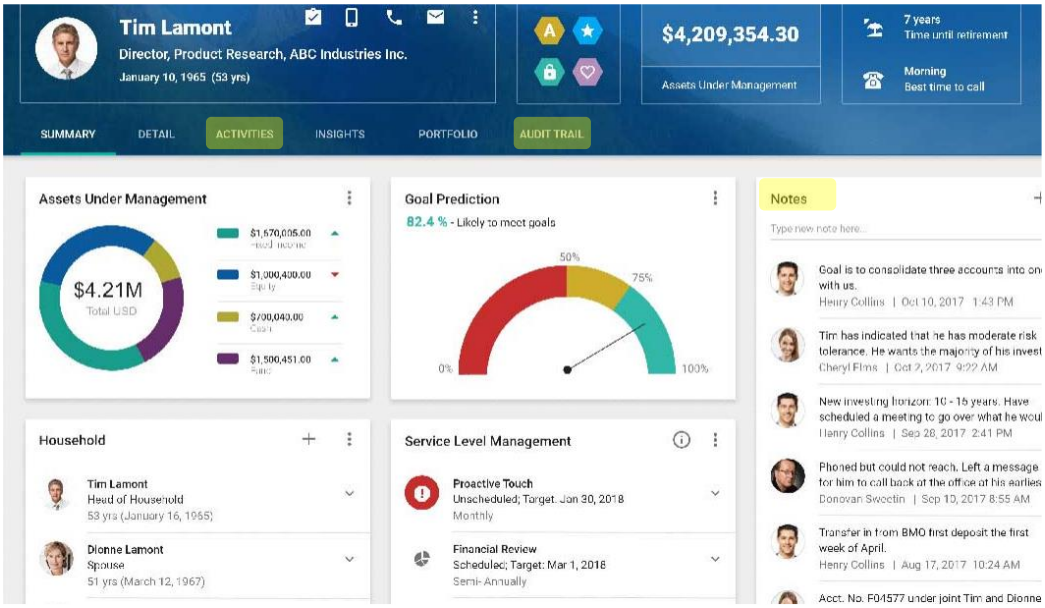
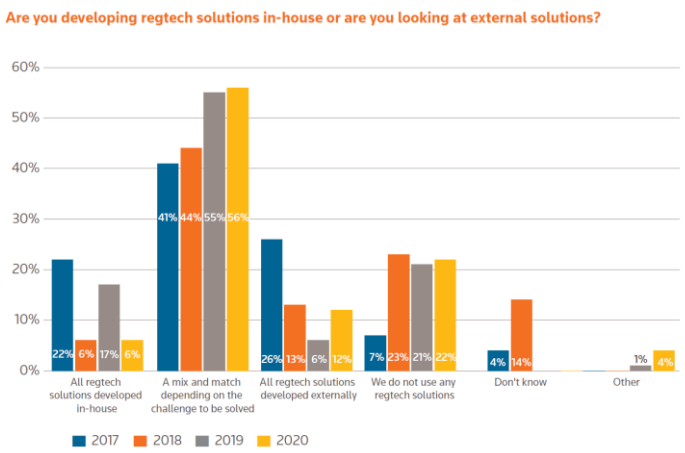
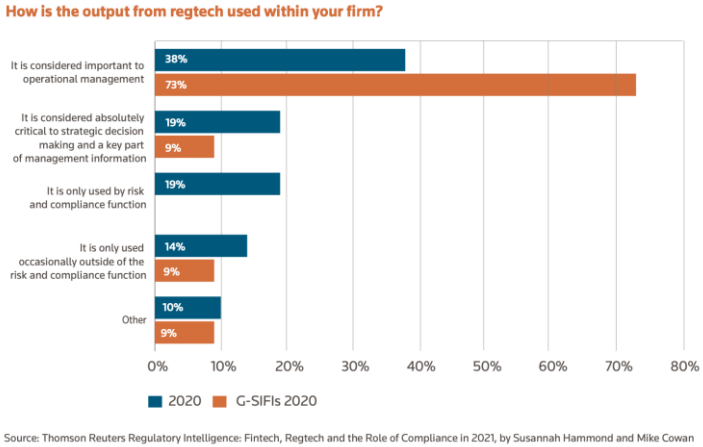


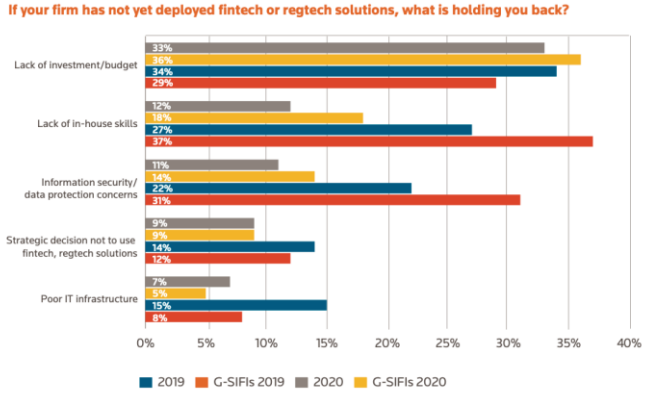
Figure 3: RegTech at U.S. Financial Institutions

This figure provides excerpts from the 2021 Thomson Reuters Regulatory Intelligence Survey (Thomson Reuters 2021). The acronym G-SIFI indicates a Global Systematically Important Financial Institution.

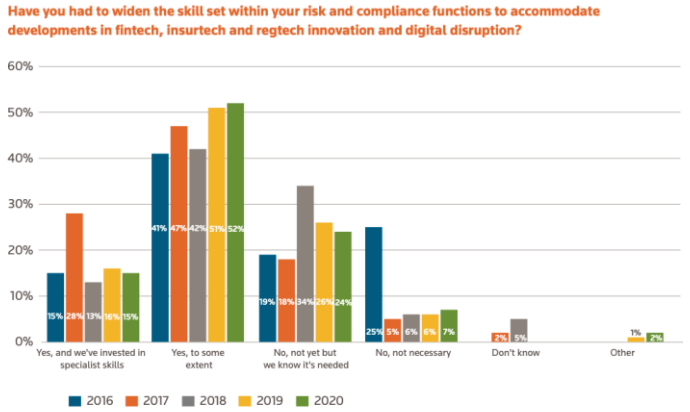




Source: Thomson Reuters Regulatory Intelligence: Fintech, Regtech and the Role of Compliance in 2021, by Susannah Hammond and Mike Cowan



Source: Thomson Reuters Regulatory Intelligence: Fintech, Regtech and the Role of Compliance in 2021, by Susannah Hammond and Mike Cowan

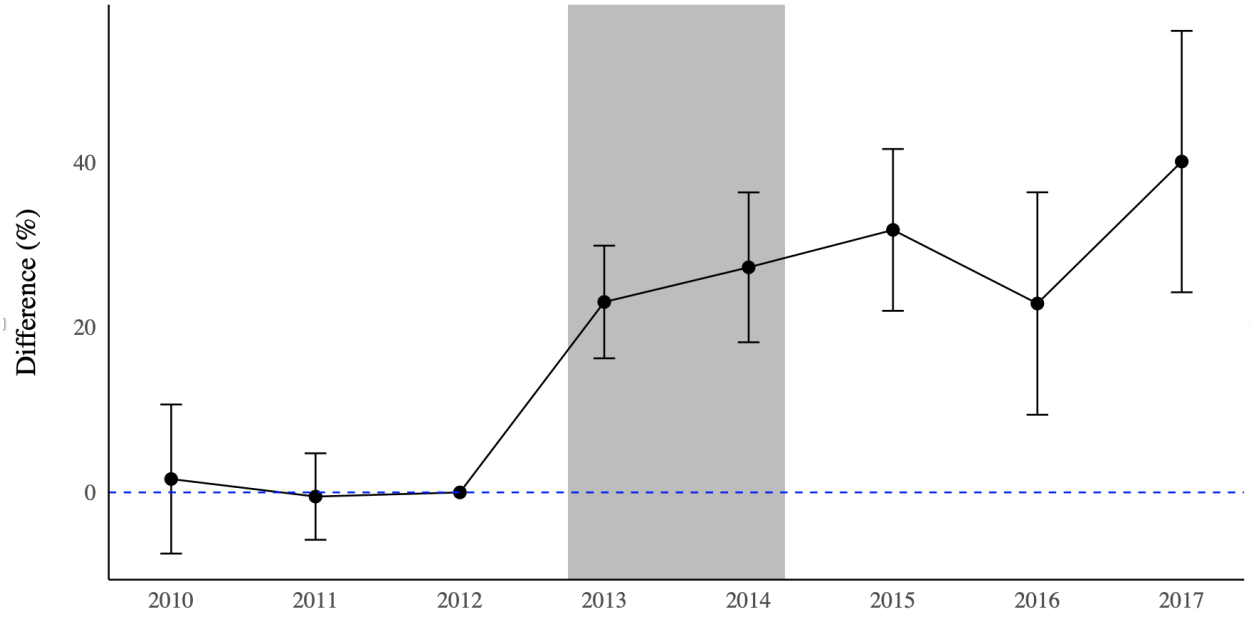


Source: Thomson Reuters Regulatory Intelligence: Fintech, Regtech and the Role of Compliance in 2021, by Susannah Hammond and Mike Cowan

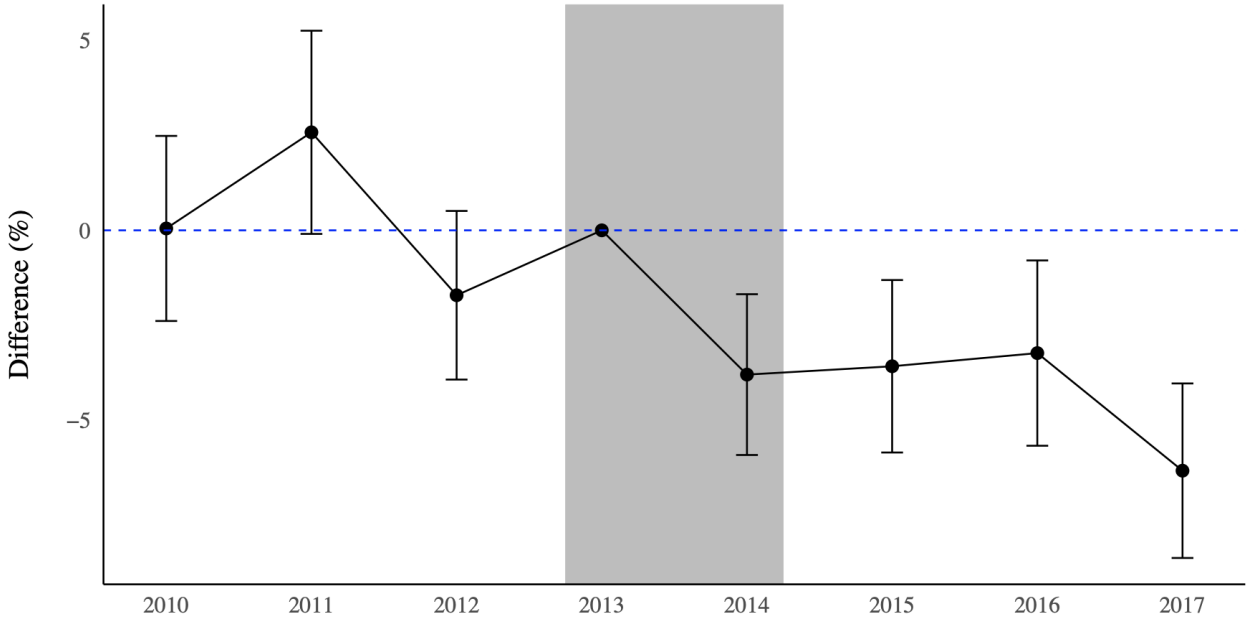
Figure 4: Event Time Plots

These figures plot coefficients from an event time version of equation (1). The gray area in each panel represents the implementation of the Rule 17a-5 amendments, which were finalized in July 2013 and effective for each BD fiscal year that ended on or after June 1, 2014. In Panel A, the dependent variable is difference between the inverse hyperbolic sine of the number of ERP and data management software programs at carrying and noncarrying BDs. In Panel B, the dependent variable is the difference between the probability of complaints at carrying and noncarrying BDs. In Panel C, the dependent variable is the cumulative change in probability of employees at noncarrying BDs switching to carrying BDs.

Panel A: RegTech Investments



Panel B: Complaint Probability



Panel C: Cumulative Change in Probability of Employee Switching

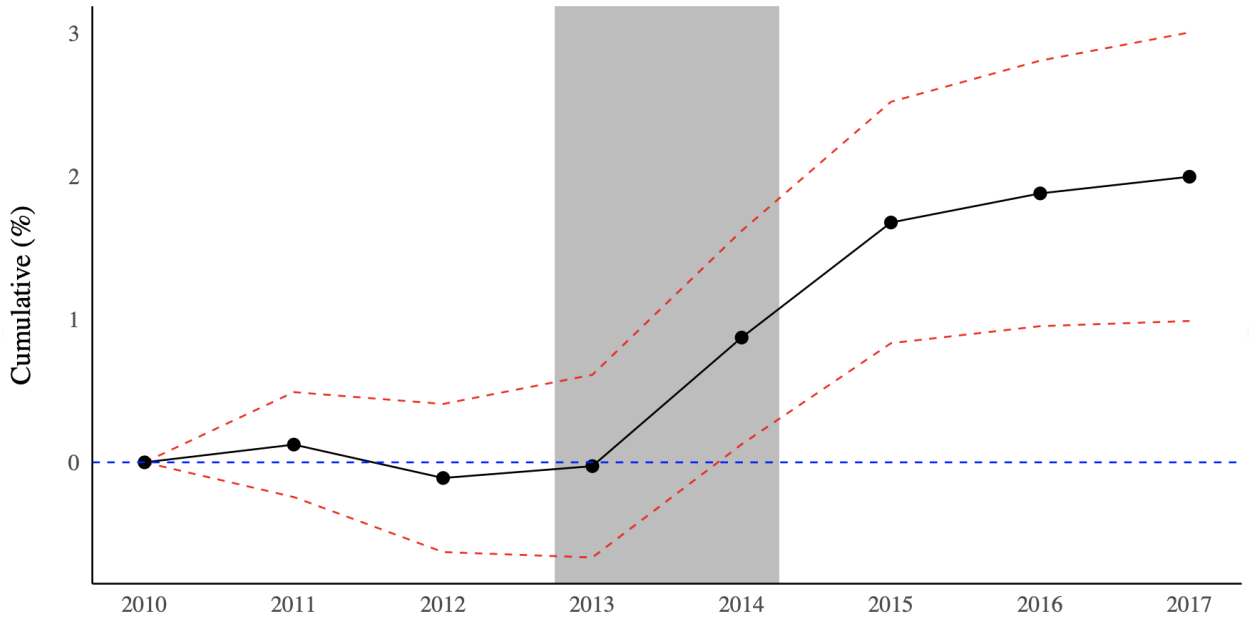


Table 1: Summary Statistics

This table presents summary statistics for BD characteristics in Panel A and RegTech investment variables in Panel B. All observations are at the BD-year level. Values in Panel B are count variables as defined in Section 4.1 (except for the IT Budget, which is in $000s). The BD characteristics sample has 26,721 BD-year observations from 4,660 unique BDs. The Aberdeen Software sample has 5,238 BD-year observations from 1,863 unique BDs. The Aberdeen Hardware sample has 11,352 BD-year observations from 2,087 unique BDs. The BGT Skill Demand sample has 1,307 BD-year observations from 357 unique BDs.

Panel A: BD Characteristics					
Variable	Mean	SD	P25	Median	P75
BD Characteristics:					
Total Assets ($000s)	1,272,287	16,738,871	150	707	5,161
Total Net Capital ($000s)	647,952	87,408,383	61	293	1,904
Treated	0.054	0.227	0	0	0
Post	0.474	0.499	0	0	1
Lag Num. Employees	211	1,709	5	11	37
Lag Avg. Tenure (years)	6.219	5.311	2.600	4.800	8.027
Lag Fraction of Dual-Registered Employees	0.294	0.309	0.000	0.200	0.523
Fraction of Employees with Complaint History	0.045	0.101	0.000	0.000	0.041
Affirmer is the CCO	0.046	0.210	0	0	0
Complaint Measures:					
1(Complaints > 0)	0.100	0.300	0	0	0
Num. Complaints	1.451	14.674	0	0	0
1(Misconduct> 0)	0.100	0.300	0	0	0
Num. Misconduct Incidents	0.872	8.731	0	0	0
Panel B: RegTech Investments					
Aberdeen Software:					
Enterprise Resource Planning	1.077	2.890	0	0	0
Data Management	3.319	6.657	0	0	4
Aberdeen Hardware:					
Servers	237	1,617	2	4	23
PCs & Laptops	1,169	7,152	12	31	148
IT Budget ($000s)	27,414	209,576	95	330	2,201
BGT Skill Demand:					
Compliance	42.189	136.725	0	0	7
Computer Manager	0.434	2.217	0	0	0

Table 2: RegTech Software Investments

This table studies RegTech software investments using equation (1). In Panel A, the dependent variable is 100 times the inverse hyperbolic sine of the number of each software type. *RegTech* is 100 times the inverse hyperbolic sine of the number of ERP and data management software programs. In Panel B, the dependent variable is 100 times an indicator for having each software type. *Post* is an indicator variable equal to one starting in 2014. *Treated* is an indicator variable equal to one for carrying BDs (static throughout the sample). Observations are at the BD-year level. All regressions include controls from equation (1) and BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$. At the bottom of the table, we present the mean and standard deviation of the transformed dependent variable.

Panel A: Intensive + Extensive Margins			
Dep Var:	ERP	Data Management	RegTech
	(1)	(2)	(3)
Treated × Post	27.550***	17.418**	23.591**
	(8.814)	(9.053)	(9.885)
N	5,238	5,238	5,238
R^2	0.682	0.844	0.857
Mean Dep Var	46.5	103.4	120.5
SD Dep Var	89.6	126.9	136.8

Panel B: Extensive Margin Only			
Dep Var:	Has ERP	Has Data Management	Has RegTech
	(1)	(2)	(3)
Treated × Post	13.140***	7.694**	7.269**
	(3.826)	(3.506)	(3.459)
N	5,238	5,238	5,238
R^2	0.691	0.824	0.826
Mean Dep Var	22.9	47.6	51.5
SD Dep Var	42.1	49.9	50.0

Table 3: RegTech Hardware Investments and Labor Demand

This table studies RegTech hardware investments and labor demand using equation (1). In Panel A, the dependent variable is 100 times the inverse hyperbolic sine of the number of servers or personal computers and laptops, or the IT budget. In Panel B, the dependent variable in column 1 (2) is 100 times the inverse hyperbolic sine of the number of job postings with a compliance skill (for computer and information systems managers). *Post* is an indicator variable equal to one starting in 2014, and *Treated* is an indicator variable equal to one for carrying BDs. Observations are at the BD-year level. All regressions include controls from equation (1) and BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$. At the bottom of the table, we present the mean and standard deviation of the transformed dependent variable.

Panel A: Hardware Investments and IT Budget			
Dep Var:	Servers	PCs & Laptops	IT Budget
	(1)	(2)	(3)
Treated × Post	39.130***	21.294***	39.812***
	(6.786)	(5.432)	(9.005)
N	11,352	11,352	11,352
R^2	0.926	0.954	0.897
Mean Dep Var	276.2	468.9	1,395.7
SD Dep Var	215.5	203.5	238.8

Panel B: Labor Demand		
Dep Var:	Compliance	Computer & IS Managers
	(1)	(2)
Treated × Post	34.780*	14.485**
	(18.377)	(6.818)
N	1,307	1,307
R^2	0.890	0.719
Mean Dep Var	95.5	19.1
SD Dep Var	161.0	58.9

Table 4: RegTech Software Investments—Robustness

This table investigates the robustness of our Table 2 results. The dependent variable *RegTech* is 100 times the inverse hyperbolic sine of the number of ERP and data management software programs. Columns 1 and 2 perform a coarsened exact matching analysis. Column 2 eliminates observations without sufficient balance between treated and control BDs. Column 3 eliminates bank-affiliated BDs. In column 4, *Size* is an indicator for BDs with above-median lag headcount. *Post* is an indicator variable equal to one starting in 2014, and *Treated* is an indicator variable equal to one for carrying BDs. Observations are at the BD-year level. All regressions include controls from equation (1) and BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$.

Dep Var:	RegTech	RegTech	RegTech	RegTech
	(1)	(2)	(3)	(4)
Treated × Post	22.057**	22.552**	29.925***	23.575**
	(10.215)	(10.809)	(11.164)	(9.933)
Post × Size				0.325
				(8.868)
Specification	CEM	CEM – Drop Subclasses with Imbalance	Drop Bank Affiliates	Size Trends
N	5,238	3,140	4,582	5,238
R^2	0.864	0.844	0.860	0.857

Table 5: Complementary Investments

This table studies complementary investments using equation (1). Panel A presents summary statistics. The Aberdeen Software sample has 5,238 BD-year observations from 1,863 unique BDs. The BuiltWith Website Technologies sample has 12,743 BD-year observations from 2,342 unique BDs. The dependent variables are 100 times the inverse hyperbolic sine of the number of each software type or number of website technologies. *Post* is an indicator variable equal to one starting in 2014, and *Treated* is an indicator variable equal to one for carrying BDs. Observations are at the BD-year level. All regressions include controls from equation (1) and BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies p < 0.1, ** signifies p < 0.05, and *** signifies p<0.01. At the bottom of the table, we present the mean and standard deviation of the transformed dependent variable.

Panel A: Summary Statistics

Variable	Mean	SD	P25	Median	P75
Aberdeen Software:					
Communications & Document Mgt	1.470	2.840	0	0	2
Anti-Virus	1.610	2.230	0	1	2
Other Technologies	75.10	114.020	10	29	94
BuiltWith Website Technologies:					
CRM Website Technologies	1.630	3.160	0	1	1
Premium Technologies	1.330	2.510	0	1	1

Panel B: Complementary Investment

Dep Var:	Communications & Document Mgt	CRM Technologies	Premium Technologies
	(1)	(2)	(3)
Treated × Post	12.641**	26.766***	28.887***
	(5.641)	(5.700)	(5.343)
N	5,238	12,743	12,743
R^2	0.832	0.846	0.787
Mean Dep Var	73.4	86.1	71.6
SD Dep Var	92.4	81.2	85.0

Panel C: Placebo

Dep Var:	Anti-Virus	Other Tech
	(1)	(2)
Treated × Post	4.137	-4.298
	(5.248)	(7.714)
N	5,238	5,238
R^2	0.873	0.892
Mean Dep Var	89.2	407.8
SD Dep Var	89.6	150.8

Table 6: Complementary and RegTech Investments

This table studies complementary investments. The dependent variable is 100 times an indicator variable for BDs with above-average number of the type of website technologies labelled in each column. *Has RegTech* is an indicator variable for BDs with either ERP or data management software. Observations are at the BD-year level. All regressions include controls from equation (1) and BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$.

Dep Var:	High CRM Technologies	High Premium Technologies
	(1)	(2)
Has RegTech	5.227**	7.016***
	(2.250)	(2.400)
N	5,238	5,238
R^2	0.714	0.719

Table 7: Technological Investment, Customer Complaints, and Employee Misconduct

This table studies customer complaints and employee misconduct using equation (1). The dependent variable in Panel A, column 1 (2) is 100 times an indicator for whether the BD has a customer complaint recorded on BrokerCheck that year (the inverse hyperbolic sine of the number of customer complaints). The dependent variable in column 3 (4) is 100 times an indicator for whether the BD has a misconduct incident that year (the inverse hyperbolic sine of the number of misconduct incidents). The dependent variable in column 5 is an indicator variable for whether the BD has a complaint with alleged damages of at least $5,000. In Panel B, *Tech Index* is the average Z-score for the BD's investments in ERP software, servers, and CRM website technologies. *Post* is an indicator variable equal to one starting in 2014, and *Treated* is an indicator variable equal to one for carrying BDs. Observations are at the BD-year level. All regressions include BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$. At the bottom of the table, we present the mean and standard deviation of the transformed dependent variable.

Panel A: OLS					
Dep Var:	Complaint	*f*(Complaints)	Misconduct	*f*(Misconduct)	Complaint >$5000 Damages
	(1)	(2)	(3)	(4)	(5)
Treated × Post	-4.321***	-9.260***	-3.376**	-9.345***	-4.279***
	(1.319)	(2.693)	(1.650)	(3.501)	(1.356)
N	26,721	26,721	26,721	26,721	26,721
R^2	0.680	0.857	0.589	0.749	0.677
Mean Dep Var	10.0	86.1	10.0	18.4	9.1
SD Dep Var	30.0	81.2	29.9	62.6	28.8

Panel B: Instrumental Variables		
Dep Var:	Tech Index	Complaint
	(1)	(2)
Treated × Post	0.327***	
	(0.046)	
$\widehat{\text{Tech Index}}$		-12.836**
		(5.099)
F-Stat	50.9	
N	15,065	15,065
R^2	0.808	0.684
Mean Dep Var	-0.1	14.1
SD Dep Var	0.8	34.8

Table 8: Technological Investment and Customer Complaints—the Case of COVID

This table studies customer complaints using equation (2). The dependent variable is 100 times an indicator for whether the BD has a customer complaint recorded on BrokerCheck that quarter. *COVID* is an indicator variable equal to one starting in Q2 2020. *Log Cases* is the natural logarithm of the number of COVID cases in a county-quarter. *Tech Index*$_{2017}$ is the average Z-score for the BD's investments in ERP software, servers, and CRM website technologies, measured in 2017. The sample period spans Q3 2018 to Q3 2021, and excludes Q1 2020. Observations are at the BD-quarter level. All regressions include cubic controls for the log number of employees and BD and FINRA district-by-quarter fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$.

Dep Var:	Complaint	
	(1)	(2)
COVID × Tech Index$_{2017}$	-0.535*	
	(0.290)	
Log Cases × Tech Index$_{2017}$		-0.080***
		(0.031)
Log Cases		0.162***
		(0.055)
N	22,947	22,947
R^2	0.609	0.609
Mean Dep Var	6.6	6.6
SD Dep Var	24.7	24.7

Table 9: Investigating Customer Complaints—Customer Type and Affirmer

This table studies customer complaints using equation (1). The dependent variable is 100 times an indicator for whether the BD has a customer complaint recorded on BrokerCheck that year. *Retail* is an indicator variable for whether the BD offers retail-facing products. Retail-facing products include investment advice, mutual funds, variable life insurance, and debt products. *CCO in 2011* is an indicator variable for whether the affirmer in 2011 is a Chief Compliance Officer. *Post* is an indicator variable equal to one starting in 2014, and *Treated* is an indicator variable equal to one for carrying BDs. Observations are at the BD-year level. All regressions include controls from equation (1) and BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$.

Dep Var:	Complaint	Complaint
	(1)	(2)
Treated × Post	-1.293	-3.967***
	(1.248)	(1.349)
Treated × Post × Retail	-4.427**	
	(2.217)	
Treated × Post × CCO in 2011		4.212*
		(2.178)
N	26,721	25,572
R^2	0.680	0.677
Mean Dep Var	10.0	10.7
SD Dep Var	30.0	31.0

Table 10: Employee Switching

This table studies employee switching using equation (3). The dependent variable in column 1 (2) is 100 times an indicator for whether the BD has an employee join from another specific BD that year, e.g., BD_i from BD_j (the inverse hyperbolic sine of the number of switchers). The independent variables are indicators for combinations of types of origin and destination BDs for the employee, times *Post*, an indicator variable equal to one starting in 2014. The sample includes all pairs of destination and origin BDs with nonzero movement during our sample window. Observations are at the BD firm pair-year level. All regressions include origin-by-destination BD-pair and year fixed effects. Standard errors are clustered by destination BD and shown in parentheses. * signifies p < 0.1, ** signifies p < 0.05, and *** signifies p<0.01.

Dep Var:	Has Switcher	*f*(Switching)
	(1)	(2)
Leaves Noncarrying, Joins Carrying × Post	0.535**	0.614**
	(0.204)	(0.246)
Leaves Carrying, Joins Noncarrying × Post	-0.053	-0.279
	(0.209)	(0.247)
Leaves Carrying x Joins Carrying × Post	-0.301	-0.764
	(0.380)	(0.508)
N	808,773	808,773
R^2	0.307	0.492
Mean Dep Var	12.8	15.1
SD Dep Var	33.4	44.5

Table 11: Labor Market Concentration

This table studies labor market concentration. The dependent variable in column 1 is the Herfindahl-Hirschman index for the MSA-year, where the index is based on headcount and spans [0,10000]. The dependent variable in column 2 (3) is the aggregate market share of headcount in percent at the top four (10) BDs in the MSA. *Post* is an indicator variable equal to one starting in 2014. Observations are at the MSA-year level. All regressions include MSA fixed effects, and standard errors are clustered by MSA and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$.

Dep Var:	HHI	C4	C10
	(1)	(2)	(3)
Post	32.168**	0.922***	1.928***
	(15.587)	(0.194)	(0.160)
N	4,113	4,113	4,113
R^2	0.931	0.954	0.965
Mean Dep Var	740	39.7	62.9
SD Dep Var	830	13.5	13.3

Online Appendix

A.1. Data Merging

We merge our main sample of BDs with Aberdeen CiTDB, Burning Glass Technologies, and BuiltWith using a variety of methods, as the databases have no common identifiers. For these data merges, we include observations that have values of zero and drop observations with missing data.

To match BDs to Aberdeen, we use three methods. First, we use CIK codes and EINs provided by Form BD to form a link to EIN, which allows us to link to firmographic databases, such as Orbis containing DUNS numbers and websites. The websites and DUNS numbers serve as common identifiers with Aberdeen. Second, we conduct fuzzy-name matching on name and phone number and name and address directly between Form BD and Aberdeen. Third, we use the Bing Search API to identify web search results for BDs and manually screen out false positives. Our final software (hardware) dataset sample with nonmissing control variables includes 1,863 (2,087) unique BDs and 5,238 (11,352) BD-year observations.

To match to BGT, we rely entirely on fuzzy matching of names and locations, as BGT does not provide any mappings to standard identifiers. Using conservative criteria, we obtain 675 BD matches between Form BD and BGT. Our final sample with nonmissing control variables includes 357 unique BDs and 1,307 BD-year observations.

To match to BuiltWith, we merge with the BD's website collected using the Bing Search API described above. Noncoverage implies that BDs do not have websites (which is the case for some smaller BDs) or that BuiltWith lacks information on their website. Our final sample with nonmissing control variables includes 2,342 unique BDs and 12,743 BD-year observations.

A.2. Business Model Differences

Figure A.1. Covariate Balance

This figure illustrates the covariate balance for both the matched ("adjusted") and raw ("unadjusted") samples, based on the mean absolute difference.

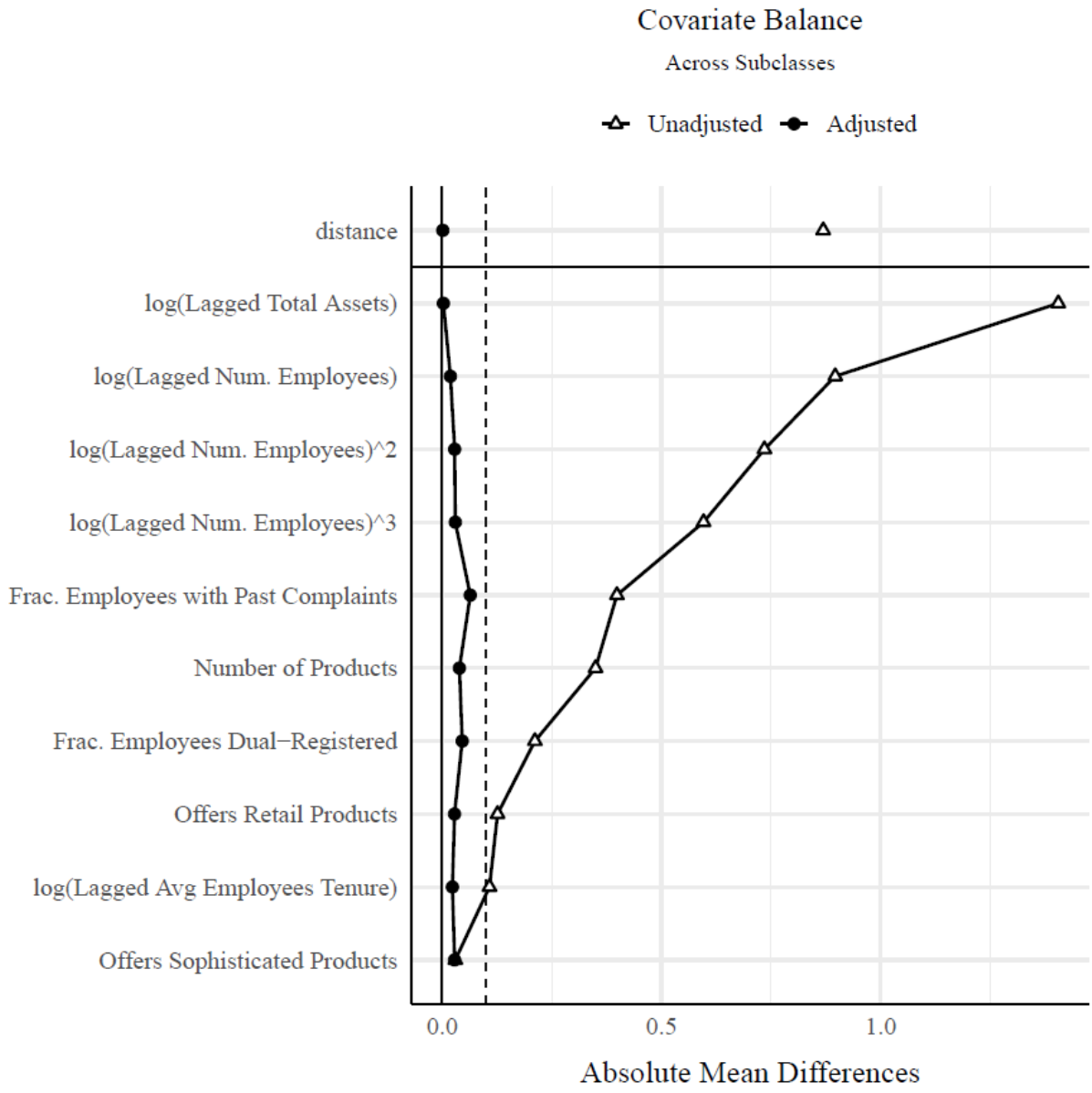


Table A.2: Complaint Analysis Robustness

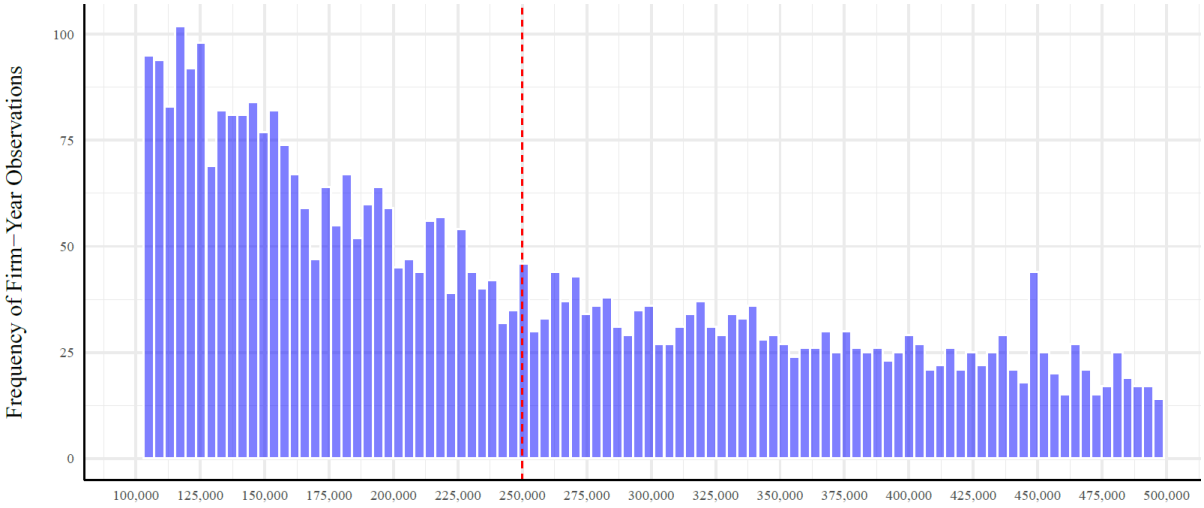
This table assesses the robustness of our Table 7 results using equation (1). The dependent variable is 100 times an indicator for whether the BD has a customer complaint recorded on BrokerCheck that year. Columns 1 and 2 perform a coarsened exact matching analysis. Column 2 eliminates observations without sufficient balance between treated and control BDs. In column 3, *Size* is an indicator for BDs with above-median lag headcount. The dependent variable in column 4 (5) is 100 times an indicator for whether the BD has recorded an auditor-related (non-auditor related) complaint on BrokerCheck that year. The dependent variable in column 6 is 100 times an indicator for whether the BD has a regulator-reported complaint on BrokerCheck that year. Column 7 eliminates bank-affiliated BDs. *Post* is an indicator variable equal to one starting in 2014, and *Treated* is an indicator variable equal to one for carrying BDs. Observations are at the BD-year level. All regressions include controls from equation (1) and BD and FINRA district-by-year fixed effects. Standard errors are clustered by BD and shown in parentheses. * signifies $p < 0.1$, ** signifies $p < 0.05$, and *** signifies $p<0.01$.

Dep Var:	Complaint	Complaint	Complaint	Auditor Related Complaint	Not Auditor Related Complaint	Regulator Action	Complaint
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated × Post	-4.356***	-3.944**	-3.896***	0.009	-4.517***	0.229	-4.620***
	(1.348)	(1.627)	(1.336)	(1.145)	(1.298)	(1.244)	(1.429)
Post × Size			-1.617***				
			(0.541)				
Specification	CEM	CEM – Drop Subclasses with Severe Imbalance	Size Trends	Complaint Type	Complaint Type	Complaint Type	Drop Bank Affiliates
N	26,721	7,536	26,721	26,721	26,721	26,721	24,273
R^2	0.682	0.802	0.680	0.500	0.683	0.470	0.675

Figure A.2: Net Capital around Rule 17a-5 Amendment

This figure presents the histogram of Net Capital for BDs, focusing on those with between $100,000 and $250,000 of Net Capital.

Panel A: Pre-Amendment Period



Panel B: Post-Amendment Period