Automation Adoption and Financial Regulation: Evidence from Stock Trading Firms and Workers*

Pedro Tremacoldi-Rossi†

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Abstract

How did trading automation impact broker-dealer firms and workers? While electronic trading platforms have been available for decades, widespread adoption of automated trading mostly occurred after the 2007 major market redesign promoted by the US Securities and Exchange Commission. With the intent of lowering access costs to stock markets, the policy fostered speed-driven competition between exchanges and trading firms. By leveraging several regulatory records to construct a rich linked employer-employee panel of equities traders, I study how employment, profits, and market structure were affected by higher returns to technology upgrading. Using variation in availability of local IT stock in investment firms, I find that automation eliminated 100 trading jobs on average during 2007-2009 for each additional computer per worker existing before SEC's Regulation National Market System became effective. Through a series of tests, I show that these results are unlikely to be driven by the Great Recession or the rise in online brokerage services.

Keywords: electronic trading, finance jobs, financial regulation
JEL Classification: G23, G24, G18, J24.

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†Ph.D. candidate, University of Illinois at Urbana-Champaign. Email: prossi2@illinois.edu.

1 Introduction

Electronic trading changed the traditional organization of financial markets. From the 18th century to the late-1990s, equities and derivatives trading took place in exchange-based physical marketplaces, where brokers and dealers met to buy and sell financial products for their own accounts or on behalf of customers. As electronic platforms started to proliferate in the early 2000s, machines gradually eliminated much of the need for intermediation and floor trading by replacing physical markets with computer networks. Trade orders are now routed to electronic systems that "represent" or fully constitute the trading venue, so that matching algorithms organize trade in continuous auctions markets with little human intervention.

These changes have not gone unnoticed in the finance literature, which has studied extensively how the migration from floor trading to high frequency market microstructure (O'Hara (2015)) affected liquidity provision, efficiency, and quality. An important missing element to the scope of market microstructure papers is the *trading industry*. For instance, Michael Lewis' popular book *Flash Boys* argues that automated trading and speed hampered the ability of US financial markets to execute its fundamental economic roles. Over a decade after the dominance of electronic markets and algorithms in stock trading, questions such as "Did technology make markets more equitable?", "Are trading profits now more concentrated?", or "Are traders more skilled?" remain largely unanswered. This paper begins to address these issues by studying how the electronic trading revolution impacted broker-dealer workers and firms.

Exploiting a major regulation introduced by the US Securities and Exchange Commission (SEC) in 2007, I find large negative effects on broker-dealer employment and evidence of skill complementarities of electronic stock trading. SEC's chief provision to redesign equities trading, Regulation National Market System (Reg NMS), fostered automated trading and migration to electronic markets. Using detailed firm-level data on IT use to determine local exposure to technology adoption, my main estimates imply that each additional computer per worker replaced nearly 100 trading jobs over 2007-2009. Aggregate job replacement in a large financial center like New York implies that over 400 jobs disappeared per incremental machine/worker during the three-year period.

I start the analysis by leveraging the high degree of financial regulation in the US requiring broker-dealer firms and workers to maintain detailed professional records in the Central Registration Depository (CRD) from the Financial Industry Regulation Authority (FINRA). The assembled longitudinal dataset comprises over 500,000 traders - both active and inactive - with rich employment history and location, experience, qualification, licensing, and demographic characteristics. These records allow me to recover the universe of broker-dealer firms registered to trade equities in the US, which I use to construct a novel dataset of financial filings spanning almost two decades. The sample provides a first-time comprehensive portrait of the US stock trading industry, circumventing the data opacity in financial jobs.[1]

To isolate the causal effect of electronic trading on broker-dealer firms, I first use the fact that several provisions of Reg NMS created incentives for migration to electronic trading and investments in automation by exchanges and broker-dealers. Electronic trading systems for stocks had been available since the 1970s, but adoption by broker-dealers and exchanges was slow. Floor trading, or open outcry, remained the leading form of trading even after Instinet's green screen terminals already provided off-exchange electronic trading since the 1980s, and equities markets were long connected electronically by the Intermarket Trading System.

Reg NMS changed this paradigm for stocks by installing price-protection provisions that only apply to stocks in electronic markets and with automated execution, which imposed a minimum speed requirement on participant exchanges. Initially meant to improve stock trading competition between exchanges, price integration steps in the regulation, like Rule 611 in the National Best Bid and Offer (NBBO), lead to market fragmentation and raised the returns to speed by forcing orders to be executed in the market offering the best outstanding quotes (O'Hara and Ye (2011), O'Hara (2015)).

Because the policy targeted all stocks, mapping changes in market microstructure induced by automation to treated and untreated firms is problematic without knowing each firm's portfolio. The second step I take for identification is to exploit spatial variation in a measure that is likely correlated with local automated trading take-up by broker-dealers. Areas with large pre-existing technology infrastructure in the financial investment industry, mea-

[1] Recent work by Egan et al. (2019) and Maggio et al. (2019) also compiles some of the data data from FINRA's BrokerCheck, the user interface providing public access to CRD records.

sured by computers per worker, face lower implementation costs of more sophisticated technology and imply the availability of basic services to sustain greater automation, such as high-speed internet. This IT intensity allows me to assign heterogeneous degrees of local exposure to electronic trading by comparing worker and firm outcomes in areas with high levels of IT infrastructure to the ones in low-IT areas before and after Reg NMS.

The relevance of the local exposure in broker-dealer firms relates to two channels. First, because of decreased adoption uncertainty induced by Regulation National Market System and if speed is profitable, firms have greater incentive to upgrade technology when barriers to development are lower. Second, if speed is a cost-saving technology and enables firms to cut commission fees, local competition for investors will influence automation take-up. While this second channel largely applies to broker-dealer firms competing for a local pool of costumers and the degree of localization in the demand for brokerage services, the first channel is relevant to all broker-dealers trading in stock markets that reward speed.[2]

Studying both firm-level employment and the probability of employment of stockbrokers during 2002-2009, I find that Reg NMS led to substantial employment losses even after excluding large financial centers and employers. I also test whether trading automation is a skill-biased technology, in the sense that it should benefit highly skilled traders (defined as those with at least college education) and reduce unskilled labor to a greater proportion. Contrary to a commonly held perception outside financial markets, the typical trader

Without wage information in FINRA's database, I use census data to analyze the policy effects on wages. Findings suggest modest wage gains for highly-educated brokers.

The empirical design rests on the identifying assumption that without Regulation NMS the trend in broker-dealer employment would have remained unchanged independent of the pre-existing IT intensity. Given that Reg NMS became fully operational in October 2007, the potential effects of the Great Recession correlated with treatment intensity are a direct threat to identification. I carefully show that my results are robust to shocks to local demand for brokerage services, consumption, home prices, and whether pre-policy IT exposure is associated with

[2]Evidence by Maggio et al. (2019) shows that the demand for certain brokerage service is extremely local, partially because investors prefer to be close to their brokers. For evidence on the rewards to speed in financial markets, see Baron et al. (2012).

outcomes of financial workers less affected by Reg NMS during the period, such as bankers and futures traders.

Although I cannot rule out the importance of additional channels through which the financial crisis bias the differences-in-differences estimates, taken together these tests suggest that areas with higher exposure to Reg NMS were not particularly affected by the Great Recession. Controlling for growth in local demand for online discount brokerage services also exerts minimal influence on the baseline results.

This paper relates and contributes to several strands in the finance and economics literature. Its main new contribution is to go beyond market microstructure effects (Stoll (2006), Menkveld (2016)) and show how the largest *technological* change financial markets have ever undergone impacted the finance industry more broadly. Several finance papers have looked at how migration to electronic trading affected liquidity provision, quality, and efficiency. Work by Jain (2005), Tse and Zabotina (2001), Raman et al. (2017), and many others shows that electronic markets increased pricing efficiency and liquidity. Other studies revealed how electronic markets changed market participants (e.g. Raman et al. (2017) for oil markets), which suggests trader composition shifts with unknown consequences to firm and worker outcomes.

My findings partially connect this literature to a more theoretical-based strand on the structure of skill and pay in the financial intermediation industry (e.g. Bond and Glode (2014), Reshef and Philippon (2012) and Glode and Lowery (2016)). By providing empirical evidence on employment losses and higher skill wage premia for stockbrokers caused by electronic trading, the analysis underpins skill-biased technologies as a main driver of extensive-margin adjustments in broker-dealers. Trading automation not only substitutes away unskilled work and eliminates repetitive tasks, but also requires high skill work to be operated, impacting the skill composition of traders.

By using the implementation of Reg NMS to flesh out the timing of trading automation in stock markets, this paper naturally stresses the role of financial regulation in directly shaping firm behavior. In particular, it relates to work by O'Hara and Ye (2011) and Haslag and Ringgenberg (2016) who study the effects of Reg NMS and market fragmentation on trading costs and market quality. They find that execution quality and liquidity costs have improved, with the differential in Haslag and Ringgenberg (2016) that only large stocks reaped the benefits of market fragmentation. I contribute to this body of literature by showing how the policy negatively affected trader employment by influencing firms to shift activities towards capital stock.

2 Background & Data

I briefly introduce key regulatory changes in the finance industry since 2000, in particular Regulation National Market System, which I explore in my empirical analysis. I also discuss how electronic trading became the dominant way of buying and selling securities and derivatives.

2.1 Financial Regulation: Institutional Framework

Since the creation of the National Market System (NMS) by the Securities Acts Amendments of 1975, US securities markets have been partially integrated in an attempt by policy makers to provide greater transparency and foster competition between trading venues. The NMS created a central marketplace where quotes once scattered across different exchanges could be publicly displayed. In the 2000s, the SEC introduced new regulation as a response to the development of new market mechanisms and electronic stock exchanges which rendered the 1975 national market system outdated.

Regulation ATS. Implemented in 2000, SEC Regulation ATS extended the reach of existing rules to include automated trading systems (ATS) under the national market system. Automated trading systems are one type of algorithmic trading and use sophisticated computer programs to generate and execute buy and sell orders. Reg ATS offered ATSs the option to register as an exchange or a broker-dealer, which initiated the integration of these automated systems with traditional exchanges.

Regulation NMS. Following Reg ATS, Reg NMS was passed in 2005 and became fully effective in October 2007, after major exchanges requested additional time to adapt to the policy provisions. The set of rules intended to promote "efficient and innovative trading services" and "more efficient pricing" of stocks by fostering "vigorous competition among markets", in addition to "integrated competition among orders".[3] The dramatic redesign of the national market system centered in a new requirement for brokers to execute customer orders at the best available quote (top-of-book). The most important and contentious provision of Reg NMS, the Order Protection Rule (Rule 611), known as "trade through" rule, mandates exchanges to direct market orders to the venue posting the best available quote, which is protected from trading through (executing the order at a suboptimal price). It is important to point out that rules only apply to electronic markets offering automated execution at the posted quotes.

Consequences of Reg NMS. Reg NMS is widely acknowledged as one of the main causes of market fragmentation and the rise of speed-driven competition in US financial markets. First, because Reg NMS only protects electronic quotes, stock exchanges had an incentive to adopt electronic limit order books (Chao et al. (2018)), boosting execution speed. Hendershott and Moulton (2011) argue that NYSE introduced its Hybrid Market (which expanded trading automation and consequently reduced latency) to meet the criteria of Rule NMS.

Second, since Rule 611 routes trading volume to venues offering lower quotes, it mechanically increases off-exchange volume and thereby fragmentation. Off-exchange ATSs, such as electronic communication networks (ECNs) and dark pools, now account for 44 of 57 US trading venues and much larger market shares. In 2013, dark pools had a two-fold increase in market share from 7% in 2008 (Kwan et al. (2015)). Traditional exchanges saw sharp drops in market share: equity market volume held by NYSE and NASDAQ decreased from 70% and 50% in 2006, respectively, to 20% and 30% in 2011 (Pagnotta and Philippon (2018)).

Under market fragmentation, quotes are scattered across a larger number of markets and search costs increase. Biais et al. (2015) show that in order to reduce these fragmentation costs, investment firms overinvest in speed-driven technology. Competition between exchanges also lead to significant increases in trading speed. In order to attract volume and reduce execution latency, exchanges cut transaction fees (Colliard and Foucault (2012)) and invested in new infrastructure to make trading faster (Pagnotta and Philippon (2018)).

Reg NMS fostered speed-driven competition in two ways. By imposing a minimum speed requirement (electronic trading), the legislation rendered the existence of purely floor-based exchanges economically unattractive. Second, price integration policies, like Rule 611,

[3] SEC Regulation NMS. More details in `https://www.sec.gov/rules/final/34-51808.pdf`.

result in market fragmentation (Pagnotta and Philippon (2018)), which make latency a central market structure issue. US exchanges are for-profit companies that generate revenue out of fees accruing from trading volume. If trade volume is directed to cheaper venues, exchanges lose market share and trading revenue. Taken together, these two facts increased the returns to trading speed, likely contributing to the rise of algorithmic trading, in particular of high-frequency traders (HFTs).[4]

2.2 The Rise of Electronic Trading

Electronic financial markets are not particularly a recent innovation. Launched in 1969, Instinet was the first and only electronic communications network in Wall Street, competing with traditional floor-based exchanges. Only after the diffusion of PCs in the 1980s, non-physical trading started to fully develop, in part because of regulation following the crash of 1987 pushing exchanges to adopt automated execution systems.

Transitioning to electronic markets was a slow process. Traditional exchanges operated under secular systems of memberships, where trading advantages come from member benefits. Floor-brokers pushed back automation, fearing both skill obsolescence and loss of trading fee revenues, as most exchanges were then non-profit organizations owned by floor traders. The late adoption of electronic platforms by major exchanges (NYSE in 2001 and 2004, NYMEX in 2006, and ICE in 2008) shows the uncertainty and challenges surrounding the adoption of electronic markets.

A notorious example of skepticism with respect to electronic trading adoption in the late 1990s is the case of the former futures exchange CBOT. In 1997, the exchange built in Chicago a $300 million, 65,000 ft. trading floor, betting on physical trading against its competitor CME's electronic platform Globex, introduced in 1992. In December 1998, chairman Patrick Arbor was voted out of office by CBOT members because of his attempt to offer the exchange's derivatives contracts at Eurex's electronic platform. CBOT was purchased by CME in 2007. Open outcry trading in the exchange's floor, previously called the "Taj Mahal", shut down in 2015,following

[4]With time, exchanges developed new ways to exploit electronic trading and the presence of algorithmic traders to increase profit beyond trading fees, including offering co-location slots to reduce speed latency.

the trend from competing venues, like Intercontinental Exchange (ICE) who went all-electronic in 2012.

The case illustrates the importance of Reg NMS in fostering speed-based competition and lowering development costs of algorithms and the structure necessary to fast trading. Because the policy raised the returns to (fast) automated execution, it is likely to have influenced the timing of electronic trading adoption by broker-dealer and exchanges. After Reg NMS came into effect, electronic trading became the dominant type of trading in US stock markets. High-frequency trading alone, which is just one type of automated trading, accounted for over 60% of US daily equity volume in 2009 compared to 20% in 2005, according to data from the Tabb Group.

2.3 Broker-Dealer Firms & Workers

US equities broker-dealer firms and associated individuals are required to obtain registration licenses from the Financial Industry Regulation Authority (FINRA). These records are publicly available and contain rich information on worker and firm-level data spanning decades. FINRA maintains the Central Registration Depository (CRD) which includes all securities brokers, traders, and firms currently active or that were ever registered to operate. The database also includes workers not necessarily executing stock trades or selling equities investment products, such as investment advisers, futures traders, and several other trading professionals that also require licensing. Conversely, some workers in the CRD might not trade securities, but they are necessarily employed by a broker-dealer registered to operate in securities markets.

FINRA grants access to CRD through the search website BrokerCheck.com. The platform allows the public to retrieve records on a specific broker-dealer or trader by searching their name, registration code, or location.One example of the platform output is shown in Figure (A.1).[5] To assemble the dataset, I scrape all broker-dealer records in FINRA's CRD and ho-

[5] Although these data are freely accessible online and are intended to offer greater transparency for regulators and customers who wish to consult professional records, the database remains largely unexplored. In finance, Egan et al. (2019) and Maggio et al. (2019) use some of FINRA's BrokerCheck records to study financial adviser misconduct and institutional investor demand for brokerage services.

mogenize each individual's record into a comprehensive sample containing over 1.2 million individuals currently active, inactive (no longer registered), and whose records were no longer updated after 1999. The latter group is discarded as broker-dealers employed only prior to 1990 have incomplete records.[6]

For each worker, the data allows one to observe complete employment history, litigation history, years of experience, licenses, and full name. With workers' employment records, I construct a broker-dealer longitudinal panel tracking firm location and workforce by financial occupation or job title. There are about 10,000 unique broker-dealer firms registered in the database and over 2,000 continuously operating from 2002 to 2009, which I use as my estimating period.

The sample contains the near-universe of broker-dealers registered to trade securities, only eventually missing some proprietary trading firms. Proprietary brokers are virtually unregulated because of a loophole in Rule 15b9-1 of the Securities Acts Amendments of 1975, which exempts certain individuals from registering as broker-dealers and therefore do not face the same regulation stringency as other "traditional" trading firms.[7] While proprietary shops comprise a small fraction of broker-dealer firms and therefore employment, these are heavy users of automated trading, in particular high-frequency trading, and likely to account for large traded volumes in securities. On the other hand, large investment banks with proprietary desks and market makers, such as Citadel and Virtu, are FINRA-registered broker-dealers.

I complement the detailed trader information from FINRA with data from the Current Population Survey (CPS) and 3% samples of Census American Community Survey (ACS), which are less prone to sampling error than annual 1% waves and provide information on trader wages and skills, and allow me to investigate how unlicensed professionals working at broker-dealers (e.g., software engineers, data scientists) responded to trading automation adoption. Only workers of ages 18 to 64 and earning work wage are considered. Census Public

[6]For example, details on employment history for these traders are limited, or just the last employment firm is recorded. For all individuals active after 1999, FINRA requires any changes to be updated within 30 days. This implies that BrokerCheck.com records timely reflect changes in employment and qualification, for example.

[7]In 2016, FINRA began to require individuals handling automated trading working for member firms to take the new Series 57 exam. With respect to Rule 15b9-1, the Commission proposed amendments to the rule in 2015 which would force proprietary firms currently exempt to register with FINRA to become subject to the same scrutiny from regulation agencies. SEC officials informed me that the proposed changes are still under evaluation and implementation is uncertain.

Use Microdata Area (PUMA) geographies are mapped onto counties by allocating the share of population in each PUMA to a county.

2.4 Financial Filings

As mandated by Section 17 of the Securities Exchange Act of 1934, Rule 17a-10(a)(1), registered broker-dealers are required to submit form X-17A-5, also known as FOCUS (Financial and Operational Combined Uniform Single) Report, every fiscal year. The form is mandatory even for privately-held broker dealers and generally contains a statement of financial condition (balance sheet), financial income and operation, as well as calculation of the Uniform Net Capital Rule (Rule 15c3-1). Although some information is not publicly available, such as detailed holdings position, publicly available records always contain broker-dealer balance sheet, leverage computation, and often statement of income (see Figure X), as well as market value of investments, wage bill, and capital or operational expenditures in technology.

Contrary to other financial data readily available to the public, including from forms 10-K and 8-K, until 2017, X-17A-5 documents were submitted only in paper and not indexed in SEC's Index Files. This makes scraping and handling these forms a much more difficult task than parsing financial information from most other filings. The SEC publicly stores only PDF scans of paper filings along all other documents filed by a certain entity.

To retrieve and process financial filings from US broker-dealers, I employ a lengthy process described in detail in Appendix A. The approach first exploits broker-dealer names obtained from the FINRA records, which are then matched to SEC's Central Index Key (CIK) codes. Next, I screen under which entity names or filing codes a broker-dealer files its relevant documents, retrieving each filing's Document Control Number (DCN) path. This final step allows me to access and download each filing.

Finally, after obtaining over 80,000 annual X-17A-5 forms in PDF or image format spanning 2001-2020, I convert these files into readable text and extract financial information

2.5 Information Technology

I obtain firm-level IT data from the marketing company Aberdeen. The CI Technology Database (formerly offered by Harte Hanks) contains detailed information on the hardware and software used in over 400,000 business sites in the US. For each company in 2004, one observes granular location, employment (overall and desk workers), industry code, company name, revenue, number of programmers, storage capacity, mainframe machines, PCs, internet access type, and IT variables along several other dimensions. Similar to Bloom et al. (2012) and Beaudry and Lewis (2014), I construct firm j's IT intensity measure as the number of computers per desk worker, IT_j^{fin}.

Using only firms with NAICS industry codes 523 (Securities, Commodity Contracts, and Other Financial Investments and Related Activities) and 525 (Funds, Trusts, and Other Financial Vehicles), indexed as fin, I calculate local historical IT intensity as

$$\overline{IT_c^{2004}} \equiv \frac{\sum_{j \in j(c)} \omega_j^{fin} IT_j^{fin}}{\sum_{j \in j(c)} \omega_j^{fin}}$$

where ω_j^{fin} is total employment at firm j and $j(c)$ are fin companies in county c. More details on patterns of the IT intensity measure are provided in the next section. Figure (A.2) shows that the IT intensity in the investment industry was already relatively high compared to other sectors, with an average of about one computer per worker.

2.6 Other Data

To lend further credibility to the main pre-policy IT measure, I construct a second pre-Reg NMS intensity measure based on local broadband availability. The data come from the Federal Communications Commission (FCC), which provides internet access information from Forms 477. The data is available for most US ZIP codes, and tracks the number of high-speed (200 kilobits per second or faster) internet providers with at least one subscriber per ZIP code. Access to high-speed internet is a minimum infrastructure requirement for firms trading electronically, especially those with with high-frequency database and back-end services, such as co-location and access to price feeds from exchanges.

I map 5-digit ZIP codes onto 2010 census counties by assigning the latitude and longitude of the ZIP code centroid to a unique county. In each county, I aggregate the number of different high-speed internet providers into an alternative intensity measure $\widetilde{IT_c^{2004}} = \frac{\sum_{z \in z(c)} \psi_z providers_z}{\sum_{z \in z(c)} \psi_z}$, where $z(c)$ gives the set of ZIP codes contained in county c and ψ_z are allocation factors based on the fraction of the county area occupied by each ZIP code.

In certain specifications, I control for potential factors affecting the demand for brokerage services. Personal income per capita data comes from the US Bureau of Economic Analysis (BEA) and dividends and labor income from IRS Statistics of Income data. To construct local stock market wealth, I follow the same methodology in Chodorow-Reich et al. (2019). Specifically, I retrieve Form 1040 aggregate dividend amount in a county c and income from wages and earnings to construct local stock wealth as

$$\eta_{ct} = \left(\frac{D_{ct}}{w_{ct} L_{ct}} \right) P_t^{\text{S\&P 500}}$$

where $P_t^{\text{S\&P 500}}$ is the inverse of the dividend yield (price/dividend ratio) on the S&P 500.

3 Anatomy of the US Trading Industry

This section presents both suggestive evidence of the effects of Regulation NMS and details of the US broker-dealer data. I start with descriptive facts in the data.

The location of individuals working for broker-dealer firms in the US is considerably spatially concentrated. Large urban areas and important financial centers such as New York and Chicago employ the majority of broker-dealers (Figure (1)). Trading jobs peaked early 2007, especially in those locations with exchanges and large finance sector output. These places suffered disproportionately large broker employment losses following 2007, reaching employment levels in 2018 similar to 1990, when the financial sector represented a much smaller share of the US economy.

Table (1) presents descriptive statistics for the top 10 counties of broker-dealer employment in 2004 and 2007. As expected, New York accounts for the majority of equities trading jobs in the US, with about a quarter of total employment before Reg NMS and 20% as of 2009. Other important financial centers like Chicago and LA tend to concentrate fewer broker-dealer jobs than areas in New Jersey with many trading firms. The pre-policy IT intensity considerably varies across counties. Boston and New York ranked considerably higher than other top employing areas in use of PCs per worker. Since a disproportionate number of trading firms and broker-dealer individuals in the sample are in New York, later in the paper I test for the sensitivity of my main estimates to excluding New York from the analysis.

A. Aggregate employment and IT investment

3.1 Aggregate employment and IT investment

Figure (2) provides suggestive evidence of broker-dealer employment behavior and what could be driving such movements to motivate my empirical analysis. The aggregate trend in employment in Figure (2) shows that almost 100,000 broker-dealer jobs were added during 2000-2007. Coinciding with the final rollout of Reg NMS, trader employment slumped. While the national employment data masks local drivers in broker employment decline, the behavior of IT capital stock investment in brokerage firms suggests the factor behind structural changes in the securities industry. IT capital upgrading remained stagnant over 2000-2005. During the rollout of Reg NMS, technology investment by broker-dealers increased almost two-fold and continued to rise until 2010, in line with the dramatic rise in electronic trading in the same period.

B. Entry and skills

The steep drop in broker-dealer employment over 2007-2017 stems from individuals leaving the securities industry and the declining entry of new professionals. In Figure (5), I show several examinations records from FINRA, according to the specific occupation being licensed. Financial regulations impose stringent conditions to individuals' occupation and task mobility. These examinations usually require a sponsor, so that individuals can only take Series 7, for example, if a firm agrees to support the application. The pronounced decrease in new licenses indicates that broker-dealer firms reduced demand in the extensive margin. Since having a broker-dealer as sponsor is a requirement to take these examination, the pronounced overall decrease shows a lower demand for traders and investment advisors (IA).

An additional pattern in Figure (5) are worth mentioning. First, licensing to buy and sell commodities and to become IA decreased less dramatically than new Series 7 and 25. This might suggest some degree of occupation switching and reflect the large financial inflow into commodities, known as financialization, that occurred in the period, and a smaller penetration of technology in investment advising than in trading. Finally, it is unlikely that individuals joining the securities and commodities industry are foregoing Series 7 because they are being employed by proprietary trading firms. These are usually small, highly tech-intensive companies unlikely to account for these patterns in the data.

4 Empirical strategy

I quantify the causal effects of pro-electronic trading policy using a differences-in-differences with continuous treatment (Card (1992)). Reg NMS fostered speed-driven competition by imposing a minimum trading speed requirement on stock exchanges and increasing the returns to fast trading. Exploiting spatial variation in local IT intensity in the finance industry, my main goal is to test whether securities trading employment after Reg NMS is lower in areas where technology concentration is higher. Since technology upgrading and migration to electronic trading is facilitated by pre-existing infrastructure, I expect markets with higher IT capital stock in financial firms to be more affected by the policy.

Baseline model. The impact of Regulation National Market System on broker-dealers is analyzed using firm and worker employment. Throughout, I measure employment by considering only individuals in FINRA's database holding Series 7 Examination, the basic license in order to trade securities. In my baseline specification, I run the following model for broker-dealer firms:

$$\ln\left(Emp_{fct}\right) = \alpha_0 + \delta\left(IT_c^{2004} \times \text{Post RegNMS}_t\right) + \gamma X_{fct} + \lambda_t + \mu_c + \varepsilon_{fct} \quad (1)$$

where the outcome is the log employment in firm f located in county c in year t. The difference-in-differences coefficient δ measures the change in the impact of IT intensity IT_c^{2004} before and after Reg NMS. The IT term is interacted with an indicator for the post-Reg NMS period, $\text{Post RegNMS}_t \equiv \mathbb{1}\{t \geq 2007\}$.

I include time-varying controls in X_{fct} that could be omitted variables otherwise left out of (1), such as local income per capita and local stock market wealth. Year fixed effects λ_t capture aggregate shocks affecting all counties with same incidence, e.g. S&P 500 returns and macroeconomic cycles.

To the extent that stock market fluctuations could exert differential effects on areas with higher investor density, the covariate for stock market wealth captures not only local consumption wealth effects as in Chodorow-Reich et al. (2019), but also the possibility that households may reduce risky asset holdings to smooth negative labor income shocks. County-fixed effects μ_c are also included to control for unobserved determinants of employment for each county, also absorbing the level of pre-policy IT use.

Estimation period and sample. To avoid capturing extraneous factors, I limit the analysis time horizon to 2002-2009: after Reg ATS and before more recent regulatory changes to address concerns over automated trading after the 2010 Flash Crash and the Dodd–Frank Act. I aggregate FINRA's data to annual employment levels in each broker-dealer firm, where employment is counted only for individuals holding a valid Series 7 license. These are the workers allowed to trade stocks and therefore the traders directly affected by Reg NMS. While I cannot observe whether some registered broker-dealer firms are also futures commission merchants (FCMs) or retail foreign exchange dealers (RFEDs), for example, less than 10% of traders with Series 7 also held Series 3, the license required to trade futures and options. Dropping these traders does not affect my main results.

Workers and firms affected by Reg NMS. As previously mentioned, Regulation National Market System *only* applied to stock markets. While registered broker-dealer firms in the CRD database are active in securities trading, they might also trade other financial products, such as futures and bonds. Similarly, individuals holding Series 7 are technically allowed to trade in fixed income, and those holding other licenses could in principle work in desks or departments within the firm not directly involved in stock trading. If licensing properly proxies for occupational task within the broker-dealer firm, one would expect futures traders without a Series 7 license to be at least less affected on average than stockbrokers.[8] Section (8) exploits such workers plausibly unaffected by Reg NMS to show placebo-type tests of my main estimates.

To leverage the richness of FINRA's data and control for potential sharp composition changes at aggregate firm employment, I also run an individual-level version of model (1):

$$Emp_{ict} = \alpha_0 + \delta \left(IT_c^{2004} \times \text{Post RegNMS}_t \right) + \gamma X_{ict} + \lambda_t + \mu_c + \varepsilon_{ict}$$

where the outcome now represents an indicator of whether worker i is employed in t. Controls in X_{ict} include gender and dummies for experience. Since individual traders working in Chicago in 2010 might have been living in San Francisco in 2007, I restrict the sample for individual-level regressions to workers *always* employed in the 2007 county of work. Considering all workers has no effects on the estimates. For consistency, workers taking the Series 7 Exam after 2002 are discarded.

[8]Futures trading in major markets was largely electronic by 2007 (Raman et al. (2017), Irwin and Sanders (2012)). On the other hand, bond trading remains largely voice-based (Pagnotta and Philippon (2018)). Even if slow brokerage firms switched trading for their own accounts toward fixed income markets to escape automation in NMS stocks, this move would still impact those traders specialized in stock markets. Furthermore, most retail and institutional broker-dealers in the sample would have limited ability to perform sizable inter-market movements without costumers' directions.

Identifying assumption. In model (1), the key identifying assumption is that without Regulation NMS the trend in employment would have remained unchanged independent of the IT intensity. I test the parallel trends assumption in sequence.

In additional results, I interact county and time effects to allow for flexible trends potentially driving local broker employment. Regressions for firms are weighed by 2000 employment levels and standard errors clustered at firm or individual level for all specifications.

5 Reg NMS and electronic trading

Before analyzing the consequences of Reg NMS for employment, skill composition, and financial outcomes, I take a closer look at how the policy affected electronic trading. The empirical analysis of Reg NMS on broker-dealer outcomes is challenging because firm-level electronic trading adoption is unobservable. Ideally, I would like to observe firm automated trading take-up. In this section, I analyze how a proxy for local take-up of electronic trading responded to Reg NMS.

A. Evidence from patents

Patent data comes from the United States Patent and Trademark Office (USPTO). I search through all patent description records from 1976 through 2018 and select those related to electronic trading based on a combination of terms inventors used to link the patent use to electronic markets. I retrieve the year the patent was granted, the name and geocoordinate of the company listed as "assignee", the investor's name and home address. Appendix (9) gives further detail on the retrieval process.[9]

Without broker-level data on electronic trading adoption, I proxy the intensity of local automated trading using patents. Many trading algorithms and back-end systems are developed

[9] I use patent year as the year it was eventually granted and not when its application started to capture the market availability of the technology (supply-side) rather than the innovation timing.

by specialized companies who sell these products and services to broker-dealers. This end-consumer market provides incentives for developers of trading engines and systems to file for patents to protect intellectual rights. Areas with large generation of electronic trading-related patents are likely to have a thicker market for automated trading tools, as close location to electronic network development firms is important for broker-dealers. Under the assumption that a local increase in electronic trading patenting is correlated with automated trading take-up, we can see the first-stage of equation (1) as:

$$\ln\left(Patents_{ct}^{EC}\right) = \beta_0 + \pi\left(IT_c^{2004} \times \text{Post RegNMS}_t\right) + \xi X_{fct} + \theta_t + \omega_c + u_{fct} \tag{2}$$

where the outcome measures the aggregate number of patents related to electronic trading from inventors living in county c over time.

An example. To illustrate what these patents capture, consider the example of patent US7844541B2, issued in 2009 to the Chicago firm Trading Technologies International, Inc. The patent describes a "*system and method for quick quote configuration*", allowing traders "*to quickly configure the quoting side of a trading tool, without experiencing the normal delays associated with conventional methods of quoting*" by "*automatically work*[ing] *an order to buy or sell a tradable object*". The firm provides trading tools, data flow, and other services to support electronic platforms.

First-stage. First-stage results are display in Table (3). Counties with higher IT per worker in 2004 experienced a larger increase in electronic trading patenting post-Reg NMS than areas with low IT intensity. As Figure (5) shows, all counties had similar trends in patents until Reg NMS was introduced in 2005, when the rise in the number of patents in high-IT areas drove the aggregate patent behavior in Figure (4).

Local trends in other patents. A potential concern with the behavior of electronic trading patenting trends is that perhaps areas with historical large use of IT in the financial industry were more prone to posterior technological innovation.

These results are forthcoming.

6 Results

A. Baseline Results

If trading automation is a labor-saving technology, particularly in cognitive and manual tasks that can be subsumed by automatic rules (Autor et al. (2003)), one expects employment to respond negatively to greater adoption of electronic trading. The magnitude of this extensive-margin adjustment depends on the skill composition of affected workers and whether electronic trading is a skill-biased technology. For example, if algorithms and greater execution speed make traders able to use these tools more productive, low-skill traders are more likely to be fired and wages of highly-skilled workers will increase.

Baseline results are displayed in Table (4). I start in column 1 with a two-period difference-in-differences where I take the pre-policy year to be 2004. While expecting some delay between the Reg NMS introduction and material employment effects is reasonable, the estimate from this restrictive specification rules out completely sluggish employment responses and also avoids part of the Great Recession post 2007. Throughout the table, the negative effects on employment follow the expected direction from a labor-saving technology shock. The estimated causal impact of Reg NMS in column 2 implements the baseline model and implies that increasing the local IT ratio by one computer per worker decreases employment by $\exp(-0.002) \times 100 - 1 = -0.2\%$. To give these employment effects economic magnitude, the estimate translates as annual losses of 80 jobs in New York County per additional computer/worker.

After controlling for local income per capita and stock market wealth in column 3, the main effect persists and in fact becomes stronger. In the fourth and fifth columns, I regress a dummy variable which takes the value of 1 if the broker-dealer is employed in on the post-policy measure. The significant and negative estimates confirm the impact of Reg NMS on employment at finer level. That is, not only aggregate firm-level employment responds to Reg NMS more acutely in areas with large pre-policy IT exposure, but even the employment probability of a given broker decreases in these areas.

B. Robustness checks

This subsection conducts a series of tests to verify the plausibility of the parallel trends and other possible model assumption violations, and whether the baseline model is robust to a different intensity measure. An analysis of the significance of alternative explanations, including the Great Recession and online brokerage platforms is delayed until Section (8).

Parallel trends and timing. The decline in employment estimated in Table (4) can only be attributed to the introduction of Reg NMS if the IT intensity measure is correlated with employment post-policy but uncorrelated prior to 2007. To check whether this is the case, I modify equation (1) by interacting IT_c^{2004} with a full set of year dummies:

$$\ln\left(Emp_{fct}\right) = \alpha_0 + \sum_{k=2002}^{2010} \delta_k \left(IT_c^{2004} \times \mathbb{1}\left\{k = t\right\}\right) + \gamma X_{fct} + \lambda_t + \mu_c + \varepsilon_{fct} \tag{3}$$

where we expect $\widehat{\delta_k}$ for $k < 2007$ to be non-significant. Results are displayed in column 3 of Table (1) and also visualized in Figure (6). Point-estimates are non-significant up to 2007, when estimated effects become significant and larger in absolute value.

Second, I remove year dummies from (1) and add a linear time trend and a trend interacted with IT_c^{2004}. This specification tests whether the policy still affects employment after allowing for a common linear trend across counties. The estimate in column 2 of Table (5) is remarkably similar to the coefficient from the baseline model. Next, (4) interacts the linear trend with county fixed effects, in the following specification:

$$\ln\left(Emp_{fct}\right) = \alpha_{0c} + \mu_c t + \delta\left(IT_c^{2004} \times \text{Post RegNMS}_t\right) + \gamma X_{fct} + \lambda_t + \varepsilon_{fct} \tag{4}$$

which allows counties with different levels of IT intensity to follow different trends. In other words, (4) nets out changes in local broker-dealer employment caused by Reg NMS from each county's (potential) own employment trend. Results are displayed in column 4 and again sustain the inference from my main estimates. Taken together, these specifications tests formally confirm that the parallel trends assumption is unlikely to be violated in my baseline model. A visual inspection of grouped employment pre-trends is displayed in Figure (7) and confirms less formally that areas with differential pre-policy IT exposure experienced similar broker-dealer employment trends.

Alternative intensity measure. As an additional check, I use the broadband availability measure $\widetilde{IT_c^{2004}}$. While this measure is less relevant than the IT intensity using computers per desk worker, it tests for the importance of *minimum* technology in providing heterogeneous levels of local exposure to Reg NMS. Many broker-dealers occupy the same buildings to take advantage of pre-existing high-speed internet infrastructure. Back-end communication systems and networks in trading firms to access price feeds and co-location rights offered by exchanges require advanced internet services, which might make electronic trading adoption in areas with larger high-speed internet easier. Results in column 1 are in line with the baseline estimates.

Placebo period. Next, I verify whether pre-policy differences between firms in high IT areas and the ones in low IT counties might be driving the results in Table (4). A simple test for this is to "ignore" the introduction of Reg NMS by replicating model (1) prior to 2005. Over 2001-2004, I consider 2004 as a placebo policy intervention (i.e. "Post RegNMS"$_t \equiv \mathbb{1}\{t \geq 2004\}$) and run DiD regressions up until Reg NMS became fully effective. Columns (1) through (3) in Table (6) confirm that potential observed and unobserved heterogeneity between broker-dealers in areas with varying degrees of IT intensity are unlikely to drive the employment effects I attribute to Reg NMS.

Anticipatory IT investment. A potential concern with the IT intensity measure is that if the county-level number of PCs per worker would reflect firms' ongoing shift toward electronic trading, values of IT_c^{2004} might correlate with unobserved trends in technology upgrading. This would in turn exacerbate the effects on employment attributed to Reg NMS in my baseline model, since a county with high PC-worker ratio could already be automating trading at a faster rate.

The CI Technology Database offers a variable tracking the growth of a specific technology for every firm, which I denote by ΔIT_j^{fin}. For example, if firm j had 30 computers per worker in 2004, $\Delta IT_j^{fin} > 0$ indicates whether the firm had been increasing the number of computers until the observed 30 units. I test whether the trend in IT upgrading pre-2004 predicts employment growth in columns (4) and (5) of Table (6). The non-significant coefficients indicate that local trends in IT upgrading are uncorrelated with future employment changes.

D. Market Switching

These results are forthcoming.

7 Skills and broker-dealer performance

A. Skill premium

The financial sector has experienced a dramatic increase in pay and education level since the 1980s. Most of this trend is driven by a subset within finance including traders. Reshef and Philippon (2012) show that while credit intermediation, insurance, and trading services had a wage premium of about 50% over the nonfarm private sector in 1970, average trading wages were 4-fold those in the wide economy by 2010 and credit and insurance wage premia remained relatively constant.

Various papers have proposed theoretical explanations for this surge in financial compensation, ranging from overinvestment in expertise (Glode et al. (2012)), to concentration of workers in the high end of the skill distribution (Glode and Lowery (2016), Célérier and Vallée (2019)) in financial firms and competition for talent (Thanassoulis (2012)). Trading in electronic markets involves a considerably higher level of skill and technical ability than trading did until the late 1990s. If electronic trading complements the skills of highly educated traders, one would expect the wage skill premium between this group and stockbrokers without college degree to widen after Reg NMS. I test formally for the presence of a skill-biased channel by running a difference-in-difference-in-differences (DDD) regression:

$$\begin{aligned}\ln\left(Wage_{ict}\right) =& \alpha_0 + \delta_0 \text{Post RegNMS}_t + \delta_1 \left(\text{Post RegNMS}_t \times \text{Skilled}_i\right) \\ &+ \delta_2 \left(IT_c^{2004} \times \text{Post RegNMS}_t\right) + \delta_3 \left(IT_c^{2004} \times \text{Post RegNMS}_t \times \text{Skilled}_i\right) \\ &+ \gamma X_{ict} + \lambda_t + \mu_c + \varepsilon_{ict}\end{aligned}$$

where the coefficient δ_3 in the reduced-form equation measures how Reg NMS affected high-skill (college or more) brokers in areas with historical intensive IT use deferentially from low-skill workers. The outcome is log hourly wage and personal characteristics in X_{ict} include gender, experience (linear and squared), and number of children. If electronic trading is a skill-biased technology, we expect the wage differential to be positive, $\delta_3 > 0$.

The DDD model uses pooled census data instead of a longitudinal firm-worker panel as in the baseline model. To properly identify δ_3, I rely on the stronger assumption that within county and netting out controlled observable characteristics, brokers in the repeated cross section do not differ systematically over time. The estimate is reported in column 5 of Table (5). The positive effect shows that Reg NMS increased hourly wages of high-skill workers in areas with an additional computer per broker by 0.1% compared to low-skilled workers. This translates as roughly $100 annually at the mean.

B. Financial performance

These results are forthcoming.

8 Alternative Explanations

This section discusses and tests the role of two potentially confounding factors to my empirical design. First, the Great Recession exerted differential effects in local labor and housing markets, which could affect the demand for brokerage services to a greater extent in areas with higher pre-policy IT intensity. The rise of online discount brokerage services that started in the early 2000s could also affect the demand of customers for retail and perhaps even institutional brokerage firms, which in turn could feedback into those broker-dealers trading for their own accounts.

8.1 The Great Recession

The economic downturn during 2007-2009 impacted in particular housing markets and certain financial institutions with excessive leverage, to a great extent because of mortgage-backed securities and CDO holdings. At a high level, employment losses, credit crunch, and deterioration of household balance sheets during the Great Recession could all affect the demand for brokerage services, even if stockbroker firms were not directly affected by these local shocks. One of the controls included in the baseline model - local stock market wealth - is a first attempt to control for heterogeneity in shocks to individuals' income from stock markets. The analysis below intends to capture channels through which the Great Recession could bias my main results.

A. Plausibly unaffected workers

Futures traders. Given that Reg NMS should only directly affect broker-dealer individuals trading stocks, one could test to whether other financial workers plausibly unaffected by the provision also experienced similar employment losses during 2001-2009. The idea with this exercise is to use two classes of financial workers that could be affected *only through* the Great Recession to test whether the "post-policy" period is really picking up the effects from the financial crisis. Table (7) first reproduces model (4) using the employment of individuals in FINRA's database only holding Series 3. This license allows traders to buy and sell derivatives contracts, though these workers represent the subset of futures traders employed at firms licensed as securities broker-dealers and not solely as FCMs, for example. The non-significant coefficient in column (1) indicates that Reg NMS does not appear to affect these traders, as expected.

Other financial workers. A second, related test uses local employment (at the county level) in the financial sector excluding security, commodity brokerage, and investment companies. The data use employed individuals between ages 18 and 64 working in the following industries: Banking, saving institutions, credit unions, credit agencies, and insurance companies from March supplements of Current Population Surveys (CPS) from 2001-2009. Results in column (2) indicate that employment in the finance-wide industry actually increased post-Reg NMS in counties with higher historical presence of computers per worker. Of course, these effects should not be attributed to Reg NMS. Instead, they point out to a lack or even positive trend in employment of non-stockbroker workers during 2007-2009 relative to the 2001-2006 period. There is no reason to expect differential effects of the Great Recession for these workers compared to the Series 7 individuals used in the baseline analysis given that the Reg NMS channel through electronic trading is shut off.

Investment banks. Finally, excluding large investment banks produces no effect on the the estimate of interest. The *Big 5* (Goldman Sachs, Merrill Lynch, Morgan Stanley, JP Morgan, and Lehman Brothers) were particularly affected by the financial crisis, especially Lehman Brothers who filed for bankruptcy in October 2008 (Longstaff (2010), Ivashina and Scharfstein (2010), Aragon and Strahan (2012)). Of course, it is known that the effects of the financial meltdown on these banks' spreadsheets spilled over and contaminated various financial institutions. While completely controlling for such effects is not possible with my dataset, the robustness of the baseline results to excluding those banks plausibly affected the most by the financial crisis lends further credibility to the role of Reg NMS in accounting for the employment dynamics of stockbrokers.

Omitting New York. Given that New York accounts for nearly 25% of stock traders in the US and the region was among the ones with highest pre-policy IT intensity levels, one might worry that the results throughout the paper are driven by NYC. In columns (4) and (5), I omit New York broker-dealer firms and workers, respectively. Estimates are nearly identical to the ones when NYC is included.

B. Housing Bust

Unfortunately, FINRA's database does not provide broker-dealer firms' holdings. As a consequence, I can only attempt to control for only potential effects of falling home prices on households' balance sheets and thereby on the demand for brokerage services.

Housing net worth channel. Previous work by Mian et al. (2013) has shown that the 2006-2009 housing collapse affected consumption differentially across the US depending on the local composition of household balance sheets. One potential implication of this decline in housing net worth is that perhaps the demand for risky assets decreased to mitigate income effects. I use a repeat-sales home price index from the Federal Housing Finance Agency (FHFA) to answer whether the negative effects on stockbroker employment remain after controlling for the deterioration of home values. The estimate in column (6) remains unchanged.

8.2 Online Brokerage Services

To conclude the empirical analysis, an additional test checks the possibility that growth in local demand for online brokerage services impacted broker-dealer firm employment. Online brokerage firms, usually discount brokers, offer online infrastructure for individual investors to have access to financial markets without relying on traditional broker dealer firms. Analyzing the impact of this type of online financial service is challenging if such platforms do not provide granular data on costumer accounts over time and across space. Consider for instance E*Trade, one of the first and major online brokers in the US. E*Trade only publishes the aggregate annual number of active accounts in the US. Measuring the influence E*Trade on traditional broker-dealers requires the spatial allocation of these aggregate numbers.

I circumvent this issue by exploiting spatial variation in relative search traffic for "E*Trade" using Google Trends to allocate US E*Trade accounts to each county in my sample. Other papers have used Google Trends in distinct contexts to instrument for local demand or awareness for certain services, such as AirBnb (Barron et al. (2018)). For each year, Google assigns a value of 100 to the MSA with the largest number of searches of the term "E*Trade" and then ranks other MSAs relative to the top search area. This ranking generates spatial variation in the intensity of the "interest" for the searched term, which I then use to allocate aggregate brokerage accounts available from E*Trade 10-K forms to each county in my analysis. In column (7) of Table (7), including this local measure of demand for online brokerage services as an additional control in the baseline specification does not affect the estimated effects of Reg NMS.

9 Conclusion

This paper documents large negative effects on broker-dealer employments caused by trading automation promoted by Regulation National Market System (Reg NMS) in 2007. The average US county with registered broker-dealers lost 120 stockbroker jobs during 2007-2009 for each additional computer per trader when the policy was introduced. This large elasticity of employment with respect to computer capital align with extensive-margin adjustments of labor when workers perform cognitive and manual tasks that can be automated (Autor et al. (2003)).

I show that this technology adoption process was prompted by Reg NMS, whose goal of increasing competition between trading exchanges produced several consequences for financial markets, workers, and firms. By fostering speed-driven competition, the policy is partially responsible for prompting stock trading firms to automate trading, reduce stockbroker employment, and increase pay of highly skilled traders in excess to unskilled workers. Whether these labor-saving changes made trading firms more efficient and traders more productive remains an open question for future work.

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ONLINE APPENDIX

I Detailed Data Description

I.1 Broker-Dealer Sample

More details are forthcoming.

I.2 Broker-Dealer Financial Information

Contrary to other financial data readily available to the public, including from forms 10-K and 8-K, until 2017, X-17A-5 (or Financial and Operational Combined Uniform Single (FOCUS) Reports) documents were submitted only in paper and not indexed in SEC's Index Files. This makes scraping and handling these forms a much more difficult task than parsing financial information from most other filings. The SEC publicly stores only PDF scans of paper filings along all other documents filed by a certain entity.

To retrieve and process financial filings from US broker-dealers, I do this... More details in Appendix X.

under its Virtual Private Preference Room (VPPR), from where I retrieve annual X-17A-5 documents using the following procedure.

First, I obtain SEC Central Index Key (CIK) codes for all broker-dealers in my sample after matching their names to SEC's official company names. Every X-17A-5 submitted by a company in a given year is uniquely identified by SEC's film number (or Document Control Number – DCN), and PDF scans in VPPR are organized according to combinations of DCN segments. After searching for each broker-dealer's annual DCN corresponding to their annual X-17A-5 form using the R package `edgar`, I scrape VPPR and download nearly 40,000 X-17A-5 documents filed from 2001 through 2020.

1. Obtain all entity names associated with a given FINRA CRD code
2. Obtain all Central Index Key (CIK) codes for each of the entity names
3. Find under which CIK forms 13F and X-17A-5 are filed
4. Find SEC Document Control Numbers (DCNs) of every filing
5. Retrieve paper document based on DCN

I illustrate the multiple steps necessary to connect financial information across different SEC and FINRA databases using Goldman Sachs as an example. FINRA's database lists four different entity names under Goldman Sachs' CRD code 361: i) **Goldman Sachs & Co. LLC**, ii) **Goldman Sachs Asset Management**, iii) **Goldman Sachs & Co.**, and iv) **Marcus Invest Offering of Goldman Sachs & Co. LLC**. Each of these entities may file under different Central Index Key (CIK) codes. Often times, the same nominal entity has several CIKs for filing specific forms. For example, under the **Goldman Sachs & Co. LLC** name, there are three CIKS: 42352,

734700, and 769993. Neither 734700 nor 769993 file X-17A-5 forms, but 769993 files 13F-NTs – a 13F notice required when the entity's holdings are reported by another manager, usually the parent or holding company. These forms list **Goldman Sachs Group Inc.** as the entity filling 13Fs including the assets of **Goldman Sachs & Co. LLC**. Finally, **Goldman Sachs & Co. LLC** files X-17A-5 forms under CIK 42352. Each of these filings is given a unique
, like the one below for 2002:

A. Parsing Financial Documents

As mandated by Section 17 of the Securities Exchange Act of 1934, Rule 17a-10(a)(1), registered broker-dealers are required to submit X-17A-5 forms every year. These documents have statements of financial and operations condition, among other information such as net capital requirements (Rule 15c3-1). Most PDF scans in SEC's VPRR do not have digitized text, so that extracting and parsing text data from X-17A-5 forms requires the use of an optical character recognition (OCR) engine. These are detection algorithms designed to extract text from images and can be fine-tuned to convert images of statement of cash flows tables, for example, into standard text strings. I use Google Tesseract to convert X-17A-5 forms similar to the one in Figure **X** into financial data for US broker-dealers.

I.3 Patents

Based on the description of the patent's fillings. For example, the description of an electronic spread trading tool patent filed by Trading Technologies International, Inc. from Chicago, starts as: "*A versatile and efficient electronic spread trading tool to be used when buying and selling comparable commodities either simultaneously or in conjunction with one another.*"

Figures

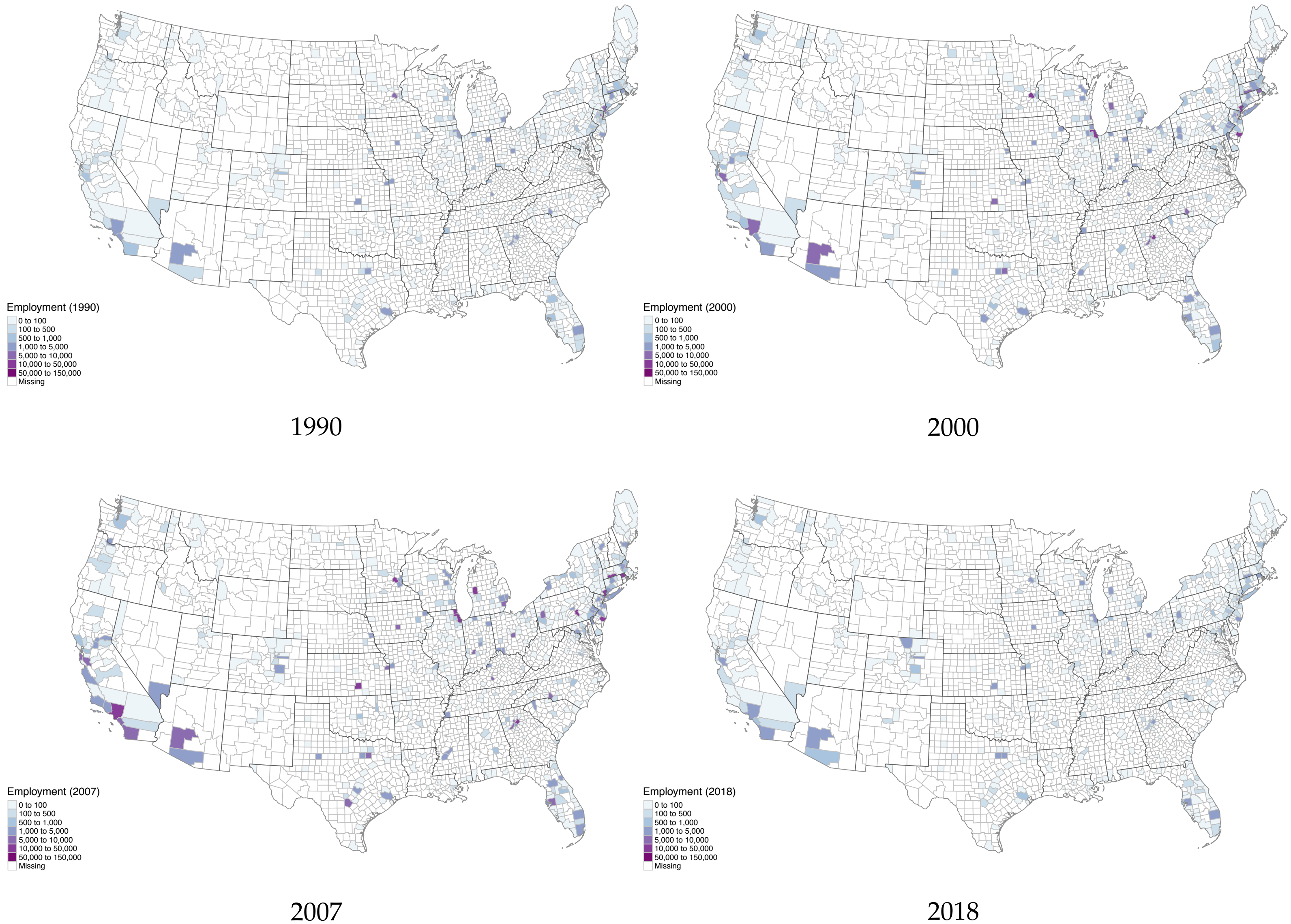
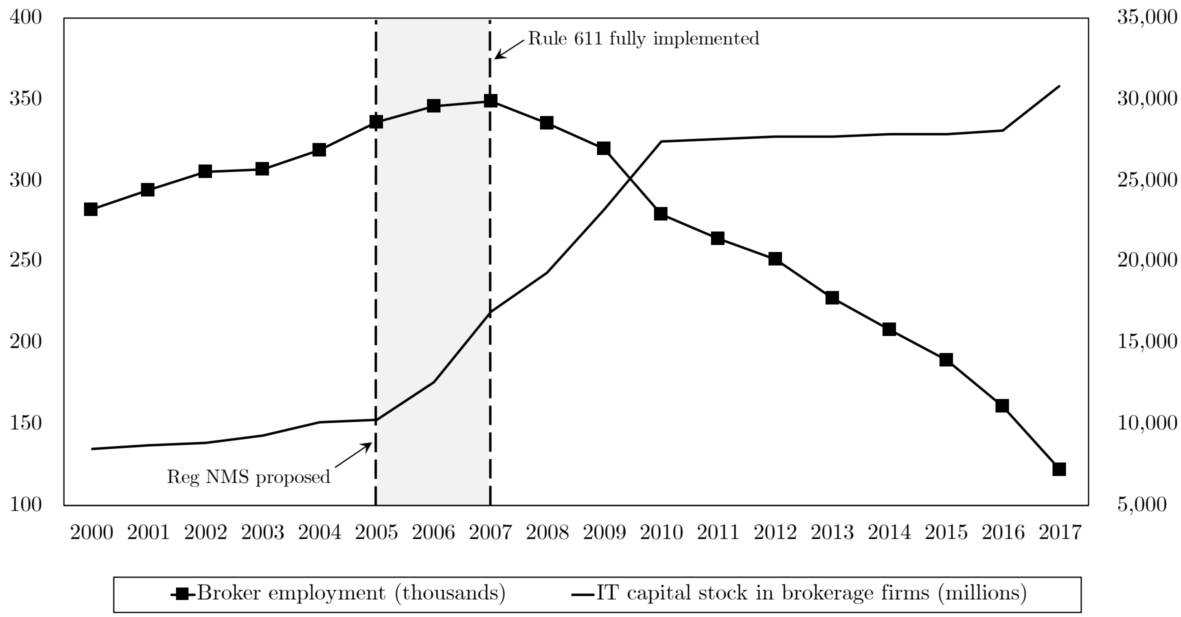
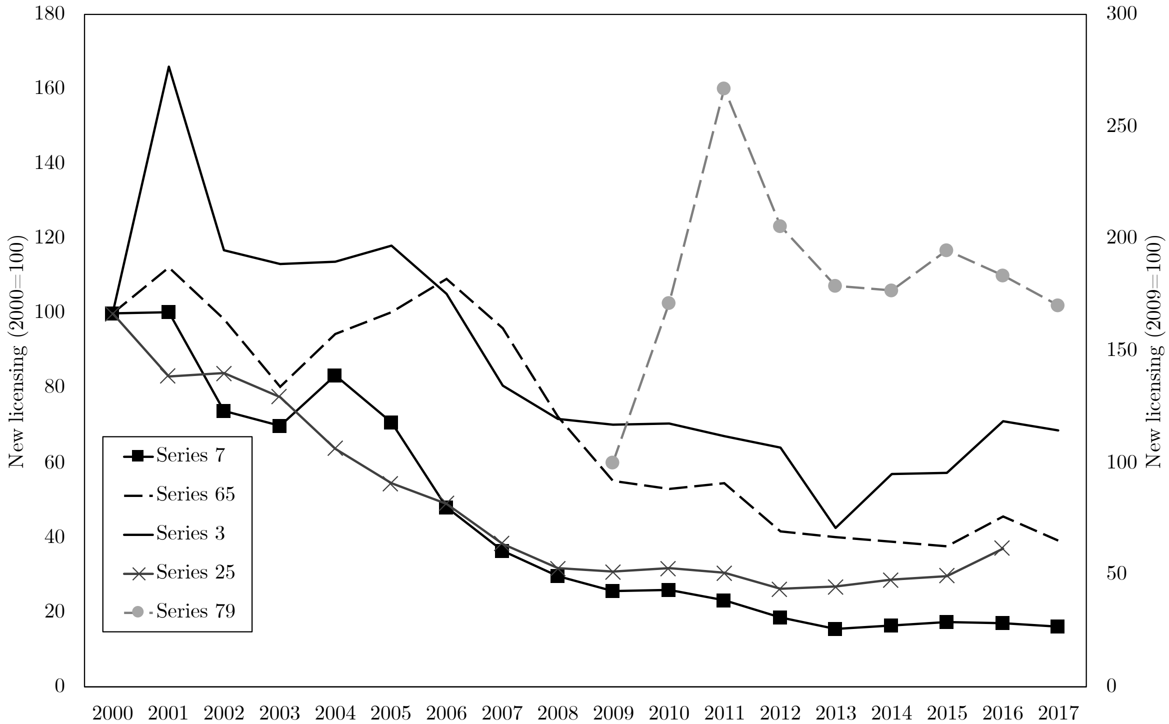


Figure 1: EVOLUTION OF BROKER-DEALER EMPLOYMENT: US COUNTIES



Notes: This figure compares the evolution of IT capital stock and employment in the securities, commodities, and investments industry. The employment series aggregates all individuals registered in FINRA's Central Registration Depository (CRD) and with an active registration and employer in each respective year. Dashed lines indicate Regulation NMS rollout period. The IT capital stock series is constructed similarly to the IT capital intensity in Reshef and Philippon (2012).

Figure 2: JOBS AND TECHNOLOGY IN TRADING



Notes: This figure shows the examination years of individuals working for broker-dealer firms registered with FINRA. Passing each exam grants an individual a license status to trade certain products or perform certain activities related to the examination's scope. Series 7, or *General Securities Representative Qualification Examination* is a broad examination used as proxy for a securities broker-dealer. Series 65 (*Uniform Investment Adviser Law Examination*) licenses individuals to become investment advisors. Series 3 (*National Commodities Futures Exam*) allows individuals to buy and sell commodities. Series 25 (*NYSE Trading Assistant Exam*) is a proxy for entry as NYSE floor-brokers. The exam was terminated in 2016. On the right-axis, Series 79 (*Investment Banking Representative Exam*) is a new examination introduced by FINRA for individuals to work as investment bankers.

Figure 3: BROKER-DEALER LICENSING

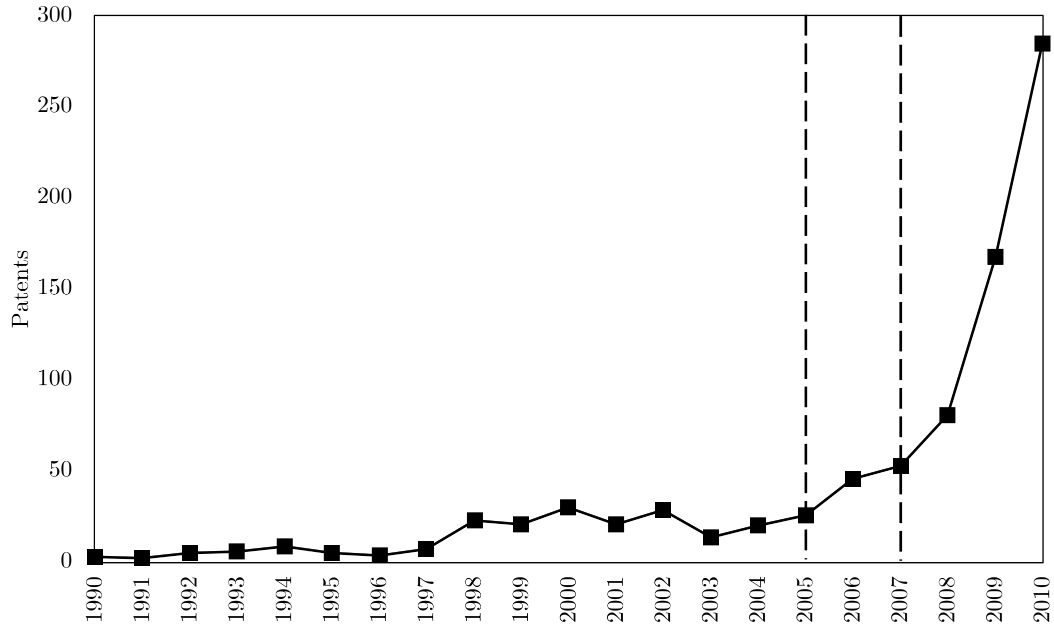


Figure 4: PATENTS RELATED TO ELECTRONIC TRADING

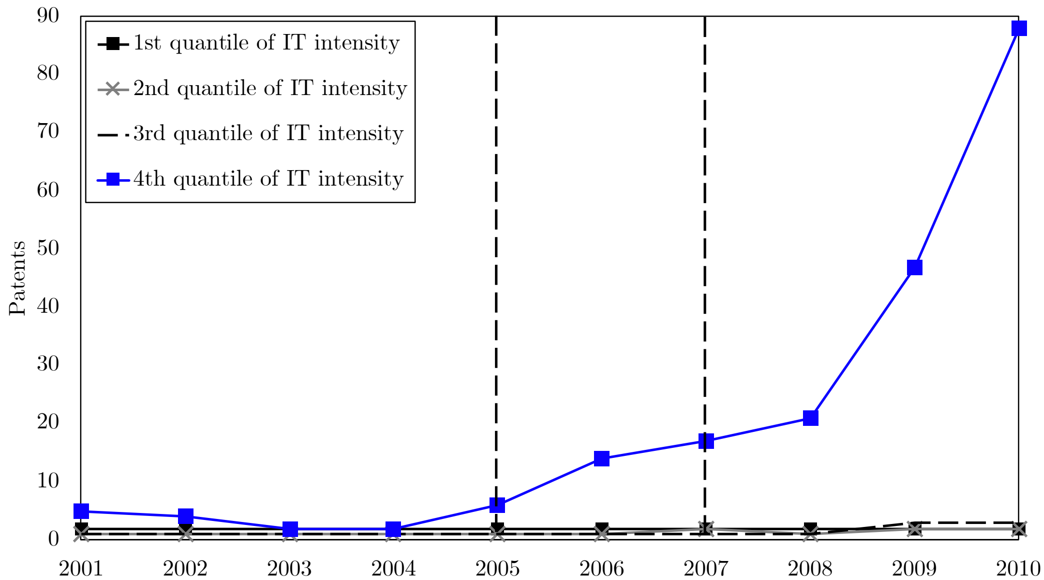
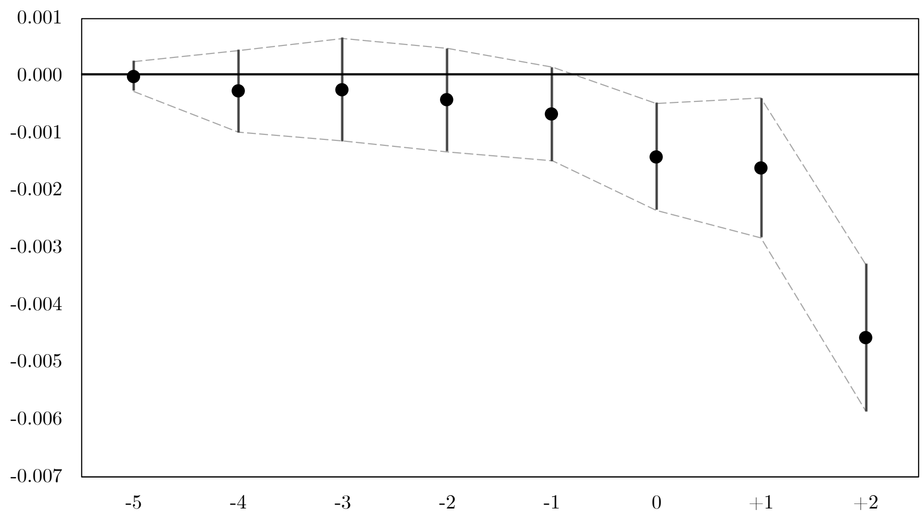
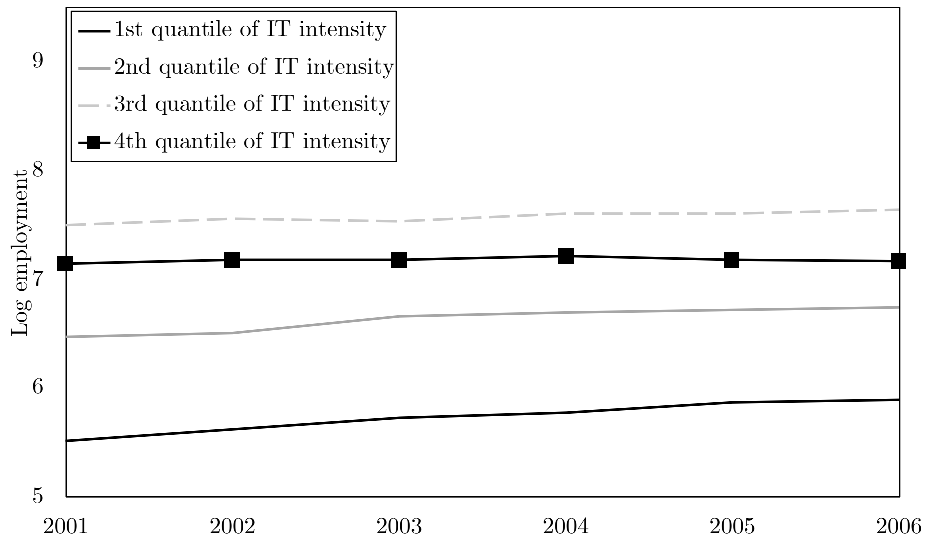


Figure 5: PATENTS RELATED TO ELECTRONIC TRADING



Notes: This figure displays 90% confidence intervals of difference-in-differences estimates of model (3).

Figure 6: TIMING ESTIMATES OF REG NMS EFFECTS ON EMPLOYMENT



Notes: This figure plots annual median log employment of Series 7 traders in broker-dealer firms at different levels of IT intensity in 2004 (pre-policy base year).

Figure 7: PRE-TRENDS IN LOG EMPLOYMENT

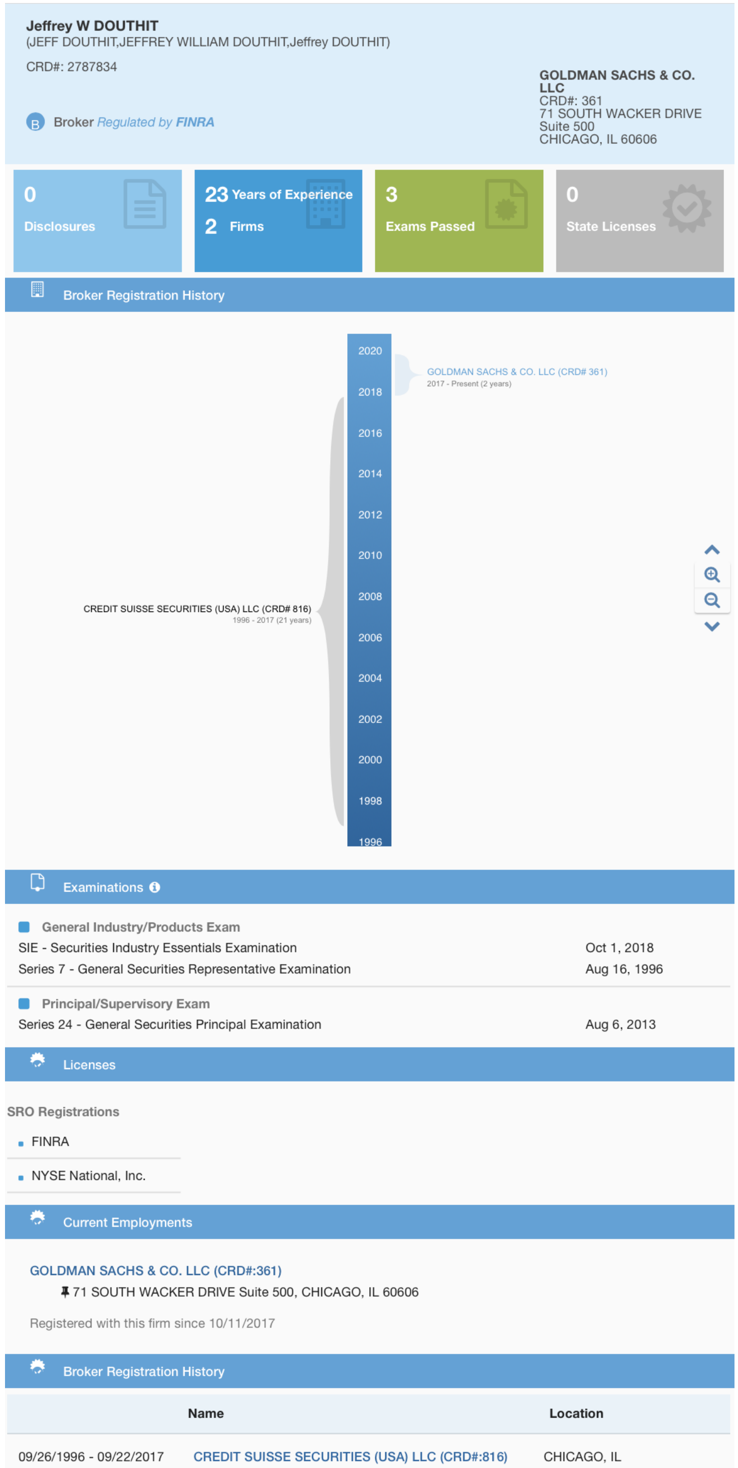


Figure A.1: Example of Broker-Dealer Registration Record from BrokerCheck.com

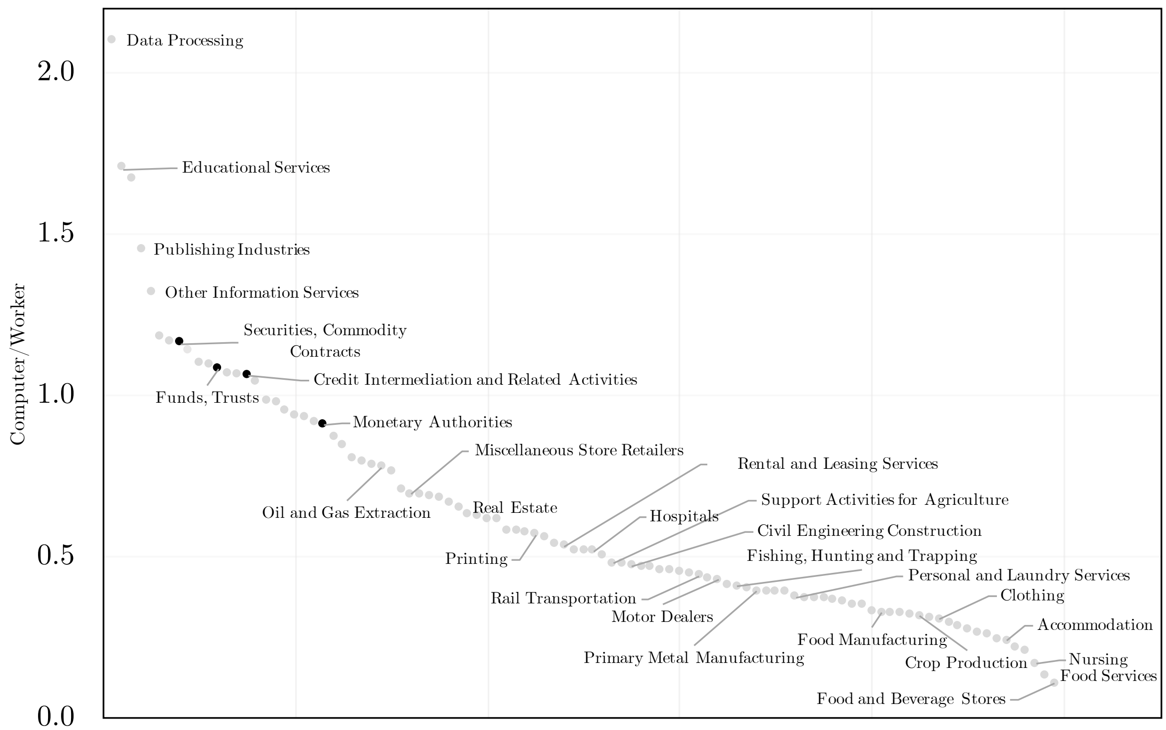
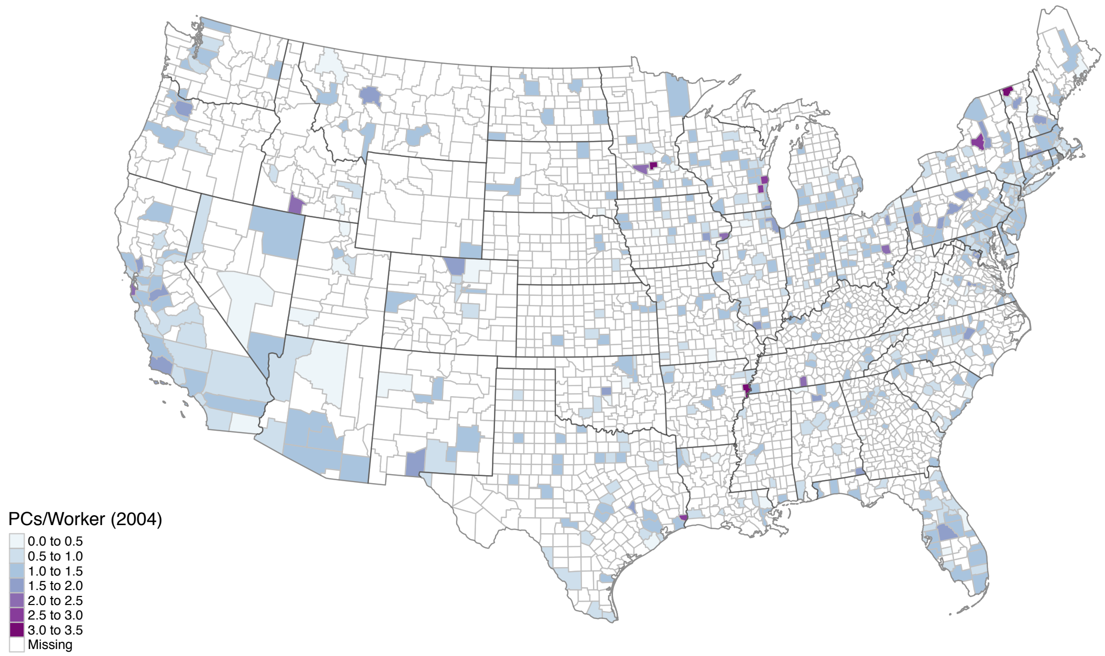


Figure A.2: IT INTENSITY ACROSS INDUSTRIES



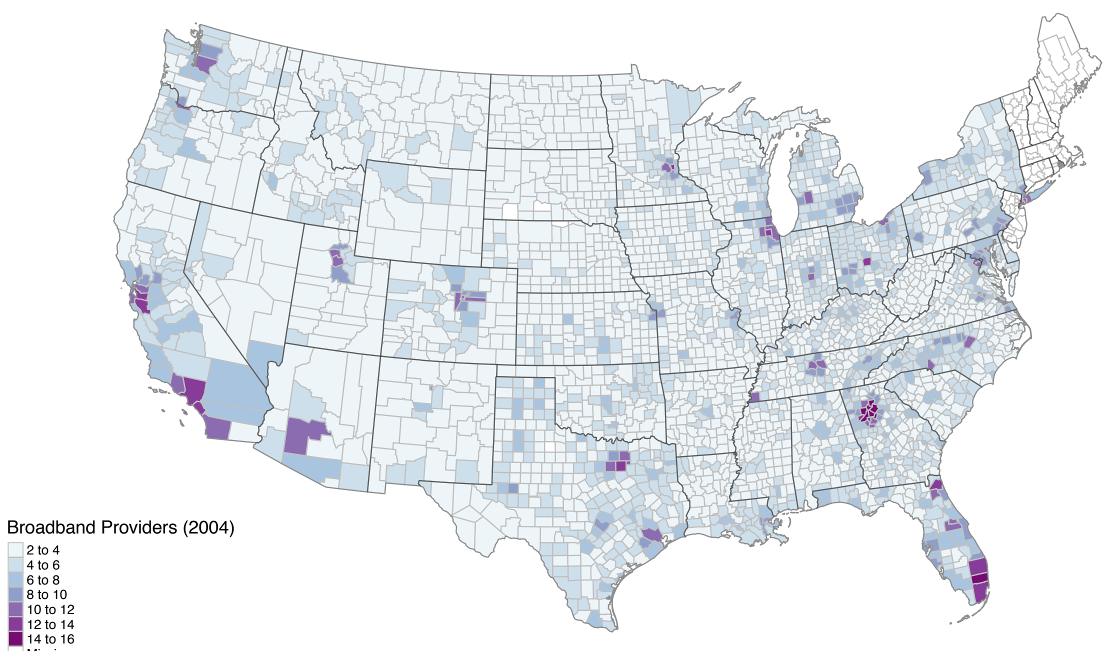


Figure A.3: CROSS-SECTIONAL VARIATION: IT INTENSITY AND BROADBAND PROVIDERS

SECURITIES 01 01 1018 COMMISSION
Washington, D.C. 20549

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ANNUAL AUDITED REPORT
FORM X-17A-5
PART III

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SEC FILE NUMBER
8-32706

FACING PAGE
Information Required of Brokers and Dealers Pursuant to Section 17 of the Securities Exchange Act of 1934 and Rule 17a-5 Thereunder

REPORT FOR THE PERIOD BEGINNING 10/01/00 (MM/DD/YY) AND ENDING 09/30/01 (MM/DD/YY)

A. REGISTRANT IDENTIFICATION

NAME OF BROKER-DEALER: NOBLE INTERNATIONAL INVESTMENTS, INC.
[illegible]

OFFICIAL USE ONLY
FIRM ID. NO.

ADDRESS OF PRINCIPAL PLACE OF BUSINESS: (Do not use P.O. Box No.)

6501 Congress Avenue, Suite 100
(No. and Street)

Boca Raton	FL	33487
(City)	(State)	(Zip Code)

NAME AND TELEPHONE NUMBER OF PERSON TO CONTACT IN REGARD TO THIS REPORT

DENNIS J. ROSA (561) 994-1191
(Are Code – Telephone No.)

B. ACCOUNTANT IDENTIFICATION

INDEPENDENT PUBLIC ACCOUNTANT whose opinion is contained in this Report*

AHEARN, JASCO + COMPANY, P.A.
(Name – if individual, state last, first, middle name)

190 SE 19TH AVENUE	POMPANO BEACH	Florida	33060
(Address)	(City)	(State)	(Zip Code)

CHECK ONE:

- ☑ Certified Public Accountant
- ☐ Public Accountant
- ☐ Accountant not resident in United States or any of its possessions.

PROCESSED
MAY 20 2002
THOMSON FINANCIAL

FOR OFFICIAL USE ONLY

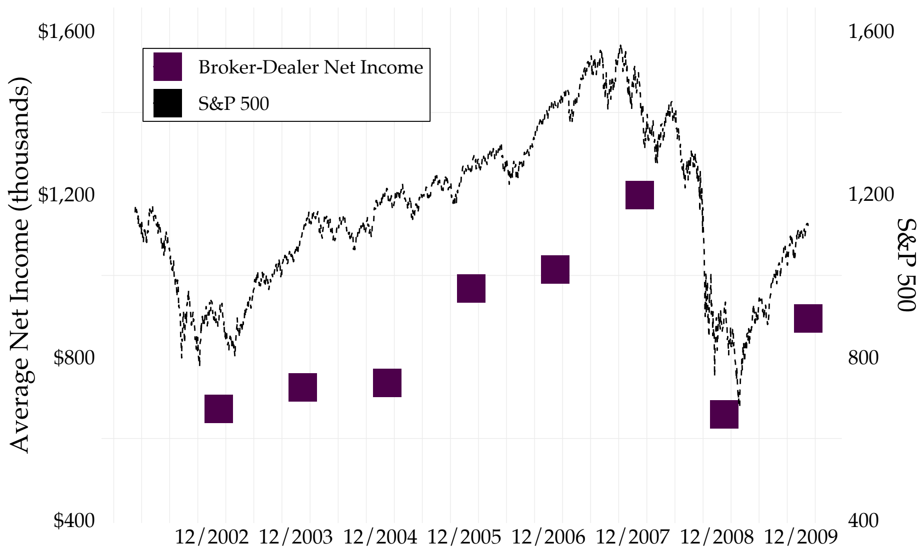
**Claims for exemption from the requirement that the annual report be covered by the opinion of an independent public accountant must be supported by a statement of facts and circumstances relied on as the basis for the exemption. See Section 240.17a-5(e)(2).*

Potential persons who are to respond to the collection of information contained in this form are not required to respond unless the form displays a currently valid OMB control number.

SEC 1410 (3-91)

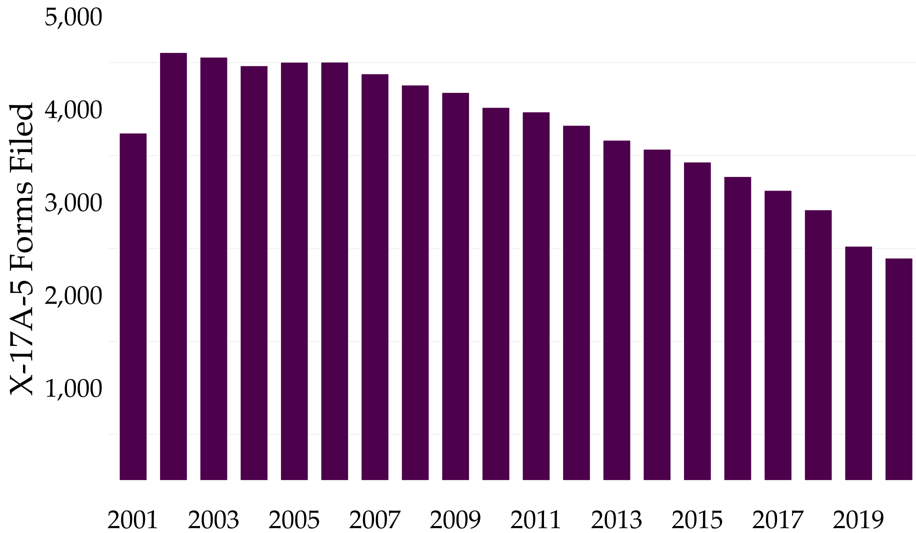
Notes:

Figure A.4: EXAMPLE OF FORM X-17A-5



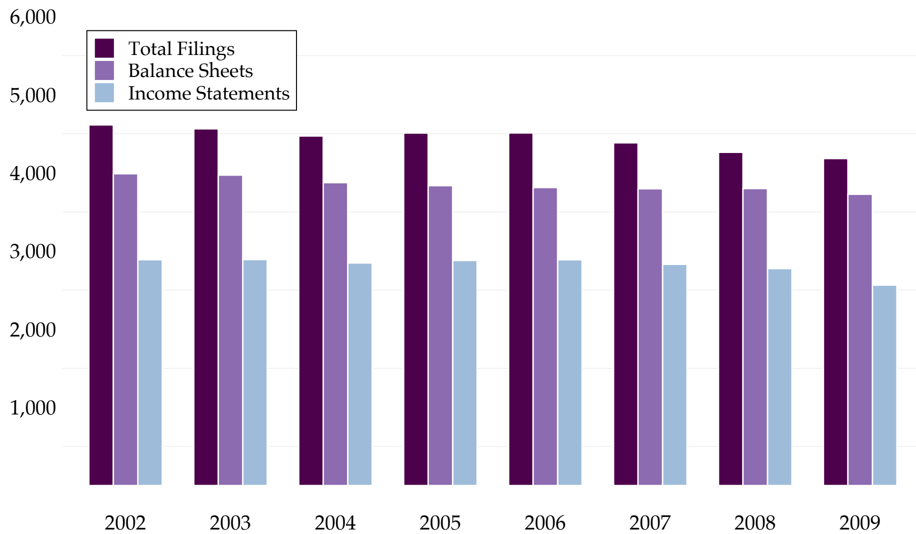
Notes: This figure plots annual median log employment of Series 7 traders in broker-dealer firms at different levels of IT intensity in 2004 (pre-policy base year).

Figure 12: Broker-Dealer Profitability and Stock Market Return



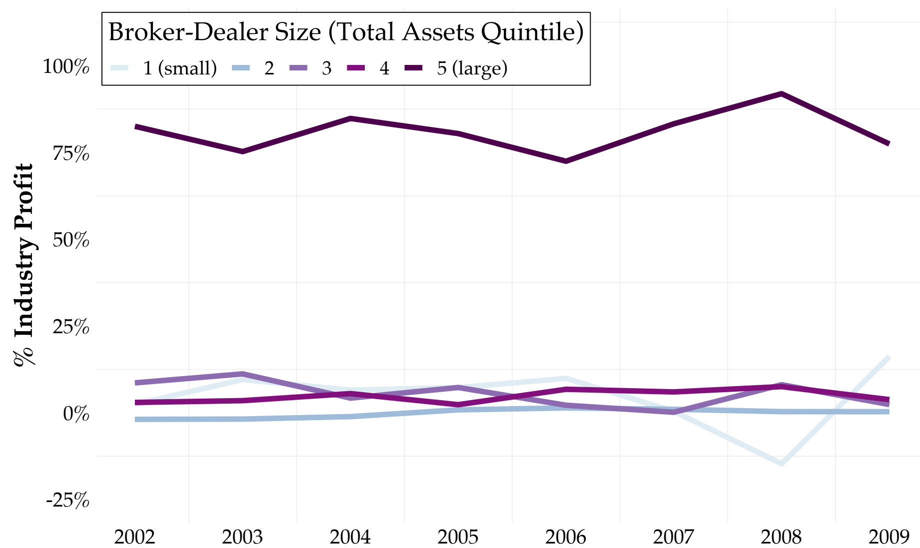
Notes: This figure plots annual median log employment of Series 7 traders in broker-dealer firms at different levels of IT intensity in 2004 (pre-policy base year).

Figure 13: NUMBER FILED EVERY YEAR



Notes: This figure plots annual median log employment of Series 7 traders in broker-dealer firms at different levels of IT intensity in 2004 (pre-policy base year).

Figure 14: NUMBER FILED EVERY YEAR



Notes: This figure plots annual median log employment of Series 7 traders in broker-dealer firms at different levels of IT intensity in 2004 (pre-policy base year).

Figure 15: NUMBER FILED EVERY YEAR

Tables

Table 1: Counties with Largest Broker-Dealer Employment

County	Major City	Broker-Dealer Employment	% Overall Employment	IT intensity rank (Out of 287)
Panel A. 2004				
New York, NY	New York City	55,276	24%	3
Atlantic, NJ	Atlantic City	17,056	7%	117
Hennepin, MN	Minneapolis	11,671	5%	44
Hudson, NJ	Jersey City	9,385	4%	30
Los Angeles, CA	Los Angeles	7,444	3%	145
Cook, IL	Chicago	7,154	3%	52
Suffolk, MA	Boston	6,527	3%	5
Providence, RI	Providence	5,471	2%	40
San Mateo, CA	San Mateo	4,872	2%	56
Fulton, GA	Atlanta	4,532	2%	4
Panel B. 2009				
New York, NY	New York City	44,636	20%	3
Atlantic, NJ	Atlantic City	15,691	7%	117
Hudson, NJ	Jersey City	10,177	4%	30
Dauphin, PA	Harrisburg	10,020	4%	80
Atlantic, NJ	Atlantic City	8,728	4%	117
Hennepin, MN	Minneapolis	7,472	3%	44
Los Angeles, CA	Los Angeles	7,247	3%	145
Lake, IL	Waukegan	6,614	3%	230
Hampden, MA	Springfield	5,286	2%	20
Suffolk, MA	Boston	4,914	2%	5
Cook, IL	Chicago	4,670	2%	52

Notes: This figure shows cross-sectional correlations between the high-low spread estimator (using the zeros adjustment) and the effective spreads from 100 random samples of 10, 100, and 1,000 stocks from DTAQ US stock data. There are 3,398 stocks in total and sample construction details are described in Appendix (**??**).

Table 2: BROKER-DEALER PROFITS
BASELINE MODEL

	Aggregate Profits$_{ct}$ (1)	Largest Brokers % of Aggregate Profits$_{ct}$ (2)	Broker-Dealer Profit$_{fct}$ (3)	Broker-Dealer Profit$_{fct}$ (4)	Broker-Dealer Entry$_{ct}$ (5)
Post RegNMS $\times$ IT_c^{2004}	0.295***	0.445**	0.059**	0.058**	−0.248**
	(0.099)	(0.215)	(0.027)	(0.028)	(0.119)
Total Assets$_{fct}$				3.076***	
				(0.854)	
$t = \{2002, 2009\}$	X	X	X	X	X
Year fixed effects	X	X	X	X	X
County fixed effects	X	X	X	X	X
Broker-dealer fixed effects			X	X	
Observations	886	886	6,940	6,940	645
R-squared	0.89	0.14	0.78	0.79	0.95

Notes: This figure shows cross-sectional correlations between the high-low spread estimator (using the zeros adjustment) and the effective spreads from 100 random samples of 10, 100, and 1,000 stocks from DTAQ US stock data. There are 3,398 stocks in total and sample construction details are described in Appendix (**??**).

Table 3: ELECTRONIC TRADING PATENTS
FIRST-STAGE & ROBUSTNESS

	$\ln\left(Patents_{ct}^{EC}\right)$
Post RegNMS $\times$ IT_c^{2004}	0.010***
	(0.001)
Year fixed effects	X
County fixed effects	X
Individual-year observations	7,416
R-squared	0.93

Table 4: EMPLOYMENT OF SECURITIES BROKER-DEALERS
BASELINE MODEL

	$\ln\left(Emp_{fct}\right)$ (1)	$\ln\left(Emp_{fct}\right)$ (2)	$\ln\left(Emp_{fct}\right)$ (3)	Emp_{ict} (4)	Emp_{ict} (5)
Post RegNMS $\times$ IT_c^{2004}	-0.001***	-0.002***	-0.003***	-0.001***	-0.001***
	(0.0003)	(0.0004)	(0.0009)	(0.0002)	(0.0002)
$\ln\left(\text{Income per capita}\right)_{ct}$			1.008*		-0.505*
			(0.574)		(0.293)
Stock market wealth$_{ct}$			-0.022		-0.004
			(0.034)		(0.005)
$t = \{2004, 2007\}$	X				
Year fixed effects		X	X	X	X
County fixed effects	X	X	X	X	X
Individual-year observations	3,946	20,853	20,853	2,066,490	1,082,196
R-squared	0.52	0.49	0.38	0.28	0.21

Notes: Table reports OLS differences-in-differences regressions. Columns (1)-(3) have as outcome the firm-level log employment of broker-dealers holding Series 7 licenses, while columns (4) and (5) regress the employment status of these brokers. The sample only includes individuals who took Series 7 Examination. The time period spans 2002 through 2009. Observations in columns (1)-(3) are weighted by 2000 level employment. Clustered standard errors are given in ().

Table 5: EMPLOYMENT AND WAGE OF SECURITIES BROKERS
ROBUSTNESS

	$\ln\left(Emp_{fct}\right)$ (1)	$\ln\left(Emp_{fct}\right)$ (2)	$\ln\left(Emp_{fct}\right)$ (3)	$\ln\left(Emp_{fct}\right)$ (4)	$\ln\left(Wage_{ict}\right)$ (5)
Post RegNMS × $\widetilde{IT_c^{2004}}$	-0.003^{***}				
	(0.0001)				
Linear trend × IT_c^{2004}		-0.002^{***}			
		(0.0001)			
$IT_c^{2004} \times \mathbb{1}\{k = t\}$					
$k = 2002$			-1.2×10^{-6}		
			(0.0001)		
$k = 2003$			-0.0003		
			(0.0004)		
$k = 2004$			-0.0002		
			(0.0012)		
$k = 2005$			-0.0004		
			(0.0005)		
$k = 2006$			-0.0007		
			(0.0004)		
$k = 2007$			-0.001^{***}		
			(0.0005)		
$k = 2008$			-0.002^{***}		
			(0.0006)		
$k = 2009$			-0.005^{***}		
			(0.0007)		
Post RegNMS × IT_c^{2004}				-0.004^{***}	
				(0.002)	
IT_c^{2004} × Post RegNMS$_t$ × Skilled$_i$					0.001^{**}
					(0.0003)
Year fixed effects	X		X	X	X
County fixed effects	X	X	X	X	X
Linear trend		X			
$t \times \mu_c$				X	
Individual-year observations	16,245	17,757	33,411	21,535	
R-squared	0.43	0.50	0.50	0.44	0.28

Notes: Column (1) uses a high-speed internet broadband availability measure as the pre-policy exposure variable. (2) Interacts the IT intensity variable with a linear trend. (3) interacts the IT measure with year fixed effects. (4) replicates the baseline model and interacts county fixed effects with a linear trend. (5) runs a DDD specification of wages with differential effects for high and low skilled traders. Clustered standard errors are given in ().

Table 6: EMPLOYMENT OF SECURITIES BROKER-DEALERS
PLACEBO TESTS

	$\ln\left(Emp_{fct}\right)$ (1)	$\ln\left(Emp_{fct}\right)$ (2)	$\ln\left(Emp_{fct}\right)$ (3)	$\Delta\ln\left(Emp_c^{2004-2006}\right)$ (4)	$\Delta\ln\left(Emp_c^{2004-2009}\right)$ (5)
$\mathbb{1}\{t \geq 2004\} \times IT_c^{2004}$	-0.0002	-0.0003	-0.0004		
	(0.0002)	(0.0002)	(0.0003)		
ΔIT_c^{2004}				-0.0003	-0.001
				(0.0006)	(0.001)
t = 2001-2004	X				
t = 2001-2005		X			
t = 2001-2006			X		
Year fixed effects	X	X	X		
County fixed effects	X	X	X		
Individual-year observations	9,268	11,585	13,902	2,442	2,442
R-squared	0.51	0.51	0.50	0.001	0.001

Notes: This table implements several place tests to assess the plausibility of the baseline model. Clustered standard errors are given in ().

Table 7: Great Recession & Online Brokerage Services Robustness

	$\ln\left(Emp_{fct}^{futures}\right)$ (1)	$\ln\left(Emp_{fct}^{otherfin}\right)$ (2)	$\ln\left(Emp_{fct}\right)$ (3)	$\ln\left(Emp_{fct}\right)$ (4)	Emp_{ict} (5)	$\ln\left(Emp_{fct}\right)$ (6)	$\ln\left(Emp_{fct}\right)$ (7)
Post RegNMS $\times$ IT_c^{2004}	0.001	0.004***	−0.002***	−0.002*	−0.0004***	−0.002***	−0.003***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.00002)	(0.001)	(0.001)
$\Delta \ln\left(\text{House Prices}_{ct}\right)$						−0.046	
						(0.307)	
E*Trade$_{ct}$							0.002
							(0.004)
Omit Big 5			X				
Omit New York				X	X		
Year fixed effects	X	X	X	X	X	X	X
County fixed effects	X	X	X	X	X	X	X
Full set of controls	X	X	X	X	X	X	X
Individual-year observations	1,287	11,904	18,496	8,994	1,617,318	22,987	9,304
R-squared	0.61	0.88	0.60	0.59	0.30	0.48	0.33

Notes: The table reports regressions similar to model (4) with sample modifications and additional controls. Clustered standard errors are given in ().