Bank Complexity, Governance, and Risk

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Abstract

While complexity in bank holding companies (BHCs) raises the costs of bank resolution when organizations fail, the contributions of complexity to the broader risk profiles of BHCs are less well understood. Complexity can engender explicit tradeoffs between the agency problems that increase risk and the diversification, liquidity management and synergy improvements that reduce risk. Outcomes of these tradeoffs may be dependent on bank governance. Using measures of organizational, business, and geographic complexity, we test these conjectures using data on large US BHCs for the period between 1996 and 2018. Organizational complexity and geographic scope tend to provide diversification gains and reduce idiosyncratic and liquidity risks while also increasing BHC systematic and systemic risks. We also find that regulatory tightenings focused on organizational complexity significantly reduced this complexity, with BHC liquidity risk also increasing and systemic risk decreasing. Bank governance in some cases significantly affected the buildup of BHC complexity, but did not moderate the effects of complexity on risk.

JEL Classification: G21, G28, G32.

Keywords: Bank complexity, risk taking, regulation, too big to fail, liquidity, corporate governance, agency problem, global banks, diversification.

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1 Introduction

Large and complex banking organizations in the United States have received considerable regulatory scrutiny after the global financial crisis (GFC), with a focus on improving their resilience and reducing the costly externalities that could occur when these organizations fail. While bank size and balance sheet structures garnered extensive analytical attention in too-big-to-fail (TBTF) discussions (Gandhi and Lustig, 2015), relatively little analytical work has focused on the implications of bank complexity. The main orientation has been on how complexity could impede orderly resolution when an institution fails (Carmassi and Herring, 2016). This gap in understanding broader consequences is particularly important, as bank holding company (BHC) complexity rose prior to the GFC and later declined, coinciding with new regulations aimed at enhancing the resolvability of banks in periods of stress (Goldberg and Meehl, 2019). Our study focuses on the relationships between complexity and types of BHC risk, also analyzing how regulatory changes influence banks to adjust complexity and alter the different risks they face.[1]

In theory, complexity should reduce the idiosyncratic risk profile of BHCs if it is accompanied by an increase in diversification of the BHCs income streams and by more efficient internal liquidity management. However, complexity may instead increase the idiosyncratic risk profile if agency problems, internal to the organization, are the dominant consequences of complexity. For example, these can arise if managers pursuing an unchecked "empire building" strategy generate an excessively complex structure, with resulting lapses in risk management. A weak corporate government environment, incentivized by external factors such as implicit subsidies from the government (as denoted in Freixas et al. (2007)), could exacerbate this likelihood.

Even in a strong governance environment, changes in BHC complexity may alter the tradeoffs across different types of risks. BHCs pursuing an income and liquidity diversification strategy may increase complexity and obtain the benefit of lowering idiosyncratic and liquidity risks. For instance, a broader business and geographic scope provides BHCs with a form of insurance against default risks given some forms of shocks (Luciano and Wihlborg, 2014), and may reduce their exposures to liquidity risk (Cetorelli and Goldberg, 2016) and sovereign stress (Baggatini et al., 2018). However, the reduction of these idiosyncratic and liquidity risks may come at the expense of an increase in systematic and systemic risks, which reduce the benefits of complexity from a societal perspective, even if optimal for the individual BHC. Regulators may take these broader tradeoffs into account when assessing the social cost of complexity from a systemic perspective, as well as the availability of toolkits for responding to different types of stresses when they materialize. Through this paper, we dimension this span of positive and negative risk tradeoffs.

[1] Our analysis is part of a coordinated cross-country research initiative of the International Banking Research Network (IBRN), with teams developing analytical tests and approaches to inform this complexity and risk topic.

Our analysis uses data on individual US BHCs larger than $25 billion (in 2012 prices), at quarterly frequency, for the period between 1996 and 2018. We explore three aspects of complexity covering the organizational, business, and the geographic complexity of US BHCs. Taking a long perspective, BHCs expanded their scope into new areas and geographies in the financial intermediation spectrum in the past 30 years, potentially yielding efficiencies in income diversification (Cetorelli et al., 2017). In general, these three areas of complexity decrease for some of the largest BHCs after the GFC. We also construct a broad spectrum of risk exposure measures for these BHCs, covering idiosyncratic risk, systematic or market risk, liquidity risk, and systemic risks. In addition, as the frequencies and drivers of complexity are hypothesized to relate to BHC governance, we construct measures of the institutional investor ownership shares, the duality of CEO and Board of Director chair roles, and BHC board independence.

We test hypotheses on the complexity-risk-governance nexus using panel specifications, which establish the average relations between complexity and risk over time, and using difference-in-difference estimations around relevant regulatory changes. Specifically, we posit that the introduction and accompanying regulations of the 2010 Living Will (LW) guidance of the Dodd Frank Consumer Protection Act (DFA) altered the relationship between bank reported risk and complexity. The DFA includes BHC resolution planning and guidance on legal entity rationalization (in 2017), requiring organizationally complex banks to simplify their structures to ease the resolution process. The DFA liquidity requirements also raised the costs of some forms of complexity by taking into account potential ring fencing, made capital requirements more sensitive to risk in off balance sheet accounts, and in some cases directly addressed banks' organizational structures by requiring a single point of entry for resolvability.

Our first set of key results inform the average relationship between forms of complexity and risk over time, and the contributing role of BHC governance. We find that increases in BHC organizational and geographic complexity are associated with better income diversification. These complexity traits also are associated with lower BHC idiosyncratic and liquidity risks. At the same time, BHCs with more organizational and geographic complexity have greater systematic and systemic risks. These findings, which are economically significant, suggest that the BHCs trade off the beneficial reductions in idiosyncratic and liquidity risks for greater exposures to systematic or market risks and systemic risks as they increase organizational and geographic complexity. Some spill backs occur from risk levels to organizational and geographic complexity, but these are much smaller in economic magnitudes. An important finding is that BHC complexity is positively related to better governance, which supports the hypothesis that it is better governed banks that pursue more complex arrangements to gain in terms of income and liquidity diversification. The alternative hypothesis, of agency problems dominating, is not supported.

Our second set of results address the outcomes of regulatory changes and show that these can have substantial effects on BHC complexity and risk. After being required to submit living wills, BHCs reduced their organizational complexity. The largest BHCs, which have to submit more stringent LWs, achieved the biggest declines in organizational complexity. The introduction of the LW rules was also associated with changes in the risk profiles of US BHCs, differentially changing for large and complex BHCs. BHC exposures to liquidity risk increased, diversification of balance sheets declined, and return volatility increased. At the same time, exposures to systemic risk declined. The most organizationally complex banks were only able to differentially reduce their systemic risks after the introduction of LWs.

Our analysis contributes to insights from recent work in three important literatures. First, significant advances are being made in measuring BHC complexity, including by Cetorelli and Goldberg (2014), Cetorelli and Goldberg (2016), Flood et al. (2017),Carmassi and Herring (2016), Barth and Wihlborg (2017), and Goldberg and Meehl (2019). Most of these studies utilize information on legal entities within BHCs, working primarily with counts of entities and some information about industry type and geographic location. Flood et al. (2017) propose using network concepts that group entities in the BHC through which communication and coordination is relatively easy, with ideas provided for quotienting dimensions. Our contribution relative to prior studies of US BHCs pertain both to measurement, regulatory effects, and relation to risk. We have a specific focus on large banks by size category, the significant changes in a range of complexity measures after regulatory changes such as the DFA (2010) and the recovery and resolution guidance (2017), and the breadth of complexity measures. The novelty on the complexity metric construction side is the use of principle component analysis to extract key features from a range of distinct measures of business and geographic complexity. We add some balance sheet data for BHCs to expand on other conventional measures constructed exclusively from bank structure information.

Second, our work contributes to the rich literatures on bank risk taking (Berger, Ghoul, Guedhami and Roman, 2017; Cetorelli, Jacobides and Stern, 2017), too-big-to-fail and moral hazard for banking organizations (Gandhi and Lustig, 2015; Cetorelli and Traina, 2018; Dam and Koetter, 2012), market pricing of diversification in financial conglomerates (Laeven and Levine, 2007), the effects of bank geographic expansion (Goetz et al., 2013), and bank governance and risks (Laeven and Levine, 2009). In this literature, size is viewed as generating TBTF subsidies that lower the cost of funding for the largest and systemically important institutions (Gandhi and Lustig, 2015). Other studies have noted that increases in business scope across banks are driven by leaders in the banking sector, and these adjustments in the sector are associated with changes in equity returns and funding costs. On geographic diversification, studies focusing on the United States find that they reduce BHC valuations (Goetz, Laeven and Levine, 2016). In general, the market's view of sources of systemic risk (threshold size, complexity, and interconnectedness) have evolved from an exclusive focus on size prior to the crisis, to viewing complexity and interconnectedness as key concerns post-crisis (Antill and Sarkar, 2018). Our paper contributes to this literatures by taking a holistic view on the association between complexity (measured in different areas), governance and the risk profiles of banks.

Third, and relatedly, we contribute to an evolving literature on the consequences of post-global financial crisis bank reforms, mostly focusing on the effects of recovery and resolution planning. We explicitly illustrate how regulations that cover bank liquidity, bank capital and bank resolution are likely to influence the optimal degree of complexity from the vantage point of a BHCs compared to that of a regulator. Each of these types of regulatory environment changes entails a distinct contribution to the tradeoffs among risks that are managed by the BHCs, and by the regulator which also considers externalities associated with systemic risks. We show, schematically, that liquidity regulations tend to reduce BHC exposure to liquidity risk and imply lower optimal geographic and organizational complexity of BHCs, living wills push firms to better internalize the contributions of complexity to systemic risk and imply lower complexity, and bank capital regulations can either raise or lower optimal complexity depending on the relative reductions in different types of risks experienced by BHCs.

Section 2 presents the key hypotheses on the relationships between complexity, governance, and risk, along with a more extensive discussion of related literature as it pertains to the hypotheses. The general forms of specifications for hypothesis testing are presented. Section 3 introduces the data concepts for BHC complexity, governance and risk, and provides key patterns in these metrics for large US BHCs (in excess of $25 billion in total assets), 1996Q1 through 2018Q2. Section 4 presents the results of the econometric exercises, starting with the average relationships between complexity, risk, and governance, specifically exploring the consequences for BHC diversification gains, idiosyncratic risk, liquidity risk, market risk, and systemic risk contributions. Findings over systems of equiations with and equations without instrumental variables provide consistent observations about risk tradeoffs. The changes around living will changes of the DFA are presented. Governance effects are not of first order importance in these relationships. Section 5 concludes with a discussion of why specific forms of complexity and risk have ultimately been changed by regulation. Ultimately we expect that BHC exposures to more idiosyncratic risk and liquidity risk, while reducing exposure to market risk and systemic risk are consistent with improved financial stability outcomes, given the operational and policy frameworks of BHCs and central banks.

2 Hypotheses and testing

This section described the main hypotheses. First, we start with an overview of the regulatory developments in recent years that have shaped the complexity of BHCs. Second, we outline hypotheses on how more complex organizations could inherently take more risks. We posit that the benefits of income diversification through more complex structures are balanced by the costs associated with agency problems . The net effect of these opposite forces could depend on the strength of monitoring and corporate governance. Econometric testing approaches begin by exploring the average association between BHC complexity, diversification and risk using panel techniques including instrumental variables. Third, we focus on the determinants of complexity, specifically addressing the roles that regulation and corporate governance could play in the development of banking organizations over time. We also identify the relation between complexity and bank risk more clearly by testing banks' reactions to regulatory changes that affect bank complexity. Throughout, we show how BHC size and governance could alter outcomes.

2.1 Determinants of bank complexity: regulations and governance

Bank organizations have evolved rapidly over the past 30 years, expanding their size and organizational structure (Avraham, Selvaggi and Vickery, 2012; Cetorelli and Goldberg, 2014), corporate complexity (Carmassi and Herring, 2016), and business scope into new areas in the financial intermediation spectrum (Cetorelli, Jacobides and Stern, 2017). Geographic footprints of banking organizations have evolved, with branch and subsidiary networks expanding for banks (Claessens and Horen, 2014a; Claessens and Horen, 2014b) and also with notable increases in nonbank entities within the bank conglomerates (Goldberg and Meehl, 2019). This process has been influenced by changes in regulations, innovation, and competitive pressures. The slow phase-out of restrictions on banks non-traditional activities, such as securities underwriting, imposed by the Glass-Steagall Act (GSA) began in the late 1980s and early 1990s (Chernobai et al., 2018). This trend culminated with the passage of the Gramm-Leach-Bliley Act (GLBA) in 1999, which repealed the GSA and allowed banks to engage in investment banking activities and also to expand into the insurance business.[2] The scope of business activities further extended to include many types of financial and nonfinancial primary activities, both in US BHCs (Goldberg and Meehl, 2019) and global BHCs (Cetorelli and Goldberg, 2014).

After the global financial crisis, a different wave of regulatory changes focused on reducing financial institutions' systemic risks by limiting their complexity. The Basel III regulatory framework takes into account the complexity of banking organizations in the regulatory capital framework, with the most visible tool being the global systemically important banks (GSIB) capital surcharge. The introduction of Basel III makes complexity more costly for banks, as the externality generated by complexity is internalized by the new capital surcharges or the introduction of additional capital regulations aimed at pricing the cost of risks due to complex structures.[3]

[2] The GLBA amended the Bank Holding Company Act to allow permissible activities related to the insurance business

[3] Note that, even though the negotiations on Basel III were only finalized in 2017, many aspects of the framework that are relevant for our analysis are in the process of being fully implemented.

The DFA passed by the U.S. Congress in 2010 also directly addressed the theme of resolvability of systemic financial institutions. The large size and complexity of some financial institutions makes them especially difficult to resolve in periods of stress, leading to arguments that too big to fail or too complex to fail firms required government bail outs during the global financial crisis. New resolution rules codified in the DFA aimed at reducing the complexity of these institutions to make them easier to resolve. In particular, DFA section 165(d) required banks with $50 billion or more in assets to submit "living wills" on an annual basis. These living wills should ultimately facilitate the resolution of systemically important financial institutions, if needed, as the living wills provide a road map to liquidate these institutions in the event of their failure. These new resolution rules also include guidance for the simplification of banks' organizational structures. For example, the "Guidance for 2017 165(d) Annual Resolution Plan Submission" published in 2016 included criteria for banks to rationalize their legal entities. The objective of these criteria is to facilitate the banks' preferred resolution strategy. The banks should consider adjusting the corporate structure of their legal entities, business models, and geography to satisfy these criteria.

2.2 Average relation between bank complexity, governance, and risk

Regulatory changes, agency problems such as empire building incentives, and business models combine to determine the average level of complexity at banking organizations. Some of that complexity may be beneficial, as the diversification of revenue streams can enhance the resilience of these institutions to some configurations of shocks. However, complexity may also increase risk at the BHC level, if the agency problem is exacerbated by a less transparent organizational structure. This section provides a set of tests to determine whether complexity improves BHCs diversification or, in contrast, whether it increases the risk profile of the banking organizations. Throughout, the hypotheses can generate different outcomes for the distinct forms of complexity, or for alternative types of risks.

Conceptually, a higher degree of complexity may entail broader spans of business activities or wider geographic locations of BHC affiliates. Laeven and Levine (2007) argued that more diversified organizational structures have a higher share of non-financial income and benefit from diversification of their sources of income. More generally, the benefits of diversification should depend on the variance covariance matrix of cash flows, the exposure to systemic risk, and the monitoring and operational costs of managing a complex organization. Moreover, international banks are particularly challenged by information costs related to operating in different jurisdictions and cultures and with adhering to a fractured regulatory landscape (Buch, Koch and Koetter, 2013).

Recent banking research illustrates of how complexity could facilitate the specialization of entities within the full organization and change the exposures to risk. One example supports how complexity could promote synergies in managing liquidity across the entities within a banking organization. If liquidity holdings at banking units are made available to meet the needs of the nonbank parts of the organization, the banking unit might be more liquid than would otherwise be the case, and the exposure of the rest of the organizations exposures to liquidity risk is reduced due to access to intra-organizational reallocations as shown for the branches of foreign complex banks operating in the United States (Cetorelli and Goldberg, 2016). Synergies could also arise if the banks are differentially able to manage risk exposures because of the existence and controls around the related nonbank entities in the organization. In the European sovereign debt crisis, German universal banks shifted risky sovereign holdings from banking units to related mutual funds (Baggatini et al., 2018). The German example showed how synergies from liquidity risk sharing complemented diversification, and actually reduced the exposure of the full BHC to fire sale risk.

At the same time, research supports the view that complex organizations are more difficult to manage, with this problem exacerbated by agency problems and moral hazard (Penas and Unal, 2004; Dam and Koetter, 2012; Duchin and Sosyura, 2014). If monitoring and information costs are high, bank risk may increase. A positive relation between internationalization and bank risk has been identified(e.g. Berger et al., 2017). Agency problems have been discussed for institutions that are considered "too big to fail" (TBTF). Given the difficulty of resolution, these institutions may gamble on government support in times of distress, benefiting from an implicit TBTF subsidy with lower cost of funding (Balasubramnian and Cyree, 2014; Acharya, Anginer and Warburton, 2016). Low funding costs and lack of market discipline create incentives for these banks to take on more risk or to grow beyond their optimal scale. This may lead to increased exposure to tail risk (Arteta, Carey, Correa and Kotter, 2017; Berger, Ghoul, Guedhami and Roman, 2017), with this "dark side" of complexity leading to excess risk taking, for example with divisional rent seeking and inefficient investment (Scharfstein and Stein, 2000).

These factors support our First set of hypotheses, namely:

Hypothesis 1a: *Bank complexity reduces the risk profile of banks if its accompanied by an increase in the diversification of banks' income streams.*
Hypothesis 1b: *Increased bank complexity should only reduce risks for banks with stronger corporate governance.*

The potential endogeneity between complexity and risk complicates the identification of this relation, as more complex organizational structures may lead to riskier banking organizations while riskier organizations may seek more complex organizational structures. This could be the case if there is an omitted variable that is correlated with complexity. The executive compensation literature observes that managers may be incentivized to pursue riskier strategies through specific compensation arrangements (Coles et al., 2006; DeYoung et al., 2013). Compensation may lead managers to develop riskier strategies through more complex organizational structures.

We test these hypotheses by estimating both single equations and also systems of equations which relate respective measures of diversification ($diversification_{b,t}$) or risk ($risk_{b,t}$) at the banking organization with respective measures of organizational, business, and geographical complexity. Tests include bank characteristics that are viewed as determining the risk profile of banks ($d_{b,t-1}$) and other macro environmental characteristics (X_t). Formally, we estimate the following system:

$$Y_{b,t} = \alpha^1 + \theta^1 \cdot C_{b,t-1} + \beta^1 \cdot G_{b,t-1} + \gamma^1 \cdot X_t + \psi^1 \cdot W_{b,t-1} + \delta_b + \epsilon_{b,t} \quad (1)$$

$$C^i_{b,t} = \alpha^2 + \theta^2 \cdot Y_{b,t-1} + \beta^2 \cdot G_{b,t-1} + \gamma^2 \cdot X_t + \psi^2 \cdot Z_{b,t-1} + \kappa_b + \omega_{b,t} \quad (2)$$

where b denotes the individual BHCs and t denotes time. $Y_{b,t}$ can either be a $Diversification_{b,t}$ proxy, such as the standard deviation of BHCs return on assets or of their idiosyncratic stock returns, or a $Risk_{b,t}$ proxy. We focus on three different types of risk: idiosyncratic (z-score, market z-score), systematic (dynamic conditional betas per Engle (2016)), and systemic (SRISK per Brownlees and Engle (2016)). We estimate this system of equations using 2SLS. Each equation is estimated separately using the respective instruments for the endogenous variables. Standard errors are clustered at the level of the banking organization (BHC).

Time fixed effects λ_t or controls X_t are introduced to capture macroeconomic or general events that impact all BHCs at time t.[4] BHC fixed effects δ_b and κ_b account for unobserved heterogeneity at the BHC level. The variables $Z_{b,t-1}$ and $W_{b,t-1}$ are the instruments for C and Y, respectively. To instrument for Y, we use the market to book ratio of the bank, which proxies for the BHC's charter value, and the VIX, which should capture general risk appetite in the economy. To determine the instrument for C we rely on BHC size. Explanatory variables are lagged by one period in order to address issues of simultaneity.

A positive coefficient on θ^1 in equation (1) using a diversification proxy as a dependent variable, would signal that more complex structures lead to more diversification of revenue streams. However, a similar positive coefficient for the estimation with a risk proxy as the dependent variable, would signal that greater complexity comes at the expense of higher risk. In equation (1) we test the reciprocal argument, whether the manager's appetite for risk produced different outcomes in term of complexity. In this specification we use time-varying governance measures that we take as predetermined to test hypothesis 1b. The coefficient of interest is β, which captures the the effect of governance on both complexity and risk (diversification). A negative value for β^1 and positive for β^2 would imply that better governance allow banks to increase complexity without any detrimental effects on risk.

[4]If X is constructed as an end of period variable, it would enter specifications with a $t-1$ value

2.3 Regulatory changes and the relation between bank complexity and risk

As noted in Brandao-Marques et al. (2018), DeYoung et al. (2013) and Laeven and Levine (2009), identifying a causal relation between complexity and risk-taking uses changes in the regulatory environment. While our primary focus is on the new regulatory frameworks for systemic banks proposed in the Dodd-Frank Act (DFA) of 2010, including the guidelines for resolution planning published in 2016, an appendix also explores results around the 1999 passage of the Graham-Leach-Bliley Act.

Before the Global Financial Crisis and ensuing regulatory developments like the DFA, Basel III, and the strengthening of recovery and resolution regimes, banking regulations did not fully capture the externalities associated with systemic financial institutions. Some banks may have transformed their organizational structure to minimize the impact of regulatory costs (Flood et al., 2017) and perhaps to enhance their receipt of implicit subsidies. For example, banks may have used a variety of legal entities, such as Asset Backed Commercial Paper vehicles, to arbitrage regulations and increase risk-taking (Gong et al., 2015). Thus, regulatory shortcomings may have incentivized banks to make the most of their complexity to dilute reported risk under the pre-crisis regulatory framework. Consequently, complexity can be associated with lower reported capital ratios or more volatile asset returns after the GLBA and before the passage of the DFA.

A direct link between regulatory changes in the post-crisis period and complexity is through the new regulatory frameworks that have targeted the resolution of systemic financial institutions. Complexity may have allowed banks to take on more risk through their involvement in low capital-cost riskier activities or by enhancing the public-sector subsidy implicitly received by these institutions. By targeting the organizational structure of banks to facilitate their resolvability, new resolution frameworks may have an effect on bank complexity and, ultimately, risk taking. Complying with new resolution frameworks, including "living wills", may force banks to rationalize their organizational structure making it more transparent to regulators and shareholders. Thus, we should observe a potential effect on risk taking if these resolution regimes are effective. Combining both the developments in the pre- and post-crisis yields the following testable hypothesis:

Hypothesis 2a: *Relaxed (tighter) regulatory restrictions on banks' participation in non-traditional banking activities should increase (decrease) banks' organizational and business complexity.*

Besides regulations, complex corporate structures may be aided by weak corporate governance arrangements. As noted in standard agency theories of the corporation Jensen and Meckling (1976) and Shleifer and Vishny (1989), managers pursuing their self interest may build empires focusing on investments that facilitates their entrenchment in the firm (Xuan, 2009). However, some corporate governance arrangements may limit the incentives of managers limiting their "empire building" activities (Shleifer and Vishny, 1997). Better corporate governance arrangement may limit the increase in complex structures when these provide no tangible benefits to the firm. If those arrangements provide benefits in the form of, for example, income diversification, banks with stronger governance arrangement may pursue more complex strategies. We formalize this argument in the following hypothesis:

Hypothesis 2b: *If "empire building" motives dominate income diversification motives, complexity should increase more for banks with weaker corporate governance.*

For our formal tests of these hypotheses, we take corporate governance measures as given, as they are slow moving, and test for the change in complexity after the GLBA was introduced and after living wills were enacted, comparing firms with weaker and stronger governance arrangements. For each estimation, we focus on the three years before and after the passage of the regulatory requirements. We expect the coefficient ϕ to have a negative sign if bank with better governance increases their complexity by less after the regulatory change. We estimate the following equation:

$$C^i_{b,t} = \alpha + \beta \cdot d_t + \theta \cdot G_{b,\tau} + \phi \cdot (d_t \cdot G_{b,\tau}) + \gamma \cdot X_t + \psi \cdot Z_{b,t-1} + \epsilon_{b,t} \tag{3}$$

We use standard corporate governance measures, denoted by $G_{b,\tau}$, such as the share of institutional ownership and the share of independent directorswith, with τ indicating the prior date at which these measures enter our specifications. The rest of equation (3) includes macroeconomic-level controls (X_t) and time-varying bank controls ($Z_{b,t}$) intended to capture aggregate or bank level characteristics that may affect banks' decision to change its complexity level. For the GLBA period, the governance proxies are measures as of 1996, when scope regulations under the GSA were still binding (Chernobai et al., 2018), for the enactment of the GLBA. The variable d_t is an indicator equal to 1 after 1999Q4, and zero otherwise, for the GLBA. The indicator for the date of implementation of living wills varies by the size of the bank, as these requirements were phased in over a period of about two years. For the implementation of living wills, we use corporate governance measures as of 2009. Banks with more than \$250 billion in assets complied with this requirement starting in July 2012, while those with assets above \$100 billion had to comply with this rule in July 2013. Other banks with assets above \$50 billion were required to comply as of end-2013 (Cetorelli and Traina, 2018).

Hypothesis 3: *More stringent regulatory frameworks, including recovery and resolution regimes, should lead to lower risk profiles for banks, especially for those with weaker corporate governance.*

Testing relies on a difference-in-difference approach similar to the one presented in equation (3), where we compare bank risk around the staggered introduction of "living wills" requirements in 2012 (and the passage of the GLBA in 1999, Online Appendix). The treatment group includes banks that are directly affected by the regulatory policy. The control group consists of domestic banks that are less directly concerned by the regulatory policy. The identification of the two groups depends on banking characteristics, including complexity measures.For the introduction of "living wills", we compare the changes in complexity for banks that are affected by this resolution planning guidelines to those that are not. [5]

3 Banking data: Complexity, governance, and risk

The data for complexity, risk, and governance are defined at the level of the broader Bank Holding Company (BHC) conglomerate. Information on the balance sheet and size of the BHC are introduced as regression control variables, and a range of measures of BHC complexity, risk, and governance are constructed. As US banking organizations under $25 billion in asset size tend to have low complexity (Goldberg and Meehl, 2019), we confine the US BHC analytical sample to the universe of BHCs with U.S. parentage (top-holder) and at least $25 billion in total assets. The period explored begins in 1996Q1 and extends through 2018Q2.

The summary statistics over the bank holding companies included in the estimation sample is presented in Table 1. The upper panel of this table presents the distribution of individual BHCs included across BHC-quarter observations, showing the distribution of total assets, deposit share in funding, loans relative to assets, and total equity capital to assets. The average number of BHCs that satisfy our inclusion criteria is 33 across all the quarters. The size distribution shifted towards larger institutions over time, with only 2-7 BHCs in the over $250 billion category before 2000 and growing to 11 in the later quarters. The total number included is a minimum of 23 and rises to a maximum of 49 in later quarters. Roughly one quarter of the BHC-quarter observations are over $250 billion, and the remaining three quarters are between $25 and $250 billion. Our data includes the new BHCs that were required to filed the FR-Y9C after 2009Q1. [6]

3.1 BHC Complexity

Large BHCs often have significant ownership positions or controlling interests in a range of legal entities (alternatively referred to as affiliates or subsidiaries) and include this information in regulatory reporting. Complexity measures utilize information on the structure, number, location, and industry type of bank and non-bank affiliates under each BHC, with conceptual foundations in Cetorelli and Goldberg (2014), refinements of concepts and evidence for large US BHCs in Gold-

[5]Banks with consolidated assets of more than 50 billion have to submit resolution planning documentations.

[6]These banks were Goldman Sachs, Morgan Stanley, American Express, CIT Group, Ally Financial, Discover Financial Services, and Metlife.

berg and Meehl (2019), and the database for US BHCs discussed in Cetorelli and Stern (2015). Organizational, business and geographic complexity metrics rely respectively on counts of legal entities in each BHC, and related information on their different business or industry types and international versus United States locations of entities. Our innovation is to introduce principal component analysis over types of complexity, as also found in Goldberg and Shen (2019), and use additional information that informs other aspects of geographic complexity.

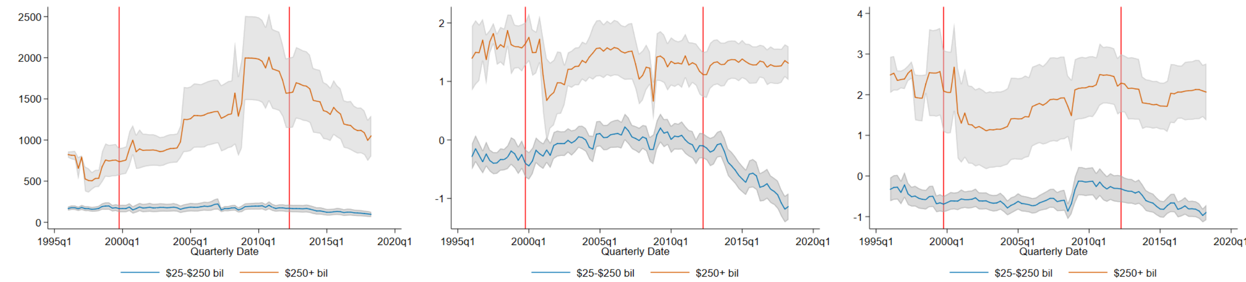
Notationally, each organizational, business, and geographic complexity index is both BHC b and time t specific. Subscripts distinguish the number and characteristics of the legal entities within each BHC: Industry type is indexed by i, or summed over every i for a BHC at a date and denoted by I; business-type is indexed by j and spans 6 types of business activities (Banking, Insurance, Mutual and Pension Funds, Other Financial, Nonfinancial Management, Other Nonfinancial) [7]; geographical location is denoted by country c, and the sum over all locations is denoted by C, taking a minimum value of 1 if all affiliates of the BHC are situated within the U.S. The construction approaches for the respective indices are presented in Table A1.

Organizational complexity is computed as the total number of legal entities within the BHC, $Count_{b,t}$. Figure 1 provides perspective on the range of values for BHC organizational complexity by broad BHC size category, with quarterly averages and standard deviation of complexity for BHCs in asset size bucket starting in 1996. The respective lines are dates of the GLBA and DFA Living Will guidance. The BHCs under $100 billion on average have around 120 legal entities, with considerable variation. By contrast, from the mid-2000s the largest BHCs on average have thousands of legal entities, on average over 2000, further discussed in (Goldberg and Meehl, 2019). While BHC size and organizational complexity are strongly positively correlated, these are different concepts. There is considerable variation in all forms of complexity we provide, even after accounting for BHC size.

Business complexity is constructing using information on the industries and businesses of the entities within each BHC, based on NAICS codes. These alternative measures are described in Table 2 and alternatively constructed as type counts or as Herfindahl-type indices normalized and defined to take values between 0 and 1 with higher values indicating more dispersion of businesses within the BHC. These constructed measures cover: the portion of these legal entities that are outside the financial sector (Nonfinancial count share$_{b,t}$); the number of industrial categories spanned by the legal entities ($CountN_{b,t}$); the total number of broad business categories spanned by these legal entities ($CountB_{b,t}$); the dispersion of legal entities across these types of businesses ($BHHI_{b,t}$); and the share of income derived from sources other than interest(Noninterest income share$_{b,t}$).

[7] Business types are defined according to NAICS codes as follows: (1) Bank: NAICS code == 5221; (2) Insurance: NAICS code == 5241, 5242; (3) Mutual and Pension Fund: NAICS code ==52511, 52591; (4) Other Financial: 2 digit NAICS code 52, but subsidiary does not fall into the categories of Bank, Insurance, or Mutual and Pension Fund; (5) Nonfinancial Management Firms: NAICS code == 5511; (6) Other Nonfinancial: 2 digit NAICS code is not 52 and 4 digit NAICS code is not 5511.

Figure 1: Complexity Measures across BHCs, average by BHC asset size categories



(a) Total Affiliate Count (b) BPC1: Business Scope (c) GPC1: Geographic Scope

Note: This figure presents average complexity measures by date across the BHCs within each asset size category. The red vertical lines indicate the time of Gramm-Leach-Bliley Act (1999) and Dodd-Frank Act Living Will Guidance (2012). The dark grey and light grey areas reflect a standard error band around the averages of banks in the asset size categories $25-$250 bil and $250+ bil respectively.

The measures vary considerably over time and for the smaller versus larger US BHCs.

As there are multiple series, and we seek to extract the key elements of business complexity, we apply principal components techniques to summarize the top two common elements that span these four business complexity series and reduce the dimensionality of the data. The resulting first and second principal components, discussed further in Appendix 1, are given the labels $BPC1_{b,t}$ and $BPC2_{b,t}$ and respectively interpreted as capturing business scope and business diversity or dispersion. Both business scope and business dispersion are higher, on average, for the largest US BHCs (Figure 1). The averages across BHCs have trended downward in the years after the DFA and living will guidance. Our empirical work exclusively focused on the first principle component.

Measures of geographic complexity use the information on location of the legal entities in the BHC, plus supplementary information from the balance sheet that further captures the degree and dispersion of geographic complexity. As detailed in Table 2, $CountC_{b,t}$ is the count of countries spanned by a BHC's subsidiaries.[8] The dispersion of BHC affiliate locations across countries is indicated by $CHHI_{b,t}$. Dispersion is zero when all of the BHC's legal entities are within the United States, but increases as the dispersion across countries internationally rises.[9] Bank-specific quarterly reporting on US bank international exposures, as contained in data from the FFEIC 009 Form, is used to construct two other measures that inform geographic complexity: *share*

[8] A variant of this measure could be the counts of locations spanned by banking subsidiaries and branches per se. Moreover, if appropriate data is available, balance sheet and income data for the BHC could be used to construct additional metrics.

[9] This measures of geographic complexity do not address the concept of dispersion of branch locations or businesses within the United States, a topic considered in some research on the consequences of the historic elimination interstate banking restrictions through the 1980s and with the Riegle-Neal Act in 1994.

of foreign office claims in total assets and $CountNDT_{b,t}$, the count net due to positions. This latter information informs intra-bank borrowing and lending internationally. Such information is important as the aforementioned structure data can miss the pattern of foreign branch locations of US banks. These respective measures vary considerably over time and for the size buckets of the BHC sample.

The count of countries, share of foreign office claims in total assets, and the count of net due to positions all show that the largest category of banks on average exhibit substantially more geographic complexity than the other BHCs below $750 billion. The dimensionality reduction across the measures of geographic complexity yields two principal components. The resulting first component, discussed further in Appendix 1, is given the label $GPC1_{b,t}$ and interpreted as capturing geographic scope of the BHC affiliates. As shown in Figure 1, on average geographic scope has been concentrated in the BHCS above $750 billion.

3.2 BHC Risk

The hypotheses of Section 2 articulate the ways that BHC complexity and risk profiles are related. Our empirical specifications use three types of risk measures at the BHC-time level: idiosyncratic, systematic, and systemic.

Idiosyncratic risk is proxied by measures commonly used in the literature (Berger et al., 2017; Lepetit et al., 2008). We focus on two idiosyncratic risk measures:

$$Zscore_{b,t} = (AverageRoA_{b,t} + \frac{AverageEquity_{b,t}}{Assets_{b,t}})/SD\_RoA_{b,t}$$

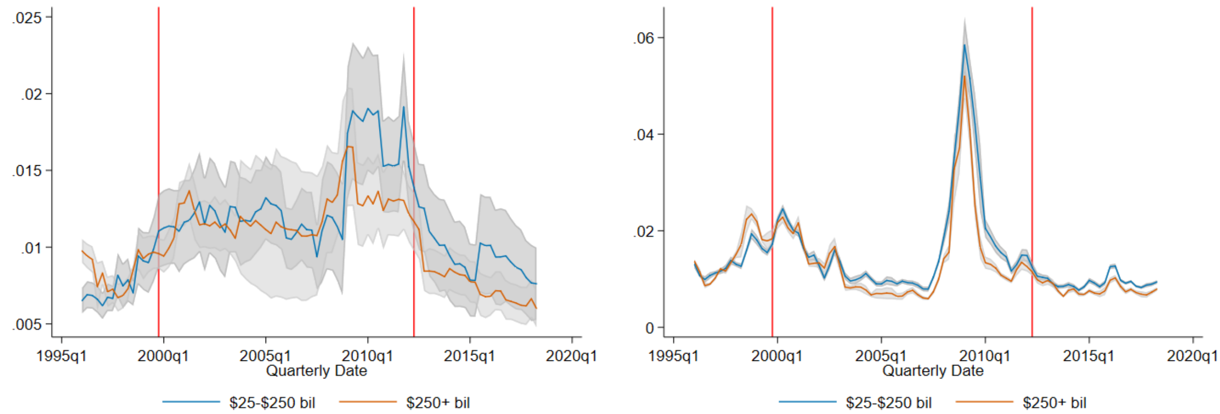
$$MarketZscore_{b,t} = (AvgReturns_{b,t} + 1)/SD\_StockReturns_{b,t}$$

Both of these idiosyncratic risk measures reflect BHC income diversification, so higher values reflect lower idiosyncratic risk. We also directly examine $SD\_RoA_{b,t}$, the standard deviation of average return on assets. Within market Zscore, $AvgReturns_{b,t}$ is the 120-day average BHC returns, and $SD\_StockReturns_{b,t}$ is the 120-day standard deviation of BHC idiosyncratic stock returns (after extracting the market return, Fama-French factors, and a momentum factor). Increasing $SD\_RoA_{b,t}$ is associated with higher levels of risk and less net income diversification, while increasing z-score is associated with lower levels of risk.

BHC liquidity risk is proxied by the LIBOR-OIS beta, which is computed from regressing the BHC returns on the LIBOR-OIS spread over a 180-day window. The betas suggest that BHCs with higher liquidity risk are associated with lower BHC returns.

The balance sheet data are accounting data from the FR Y9C report. Stock return information is sourced from the Center for Research in Security Prices (CRSP). With the first computed over 12

Figure 2: Diversification Measures across BHCs, average by BHC asset size categories



(a) Std. RoA (8 qtrs)

(b) Std. Idiosyncratic Returns

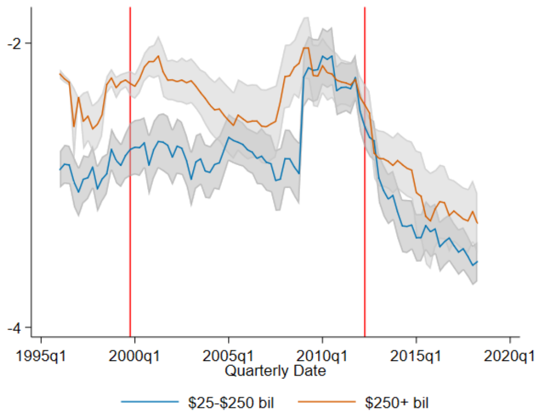
Note: This figure presents the average diversification measures by date across the BHCs within each asset size category. The red vertical lines indicate the time of Gramm-Leach-Bliley Act (1999) and Dodd-Frank Act Living Will Guidance (2012). The dark grey and light grey areas reflect a standard error band around the averages of banks in the asset size categories \$25-\$250 bil and \$250+ bil respectively.

quarters of data and the second based on rolling daily returns over 120 days. Given the skewness in the distribution of the Z-score, the econometric specifications use log Z-score values. The LIBOR-OIS spreads are from Bloomberg.

Systematic risk contributions of the BHC are proxied by the dynamic beta developed by Engle (2016). The advantage of this measure is that it does not rely on ad-hoc rolling windows for its calculation, as is the case for the commonly used measures of beta (Fama and MacBeth, 1973; Bali et al., 2017). The data to calculate this variable comes from CRSP and Kenneth French's online data library. Contributions of the BHC to systemic risk are proxied by $SRISK_{b,t}$, which is a prediction of a BHC's capital shortfall conditional on a severe market decline per the methodology of Brownlees and Engle (2016). This measure is computed using publicly available stock return information from CRSP and BHC balance sheet information from Compustat.[10] The patterns of these systemic risk measures over the full time period and all BHCs are summarized in the data summary Table.

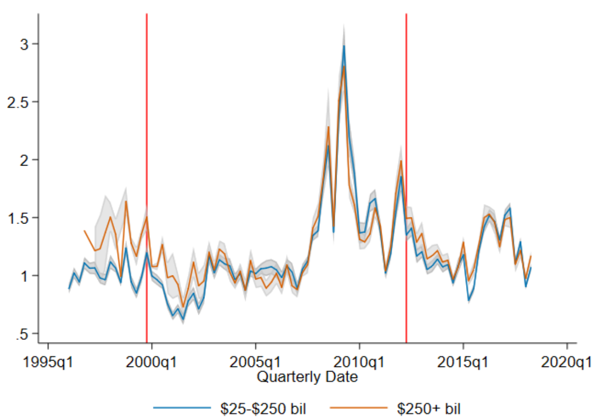
[10] The code to compute SRISK and the dynamic conditional beta was kindly shared by the Volatility Laboratory (V-Lab) at New York University.

Figure 3: Risk Measures across BHCs, average by BHC asset size categories

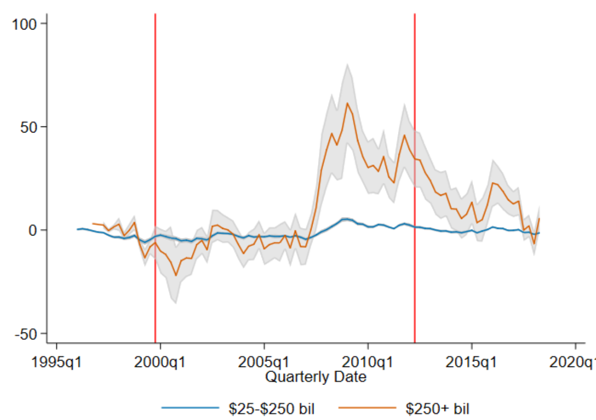


(a) Log Z-score (12 qtrs)

(b) Log Market Z-score



(c) Dynamic Conditional Beta



(d) *SRISK*

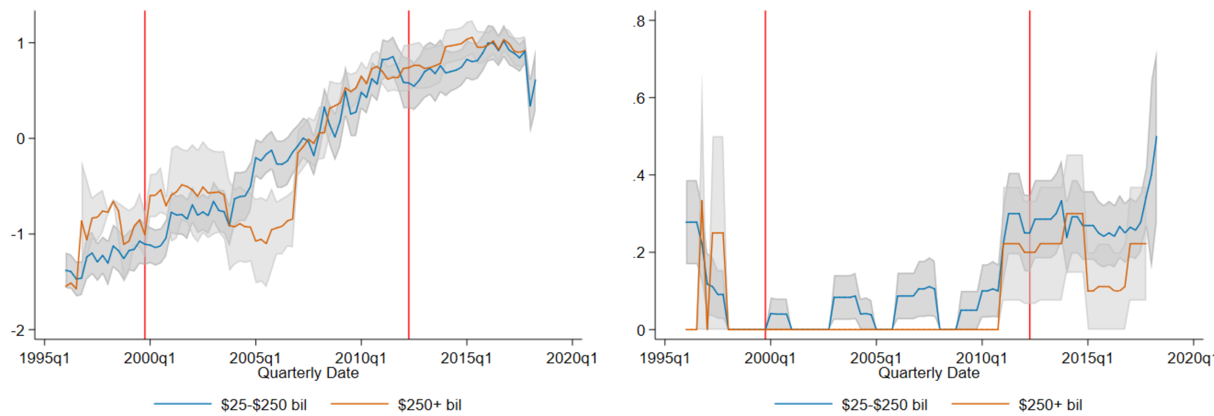
(e) LIBOR-OIS Beta

Note: This figure presents the average risk measures by date across the BHCs within each asset size category. The axis on the Z-scores are flipped to show that higher values reflect more risk. The red vertical lines indicate the time of Gramm-Leach-Bliley Act (1999) and Dodd-Frank Act Living Will Guidance (2012). The dark grey and light grey areas reflect a standard error band around the averages of banks in the asset size categories $25-$250 bil and $250+ bil respectively.

Visualizations of average values for BHCs sorted by size bucket and date are provided in Figures 2 and 3. Measures of BHC return volatility on average have declined in the post DFA living will periods for all size categories of (large) US BHCs. Contributions to systemic risk (Figure 3 panel d) have particularly diminished on average for the BHCs with assets greater than $750 bil.

3.3 BHC Governance

Figure 4: Governance Measures across BHCs, averages by date within BHC asset size categories



(a) PC1: Bank Ownership Governance

(b) CEO Non-Duality

Note: This figure presents the average governance measures by date across the BHCs within each asset size category. The red vertical lines indicate the time of Gramm-Leach-Bliley Act (1999) and Dodd-Frank Act Living Will Guidance (2012). The dark grey and light grey areas reflect a standard error band around the averages of banks in the asset size categories $25-$250 bil and $250+ bil respectively.

The hypotheses imply that banks with weaker governance arrangements may be more risky due to agency problems associated with complexity, unless better governance enables BHCs to contain adverse consequences and thus be more complex. Accordingly we construct two primary proxies for the strength of BHC governance as arising from better shareholder monitoring and transparency. The first governance proxy is the share of institutional ownership of each bank, with data collected from Thomson Reuters. Institutional owners are considered informed investors that can monitor firm managers, implying that larger share of institutional owners should lead to fewer agency problems (Gaspar et al., 2005). The second governance proxy collected is absence of CEO duality, with CEO non-duality indicating whether the CEO is also the Chairman of the Board of Directors of the BHC. CEOs with dual roles may exert excessive power over the Board, limiting the amount of information filtered to shareholders (Baldenius et al., 2014). This may exacerbate agency problems within the bank and to a potential riskier profile. We collect information on the CEOs role from S&P's Execucomp and Capital IQ.e. The third governance proxy is the share of independent directors as a measure that captures the degree of monitoring of the CEO by shareholders. This information is collected from Capital IQ and Refinitiv's ESG indicators. Visualizations of average values for BHCs sorted by size bucket and date are provided in Figure 4. On average, the years following the DFA LW showed governance improvements that continued pre-DFA trends. Institutional owners broadened their holdings of BHC stocks, with average shares lower for the group of largest BHCs. Patterns across shares of independent directors were less clear by size category and relatively similar in the post GFC period.

3.4 Macroeconomic Controls

Some regression specifications contain controls for general economic conditions: US real GDP growth, a measure of the credit cycle, and global risk conditions. The credit cycle is captured by the credit to GDP gap in the United States, calculated by the Bank for International Settlements. Risk conditions are captured by the VIX index, which shows the implied volatility in S&P500 stock index option prices from Chicago Board Options Exchange (CBOE). Robustness tests use the Bekaert et al. (2017) risk index, intended to specifically capture risk sentiment.

4 Results

4.1 Identifying the average relation between complexity, diversification and risk

Tests of **Hypotheses 1a and 1b** and determine whether, on average, complexity is associated with BHC diversification and risk. In addition, we test how governance enters these outcomes. This set of tests uses a system of equations as described in specifications 1 and 2. We estimate these equations separately in a panel setup and then we estimate them with instrumental variables for risk and complexity using 2SLS. For the latter case, the measures of complexity in equation 1 are instrumented using: the size of the bank proxied by its log of assets (measured in 2012 dollars), an indicator variable equal to one during the period between the GLBA and the passage of the DFA, and the average complexity of BHC competitors within the same tercile of the size distribution.[11] In equation 2, we follow the literature (DeYoung et al., 2013) and instrument the risk measures with the market to book ratio of each individual BHC, the nonperforming loans ratio, and by the VIX. We estimate the system of equations using data between 1996q1 and 2018q2. All specifications have BHC fixed effects and standard errors clustered at the BHC level.

Tables 2 and 3 summarize the sign and significance patterns from a series of regressions on the respective complexity variables and respective diversification or risk variables. The columns on

[11] As described in Section 2, regulations are one of the main factors that drive complexity. The period between the GLBA and the DFA is considered a period of looser regulation, which is captured by the indicator variable.

the left show the results without any instrumental variables, while those on the right instrument for both diversification (risk) and complexity variables depending on the equation. Each entry in the table represents the sign and significance of the coefficient of the respective complexity or diversification (risk) variable. The full specification results are reported in Tables OA?? through OA?? in the online appendix.

As can be seen from the results reporting the single equation estimations (no instrumental variables), there is significant association between complexity, diversification and risk for the longer time period. In the top panel of Table 2, where the dependent variables is noted by the rows in the first column, the standard deviation of idiosyncratic returns is negatively and significantly associated with organizational and business complexity. Geographic complexity has a negative and significant average relationship with the variation of ROA, our second proxy for income diversification. On the bottom panel we show that organizational and business complexity also have a negative relationships with the standard deviation of idiosyncratic returns.

The better identified system of equations using instrumental variables, shown on the right, provides more compelling evidence of causal relationships. We estimate separate equations for each complexity measure instrumenting for the lagged complexity and diversification measures in the respective equations. In the online appendix, we report the Kleiberger-Paap Wald F (KPWF) statistic as the measure for weak identification of the instruments in each regression. We are able to reject the null of weak instruments for most of our specifications.

As shown in the right part of the table, organizational complexity and the geographic scope of BHCs are associated with lower variability of ROA. In these estimations, our instruments are not weak for the complexity variables, as captured by the KPWF statistic. We also show the drivers of diversification, and find that complexity is only marginally associated with the variability of ROA, although the instruments for this diversification measure are weak. We also show similar results using the standard deviation of stock returns as the dependent variable. In this specification, we find no average relation between complexity and idiosyncratic return, our measure of diversification based on equity prices. However, BHCs with more volatile returns appear to have less business scope. These results show that in the long run, complexity is weakly associated with income diversification. Moreover, only organizational complexity and the geographic scope of BHCs seem to have dampen the variation on banks' balance sheet returns in our sample period.

We next proceed to test for the average relation between risk and complexity in Table 3. We estimate the same system of equations as for the diversification measures, but using risk measures for idiosyncratic, systematic, systemic, and liquidity risk instead. As before, the entries on the left show the results without instrumenting risk and complexity, while those on the right instrument those variables.

As reported on the left, organizational complexity and business scope are associated with lower idiosyncratic risk, as measured by the market z-score. In contrast, we find that organizational and geographic complexity are positively associated with systemic risk, as measured by SRISK. Geographic complexity is also associated positively with systematic risk. However, these complexity traits are negatively associated with liquidity risks. What these findings may imply is that more complex banks may be able to reduce idiosyncratic and liquidity risks, but at the cost of an increase in their systematic and systemic risks.

The results of the system of equations, shown on the right, are consistent with these findings. More complexity is associated with lower idiosyncratic and liquidity risks, but with higher systematic and systemic risks. As shown in the bottom panel, there is partially a feedback effect between complexity and risk. In particular, BHCs that have higher systematic and systemic risks are also more complex. Interestingly, banks with higher liquidity risks are on average less risky.

In terms of economic significance, we find a strong relation between complexity and diversification and risk. For example, using the IV estimations, we find that a one standard deviation decrease in organizational complexity, which is equivalent to a change of about 380 legal entities, would lead to 1.4 standard deviation increase in income diversification, as measured by the ROA, and to a 1.7 standard deviation change in the z-score. Similarly, a one standard deviation change in geographic complexity would lead to and 1.03 standard deviation change in liquidity risk. In contrast, similar increases in organizational and geographic complexity are associated with a 1.5 and 2.3 standard deviation increases in systematic risks.

The economic significance of the reverse relation, from diversification and risk to complexity is low. We find that one standard deviation changes in the statistically significant risk measures are only associated with changes in complexity that are just a fraction of their standard deviations.

In sum, the results from the these estimations lead us to partially reject the **Hypothesis 2a**. More complex and diversified BHCs appear to have lower idiosyncratic and liquidity risks, but this comes at the expense of having higher systematic and systemic risks.

We next turn to test **Hypothesis 2b**. In particular, we want to assess whether BHCs with better governance arrangements are able to increase complexity without increasing their risk. We use the same specifications reported in Tables 2 and 3, but focus on the coefficients of the two governance variables: the first principal component encapsulating institutional ownership and board independence, and the CEO duality indicator variable. In both cases, a higher value for these governance traits signals that the BHC has better governance arrangements.

Table 4 shows the sign and significance of the coefficients for these governance measures in each one of the diversification and risk regressions shown previously. Panel A focuses on the first principal component of institutional ownership and board independence. We find that in general, better governance, as measured by this principal component, is only consistently associated with larger idiosyncratic and liquidity risks. In contrast, this governance trait is positively associated positively with the organizational and business scope of banks across almost all specifications. These results appear to reject **Hypothesis 2b**, that is, better governed banks appear to increase complexity as they seek more diversified income streams.

Turning to panel B, we focus on CEO duality. We find similar results as with the other governance measure, but a but weaker. Altogether, we find some evidence that some governance traits may help banks to navigate an increases in complexity while at the same time controlling the levels of risk of the organization.

The results presented in this section characterize the link between different aspects of complexity and risk. We find that organizational complexity enhances income diversification and reduces idiosyncratic risks. This result is driven by banks with better governance arrangements that push for more complex organizational structures. However, although more complex organizational structures may reduce idiosyncratic risks, the same structures increase the systematic risks of BHCs, making them vulnerable to large coordinated events.

4.2 Complexity, governance, and regulations

As discussed in Section 2, changes in the regulatory environment has been associated with bank complexity. This section presents the results of tests focusing on the introduction of LWs in 2012 (we present similar test for the passage of the GLBA in 1999 in the online appendix). The first set of tests assess whether BHC complexity changed when these regulatory actions were implemented per **Hypothesis 1a**. The second set of tests focus on **Hypothesis 1b**, establishing whether banks with weaker governance arrangements had larger changes in complexity after the introduction of LWs.

We present our results on LWs in Table 5. The dependent variables are the levels of the three complexity measures described in Section 3.1: organizational complexity, business scope, and geographic scope. $PostLW$ is an indicator variable equal to 1 after the staggered introduction of LWs in mid-2012. We use a window between 2009q2 and 2018q2 to assess the impact of this regulation. All regressions include bank (log of real assets, the loans to assets ratio, the deposits to assets ratio, the liquid assets ratio, and equity to assets) and aggregate (GDP growth, the credit to GDP gap, and the VIX) controls lagged by one quarter. The regressions also include bank fixed effects and standard errors are clustered at the bank level. In columns (2)-(3), (5)-(6), and (9)-(10), we interact $PostLW$ with an indicator variable equal to 1 for BHCs with assets above \$750 billion. The coefficient on this interaction term allows us to asses whether the impact of the regulation was larger for BHCs with a more important systemic footprint.

The introduction of LWs had a significant effect on BHCs' organizational complexity. Columns (1) and (2) show that the overall number of affiliate across BHCs decreased after the introduction of LWs. This decrease was concentrated in the largest BHCs (more than \$750 billion in assets), which, as shown in figure 1a, had a notably larger number of affiliates prior to the introduction of LWs. We do not observe any significant changes in other measures of complexity for the average BHC nor for the largest BHCs.

In columns (3), (6), and (9), we estimate a similar set of regressions, but including interactions between *PostLW* and two governance measures, in addition to the size indicator. We focus on governance as captured by the first principal component of institutional ownership in BHC and by the share of independent directors and by the CEO duality indicator variable. The values for this measures are as of 2009. As noted in **Hypothesis 1b**, we expect banks with better governance to adjust less to regulatory loosenings if "empire building" motives dominate diversification motives. The opposite would be true if diversification is a stronger determinant of complexity.

The results presented in the table show that governance did not appear to influence the change of complexity after the introduction of LWs, on average. As per the size results, organizational complexity appears to be most affected by the change in regulation, but the BHCs with better governance did not adjust their structure significantly differently than other BHCs.

The results shown in this table confirm that regulations affect specific aspects of complexity, as described in **Hypothesis 1a**, especially those directly targeted by those regulations. In the case of LWs, the legal entity rationalization guidance (LER) described in Section 2, specifically targeted the organizational structure of banks. Thus, it is not surprising that BHCs reduced their number of affiliates following the regulation. In contrast, we don't find support for **Hypothesis 1b**, as we find that our governance measures are not associated with a change in complexity following the introduction of new regulations. In this case, it appears that regulatory changes substitute for governance in limiting organizational complexity.

4.3 Regulations and its impact on diversification and risk

4.3.1 Regulation, complexity and diversification

In this section we test whether regulatory actions that affect banks' complexity are associated with changes in the diversification of banks' income streams and their risk profiles. As noted in Section 2, the DFA included several provisions to increase the resilience of banking organizations, specifically those that posed systemic risks to the financial system. New capital and liquidity regulations were implemented to reduce the probability of failure of banks, while new resolution rules where enacted to facilitate the resolution of systemic institutions. In this section, we test whether the introduction of LWs changed the risk profile of banks.

The first set of tests, reported in Table 6, focus on the change in banks' diversification after the staggered introduction of LWs starting in mid-2012. The measure of diversification used in the tests are the standard deviation of ROA calculated over a 12 quarter period in columns (1)-(3) and the standard deviation of the idiosyncratic stock returns of the included BHCs in columns (4)-(6). We add bank and country controls and fixed effects at the bank level.

As shown in column (1), the introduction of LWs was associated with a general reduction in ROA variability. However, these decrease in the standard deviation of ROA was not associated with the the size of the BHCs or their governance traits, as noted in columns (2) and (3).

In columns (4)-(6) we present results for the same specification, but with the standard deviation of the idiosyncratic returns of BHCs as the dependent variable. We find that BHCs' variability of returns did not decrease after the introduction of LWs, on average. However, we do find a relative increase for the largest banks, where the interaction between $PostLW$ and a dummy equal to 1 for banks with more than \$750 billion in assets is positive and significant.

Altogether, these findings suggest that the regulatory change had a mixed effect on banks' income diversification, despite the introduction of LWs having an impact on the level of BHCs' organizational complexity.

4.3.2 Regulation, complexity and risk

In the next set of tests, we proceed to analyze the relation between complexity, governance, and bank risk after the introduction of LWs. The setup is the same as the one we used for the diversification tests. These specifications allow us to test **Hypothesis 3**, whether more stringent (looser) regulatory frameworks lead to lower (higher) risk profiles of banks. In addition, we assess whether the change in risk is related to the governance structure of banks, as BHC with weaker governance arrangements may benefit in terms of lower risk-taking as regulatory changes are implemented.

We present the results in Table 7. The table is divided into five blocks of three columns, each using a different risk measure as dependent variable. Two of the risk measures capture the idiosyncratic risk of BHCs (z-score and market z-score), one captures banks systematic risk (dynamic beta), another their systemic risk (SRISK), and the last one the BHCs' liquidity risk. This set up allows us to assess whether changes in regulation that alter complexity shift banks' risk profiles. The activities associated with the regulation may force banks to engage in strategies that may reduce one type of risk but increase another one. The estimations presented in the table include the same bank and aggregate controls used in the previous estimations. The also include bank fixed effects and standard errors clustered at the bank level.

The first two blocks report the results for our idiosyncratic measures of risk. Higher values of these measures imply higher risk. As shown in columns (1)-(3), the introduction of LWs is associated with a decrease in the z-score for those banks that started reporting LWs. This is shown by the negative and statistically significant coefficient for $PostLW$. In columns (4)-(6), we get a consistent story, when using the log of the market z-score as dependent variable. LW reporters had lower idiosyncratic risk after the started reporting LWs.

In general, we do not find that size or governance measures are consistently associated with a change in idiosyncratic risk in this period. The only exceptions is the principal component of our first governance measure, which is associated with a larger reduction of liquidity risk after the introduction of LWs.

The table continues in the next panel with three blocks for systematic, systemic, and liquidity risks. Columns (1)-(3) report the results for our measure of systematic risk, the dynamic beta proposed by Engle (2016). Higher values of this measure implies that the banks have more systematic risk. As shown in the table, the reporting of LWs do not appear to be associated with an increase in banks systematic risk on average, as the coefficients on $PostLW$ are mostly not significant.

In columns (4)-(6), we report the results using SRISK as our risk measure. SRISK captures the systemic risk of each institution, or how it may be affected by a large drop in market prices conditional on its size and capitalization. As shown in column (4), we find that SRISK decreased, on average, after banks started reporting LWs. Importantly, in columns (5) and (6) we also find that, in general, SRISK decreased more markedly for the largest BHCs.

Lastly, we show the results for liquidity risk. We find an average increase in liquidity risk after the introduction of LWs. However, this result is weaker for larger banks and banks with more institutional owners and independent directors. This finding is consistent with the results shown in the system of equations in the previous section. A reduction in complexity and systemic risk may come at the expense of larger liquidity risk. In this particular case, the trade off is somewhat muted, as the more systemic banks did not experience an outsized increase in their liquidity risk.

This set of results on risk consistently show that BHCs that had to report LWs had lower measures of idiosyncratic and systemic risk after the introduction of this regulatory requirement, consistent with **Hypothesis 3**. For systemic risk, the change was stronger for larger BHCs. In the case of liquidity risks, the opposite is true, as BHCs have experienced and increase in this type of risk, especially for the smaller ones. This set of result suggest that the regulatory change influenced the risk profile of BHCs, for both large and smaller BHCs.

4.3.3 The effect of regulatory changes conditional on complexity

In the previous set of results, we showed that the introduction of LWs was associated with changes in risk. In this section, we test whether those changes where larger for banks that were more complex in the dimension that was most affected by the introduction of LWs, organizational complexity. This set of tests allows us to further identify the effect of the introduction of LWs relative to other regulatory changes that may have been phased in at the same time.

Table 8 reports the results for the diversification measures and Table 9 for the risk measures. In these specifications we replace the size indicator variable for the level of organizational complexity of each BHC as of 2009. We expect that banks with higher organizational complexity prior to the introduction of LWs had to perform adjustment that were associated with more significant changes in their income diversification and risks. In addition, we also introduce triple interaction terms between the *PostLW* indicator variable, the governance measures, and the level of organizational complexity to assess whether banks with weaker governance had to adjust by more after the adoption of the new LW rules.

Starting with the results in Table 8, we find that income diversification for more organizationally complex banks increased by less than their peers after the introduction of LWs. This is consistent with our average results, that noted that complexity was associated with better income diversification. As these banks had to reduce their organizational complexity, their risk diversification suffered relative to other banks.

Turning to the risks in Table 9, we find that organizationally complex banks did not alter there idiosyncratic risks differently than other banks after the introduction of LWs. Given the result on diversification, which is a component of these idiosyncratic risk measures, this result signals that the overall change in idiosyncratic risk was probably driven by changes in other regulations such as those on capital requirements. This would be more consistent with our earlier finding that complexity is associated with lower levels of idiosyncratic risks.

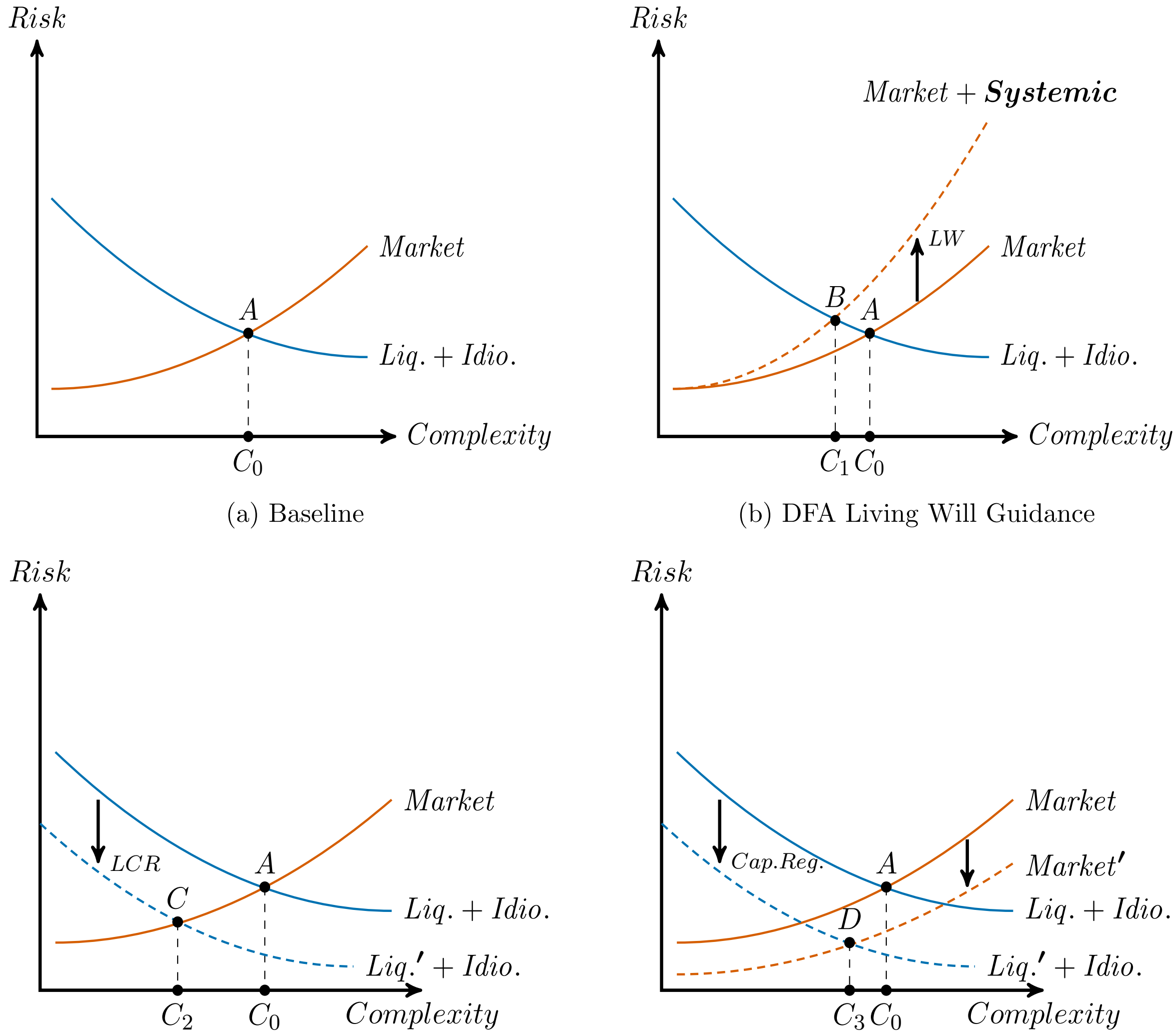
We find generally mixed results on systematic and systemic risks. Consistent with our earlier findings, more organizationally complex banks had a larger decrease in systemic risk after the introduction of LWs. In contrast, these same group of banks had a smaller reduction of systematic risk after the establishment of these new rules. However, within this group, banks with better governance, as measure by CEO duality, were able to effectively decrease their systematic risk relative to their less complex peers.

In sum, we find that some of the changes we observe after the introduction of LWs are consistent with the average relations documented earlier. In those cases, where this is not the case, other factors not associated with complexity may have driven some of the changes in risk.

4.4 Discussion of results

Having established the sign of relationships between forms of complexity and forms of risk, a simple illustration is useful for underscoring the logic of expected implications of different types of regulation (around resolution, as in LWs; on liquidity, as in tighter liquidity coverage ratios; and on capital, as in Basel III higher minimum capital ratios and stress testing outcomes). Consider first a simple illustration of the empirical findings, with Figure 5 panel a showing the positive relationship between complexity (organizational and geographic) and BHC market risk, as observed in the data, and a negative relationship with idiosyncratic risk from diversification and liquidity risk from internal capital markets and management at a conglomerate level. Under this partial equilibrium setting, the BHC would chose a level of complexity, for example C_0, that captures the tradeoffs as

Figure 5: Illustration of Risk and Complexity Relationships, with Regulation Shifts



(a) Baseline

(b) DFA Living Will Guidance

(c) Liquidity regulation

(d) Capital regulation

Note: The red curve presents market (*Market*) and systemic risk, while the blue curve presents liquidity (*Liq.*) and idiosyncratic (*Idio.*) risks. The dashed red and blue lines are shifts in market and liquidity and idiosyncratic risks respectively around major regulatory changes. A is the starting equilibrium point, and B, C, and D are equilibrium points after the DFA Living Wills, Liquidity Coverage Ratio, and Capital Requirement regulations respectively. $'$ refers to changes in risk across all BHCs.

complexity rises along the horizontal axis.

The other three panels consider the effects of resolution frameworks (panel b), tighter liquidity requirements (panel c) and tighter capital requirements (panel d). Under LWs, the BHC internalizes more of the externalities associated with systemic risk contributions. Instead of exclusively considering the upward sloping market risks, the tradeoffs on the increasing risk side also consider the systemic risk effects which expand with complexity. The level of complexity chosen by the BHC is thus smaller, shifting to C_1. In panel c, regulations that reduce BHC exposure to liquidity risk shift down the associated curve corresponding to liquidity and idiosyncratic risks. As the liquidity risk gains from organizational and geographic diversification are lower, the desired amount of complexity at the BHC level can decline, consistent with Luciano and Wihlborg (2014). Tighter bank capital requirements, depicted in panel (d), can either raise or lower optimal complexity from the vantage point of the BHC depending on the relative size of the curve shifts and their shapes.

5 Conclusion

The link between BHC complexity and risk became apparent during the global financial crisis. Large complex banks took significant risks prior to this event and, given their systemic importance, were very difficult to resolve during the crisis. The too big to fail phenomenon, also a too complex to fail phenomenon, underscored extensive post crisis efforts to make banks more resilient so that failure probabilities would decline, and make banks less complex, so that externalities from failures would have fewer costly externalities.

In this paper, we take as a starting point that the broader relationship between BHC complexity and risk is not well understood. Agency problems are posited to weigh against diversification gains. We show that regulatory actions taken after the global financial crisis did have significant impacts on types of complexity of among the large US. BHCs, where the large group are BHCs over $25 billion in assets. For the largest of these BHCs, the introduction of living will requirements as part of the new DFA resolution framework for systemically important institutions led to a decrease in organizational complexity. These changes translated into reductions in BHCs' idiosyncratic and systemic risks, partially explained by a decrease in BHCs' income variability.

We also find that BHC governance and regulatory changes jointly influence BHCs' risk profiles. In some cases, regulatory changes force BHCs to adjust their complex structures. BHCs with weak governance change the most, as they are pushed into taking actions that improves their risk profile. In other cases, BHCs with better governance are able to navigate complex structures, which benefits their income diversification and reduce their risk. Although new regulations have decreased idiosyncratic and systemic risks through changes in complexity, we find an increase in systematic risks associated with BHCs' level of complexity. This finding is consistent when we focus on a longer horizon and the association between risk and complexity. Left unchecked, such systematic risks could pose financial stability concerns, as BHCs are more exposed to common risks in a downturn.

Overall, it is important to recognize that the largest of the US BHCs differ in measures of complexity. These measures of complexity, which we present as organizational, business and geographic, go well beyond the more balance sheet and opacity based constructs that used in international policy circles to describe complexity. The ability to manage complexity taking the form of extracting diversification benefits and reducing agency problems, and thereby reducing adverse risk consequences - also depends on the governance of BHCss. Such observations could feed into more nuanced approaches to balancing the contributions of complexity to financial stability benefits and costs over the life cycle of banking organizations.

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Table 1: Summary Statistics of Variables

	mean	sd	min	p25	p50	p75	max	count
BHC Sample								
Assets ($2012 billions)	258.283	457.92	23.014	48.366	90.709	202.368	2541.892	3659
Loans to Assets Ratio	0.582	0.19	0.022	0.519	0.648	0.706	0.870	3658
Deposits to assets ratio	0.625	0.18	0.000	0.576	0.664	0.735	0.935	3538
Liquid assets ratio	0.256	0.15	0.002	0.155	0.215	0.308	0.824	3652
Equity to assets ratio	0.092	0.03	0.030	0.074	0.088	0.108	0.217	3659
Number of BHCs	32.917	5.55	23.000	29.000	32.000	34.000	49.000	3659
BHC Complexity								
Total affiliate count	382.352	672.69	4.000	58.000	115.000	388.000	4494.000	3601
Non-Financial Count Share	0.452	0.18	0.053	0.322	0.418	0.547	0.973	3601
CountB	5.216	0.55	3.000	5.000	5.000	6.000	6.000	3601
BHHI	0.745	0.16	0.076	0.678	0.785	0.852	1.000	3601
CountN	17.192	8.16	4.000	12.000	14.000	20.000	53.000	3601
Non-interest income share	0.447	0.19	0.000	0.311	0.406	0.531	1.000	3651
CountC	14.775	18.10	1.000	2.000	6.000	22.000	87.000	3601
CHHI	0.311	0.29	0.000	0.038	0.214	0.596	0.935	3601
Share of foreign office claims in total assets	0.080	0.12	0.000	0.001	0.014	0.125	0.518	3659
Count Net due to positions	11.657	18.07	1.000	1.000	3.000	16.000	100.000	3659
Business Scope	0.000	1.28	-3.573	-1.030	-0.169	1.057	3.265	3593
Geographic Scope	0.000	1.77	-1.533	-1.349	-0.735	1.190	6.530	3601
BHC Diversification								
SD. RoA (12 qtr)	0.010	0.01	0.000	0.004	0.007	0.011	0.078	3467
Idiosyncratic Returns	0.014	0.01	0.004	0.009	0.011	0.016	0.159	3564
BHC Risk								
-Log Z-Score (12 qtr)	-2.811	0.84	-5.885	-3.372	-2.770	-2.216	-0.565	3467
-Market Z-score	-4.043	0.47	-5.141	-4.358	-4.118	-3.796	-1.791	3565
Beta	1.160	0.43	0.173	0.903	1.087	1.336	4.381	3111
SRISK	1.794	16.44	-68.088	-2.340	-0.158	1.898	142.643	3111
LIBOR-OIS Beta	-0.030	0.11	-0.873	-0.054	-0.009	0.015	0.402	2151
BHC Governance								
Total Inst. Ownership, Pct. Shares Outstanding	0.635	0.17	0.002	0.517	0.632	0.764	1.935	2960
Share of independent directors	78.207	11.83	28.571	71.429	80.000	87.500	100.000	2619
CEO duality	0.125	0.33	0.000	0.000	0.000	0.000	1.000	2619
Macro Controls								
VIX	19.35	7.24	10.31	13.72	17.40	23.17	58.59	114
Credit to GDP Gap (BIS)	-0.50	8.41	-16.10	-6.90	1.45	7.20	12.20	134
Annualized real GDP Growth	2.66	2.32	-8.40	1.50	2.95	4.00	7.50	134

Table 2: Complexity and Diversification, Average Long Run Relationship

This table presents signs and significance of estimates of equations 1 and 2 without IV. Panel A uses the regression with diversification measures on the left hand side and complexity on the right hand side, with bank and macro controls. Panel B uses the regression with complexity measures on the left hand side and diversification on the right hand side, with bank and macro controls. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth and the credit to GDP gap. All regressions include standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Single Equation Estimates			**IV System Estimates**		
Diversification as Dependent Variable	Org.	Bus. Scope	Geo. Scope	Org.	Bus. Scope	Geo. Scope
Income Diversification	+	+	−**	−**	−	−***
Idiosyncratic Returns	−***	−***	+	−	−	−
Complexity as Dependent Variable	Org.	Bus Scope	Geo. Scope	Org.	Bus Scope	Geo. Scope
Income Diversification	+	+	−	+	+	+*
Idiosyncratic Returns	−**	−**	+	−	−***	+

Table 3: Complexity and Risk, Average Long Run Relationship

This table presents signs and significance of estimates of equations 1 and 2 without IV. Panel A uses the regression with risk measures on the left hand side and complexity on the right hand side, with bank and macro controls. Panel B uses the regression with complexity measures on the left hand side and risk on the right hand side, with bank and macro controls. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth and the credit to GDP gap. All regressions include standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Single Equation Estimates			**IV System Estimates**		
Risk as Dependent Variable	Org.	Bus. Scope	Geo. Scope	Org.	Bus. Scope	Geo. Scope
Z-score	+	+	−	−**	−	−***
Market Z-score	−***	−***	+	−	−**	+
Dynamic Beta	+	−	+***	+**	+	+***
SRISK	+**	+	+**	+***	+**	+**
LIBOR-OIS Beta	−**	−	−**	−	−	−**
Complexity as Dependent Variable	Org.	Bus Scope	Geo. Scope	Org.	Bus Scope	Geo. Scope
Z-score	+	+	−	+	−	+**
Market Z-score	−***	−***	+	−	−***	+
Dynamic Beta	+	−	+***	+*	−	+***
SRISK	+***	+	+**	+***	+	+**
LIBOR-OIS Beta	−***	−	−*	−***	−	−***

Table 4: Governance effects on Risk and Complexity, Average Long Run Relationship
Panel A: Governance PC1

This table presents signs and significance of the coefficients on GovPC1 in regressions of equations 1 and 2 with and without IV. Panel A uses the regression with risk or diversification measures on the left hand side and complexity and governance on the right hand side, with bank and macro controls. Panel B uses the regression with complexity measures on the left hand side and risk or diversification on the right hand side, with bank and macro controls. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. All regressions include standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Single Equation Estimates for:			**IV System Estimates for:**		
Risk as Dependent Variable	Org.	Bus. Scope	Geo. Scope	Org.	Bus. Scope	Geo. Scope
Income Diversification	+	+	+	+*	+	+*
Idiosyncratic Returns	+	+	+	+	+	+
Z-score	+	+	+	+*	+	+
Market Z-score	+***	+***	+**	+***	+***	+**
Dynamic Beta	+***	+***	+***	+*	+	+*
SRISK	+	+	+	−	−	−
LIBOR-OIS Beta	+**	+**	+**	+**	+**	+**
Complexity as Dependent Variable	Org.	Bus Scope	Geo. Scope	Org.	Bus Scope	Geo. Scope
Income Diversification	+**	+***	+	+**	+***	+
Idiosyncratic Returns	+*	+***	+	+*	+***	+
Z-score	+**	+***	+	+**	+***	+
Market Z-score	+**	+***	+	+**	+***	+
Dynamic Beta	+**	+***	+	+*	+***	+
SRISK	+**	+***	+	+*	+***	+
LIBOR-OIS Beta	+	−	+	+	−	+**

Table 4, continued: Governance, Risk, and Complexity, Average Long Run Relationship
Panel B:CEO Duality

This table presents signs and significance of the coefficients on CEO Duality in estimates of equations 1 and 2 without IV. Panel A uses the regression with risk or diversification measures on the left hand side and complexity on the right hand side, with bank and macro controls. Panel B uses the regression with complexity measures on the left hand side and risk or diversification on the right hand side, with bank and macro controls. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. All regressions include standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Single Equation Estimates			**IV System Estimates**		
Risk as Dependent Variable	Org.	Bus. Scope	Geo. Scope	Org.	Bus. Scope	Geo. Scope
Income Diversification	+**	+**	+**	+**	+*	+**
Idiosyncratic Returns	−**	−**	−***	−***	−***	−***
Z-score	+	+	+	+*	+	+
Market Z-score	−	−*	−**	−*	−	−**
Dynamic Beta	+	+	+	−	+	−
SRISK	+	+	+	−	−	−
LIBOR-OIS Beta	+	+	+	+	+	+
Complexity as Dependent Variable	Org.	Bus Scope	Geo. Scope	Org.	Bus Scope	Geo. Scope
Income Diversification	+**	+	+	+	+	+
Idiosyncratic Returns	+**	+	+	+**	+	+
Z-score	+**	+	+	+**	+*	+
Market Z-score	+**	+	+	+**	+	+
Dynamic Beta	+	+	+	+	+	+
SRISK	+	+	+	+	+	+
LIBOR-OIS Beta	+*	+	+*	+*	+	+**

Table 5: Complexity Change around the DFA LW Guidance, with Size and Governance

This table presents estimates of equation 3 using information around the passage of the Living Will guidance in 2012. The dependent variables are the following five measures of complexity: organizational complexity, business scope and dispersion, and geographic scope and dispersion. *PostLW* is an indicator variable equal to 1 after the LW became law in 2012Q3. *GovPC*1 is the first principal component of share of stocks owned by institutional owners, the share of independent directors of a bank, and CEO Duality. *CEO Duality* indicates whether the CEO is also the Chairman of the Board of Directors of the BHC. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. The sample period is 2009Q2-2018Q2. All regressions include bank fixed effects and standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Organizational Complexity			Business Scope			Geographic Scope		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Post LW	-0.160***	-0.108*	-0.111*	-0.053	-0.061	-0.033	-0.070	-0.088	-0.019
	(0.049)	(0.060)	(0.063)	(0.085)	(0.103)	(0.078)	(0.062)	(0.056)	(0.067)
Post LW X 750+ bil_{2009}		-0.235**	-0.237**		0.037	0.044		0.083	0.092
		(0.110)	(0.111)		(0.118)	(0.121)		(0.166)	(0.151)
Post LW X GovPC1_{2009}			-0.016			0.043			0.037
			(0.084)			(0.081)			(0.061)
Post LW X CEO Duality_{2009}			0.062			-0.321			-0.616*
			(0.209)			(0.341)			(0.355)
N	1183	1183	1183	1183	1183	1183	1183	1183	1183
Adj. within-R2	0.27	0.30	0.30	0.11	0.11	0.12	0.24	0.24	0.28
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Banks	47	47	47	47	47	47	47	47	47

Table 6: Diversification Change around the DFA LW Guidance

This table presents estimates of equation 3 using information around the passage of the Living Will guidance in 2012. The dependent variables are the following five measures of complexity: organizational complexity, business scope and dispersion, and geographic scope and dispersion. $PostLW$ is an indicator variable equal to 1 after the LW became law in 2012Q3. $GovPC1$ is the first principal component of share of stocks owned by institutional owners, the share of independent directors of a bank, and CEO Duality. *CEO Duality* indicates whether the CEO is also the Chairman of the Board of Directors of the BHC. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. The sample period is 2009Q2-2018Q2. All regressions include bank fixed effects and standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Income diversification			Idiosyncratic returns		
	(1)	(2)	(3)	(4)	(5)	(6)
Post LW	-0.004***	-0.004***	-0.004*	0.001	-0.000	0.001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Post LW X 750+ bil_{2009}		0.002	0.003		0.004**	0.004***
		(0.002)	(0.002)		(0.002)	(0.001)
Post LW X $GovPC1_{2009}$			0.001			0.000
			(0.004)			(0.001)
Post LW X CEO $Duality_{2009}$			-0.004			-0.006**
			(0.003)			(0.003)
N	1120	1120	1120	1143	1143	1143
Adj. within-R2	0.24	0.25	0.25	0.62	0.63	0.63
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Banks	48	48	48	48	48	48

Table 7: Risk Change around the DFA LW Guidance

This table presents estimates of equation 3 using information around the passage of the Living Will guidance in 2012. The dependent variables are the following five measures of complexity: organizational complexity, business scope and dispersion, and geographic scope and dispersion. *PostLW* is an indicator variable equal to 1 after the LW became law in 2012Q3. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. The sample period is 2009Q2-2018Q2. All regressions include bank fixed effects and standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	z-score			Market z-score		
	(1)	(2)	(3)	(4)	(5)	(6)
Post LW	-0.487***	-0.507***	-0.422**	-0.046**	-0.055***	-0.051*
	(0.120)	(0.135)	(0.174)	(0.020)	(0.020)	(0.027)
Post LW X 750+ bil_{2009}		0.110	0.118		0.044	0.044
		(0.246)	(0.225)		(0.058)	(0.057)
Post LW X $GovPC1_{2009}$			-0.085			0.002
			(0.236)			(0.026)
Post LW X CEO $Duality_{2009}$			-0.433			-0.039
			(0.293)			(0.089)
N	1120	1120	1120	1143	1143	1143
Adj. within-R2	0.39	0.39	0.39	0.82	0.82	0.82
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Banks	48	48	48	48	48	48

Table 7, continued: Risk Change around the DFA LW Guidance

This table presents estimates of equation 3 using information around the passage of the Living Will guidance in 2012. The dependent variables are the following five measures of complexity: organizational complexity, business scope and dispersion, and geographic scope and dispersion. $PostLW$ is an indicator variable equal to 1 after the LW became law in 2012Q3. $GovPC1$ is the first principal component of share of stocks owned by institutional owners, the share of independent directors of a bank, and CEO Duality. *CEO Duality* indicates whether the CEO is also the Chairman of the Board of Directors of the BHC. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. The sample period is 2009Q2-2018Q2. All regressions include bank fixed effects and standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Dynamic Beta			SRISK			LIBOR-OIS Beta		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Post LW	0.021	-0.004	0.039	-4.404**	0.352	1.030	0.051***	0.057***	0.069***
	(0.036)	(0.037)	(0.034)	(1.689)	(1.351)	(1.825)	(0.008)	(0.008)	(0.009)
Post LW X 750+ bil_{2009}		0.111	0.111		-21.398***	-21.450***		-0.025*	-0.026
		(0.106)	(0.097)		(7.778)	(7.613)		(0.015)	(0.017)
Post LW X $GovPC1_{2009}$			0.008			-2.027			-0.014*
			(0.030)			(1.283)			(0.008)
Post LW X CEO $Duality_{2009}$			-0.329*			-0.795			-0.060
			(0.171)			(6.492)			(0.039)
N	1082	1082	1082	1082	1082	1082	1143	1143	1143
Adj. within-R2	0.55	0.55	0.56	0.24	0.35	0.35	0.10	0.10	0.10
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Banks	44	44	44	44	44	44	48	48	48

Table 8: Diversification Change around the DFA LW Guidance for organizationally complex banks

This table presents estimates of equation 3 using information around the passage of the Living Will guidance in 2012. The dependent variables are the following five measures of complexity: organizational complexity, business scope and dispersion, and geographic scope and dispersion. *PostLW* is an indicator variable equal to 1 after the LW became law in 2012Q3. *GovPC*1 is the first principal component of share of stocks owned by institutional owners, the share of independent directors of a bank, and CEO Duality. *CEO Duality* indicates whether the CEO is also the Chairman of the Board of Directors of the BHC. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. The sample period is 2009Q2-2018Q2. All regressions include bank fixed effects and standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Income diversification			Idiosyncratic returns		
	(1)	(2)	(3)	(4)	(5)	(6)
Post LW	-0.004***	-0.012**	-0.011*	0.001	-0.005**	-0.004**
	(0.001)	(0.006)	(0.006)	(0.001)	(0.002)	(0.002)
Post LW X Org. Complex_{2009}		0.002	0.002*		0.001**	0.001***
		(0.001)	(0.001)		(0.000)	(0.000)
Post LW X GovPC1_{2009} X Org. Complex_{2009}			0.000			-0.000
			(0.001)			(0.000)
Post LW X CEO Duality_{2009} X Org. Complex_{2009}			-0.001			-0.001***
			(0.001)			(0.001)
N	1120	1114	1114	1143	1137	1137
Adj. within-R2	0.24	0.26	0.26	0.62	0.63	0.63
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Banks	48	47	47	48	47	47

Table 9: Risk Change around the DFA LW Guidance for organizationally complex banks

This table presents estimates of equation 3 using information around the passage of the Living Will guidance in 2012. The dependent variables are the following five measures of complexity: organizational complexity, business scope and dispersion, and geographic scope and dispersion. $PostLW$ is an indicator variable equal to 1 after the LW became law in 2012Q3. $GovPC1$ is the first principal component of share of stocks owned by institutional owners, the share of independent directors of a bank, and CEO Duality. *CEO Duality* indicates whether the CEO is also the Chairman of the Board of Directors of the BHC. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. The sample period is 2009Q2-2018Q2. All regressions include bank fixed effects and standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	z-score			Market z-score		
	(1)	(2)	(3)	(4)	(5)	(6)
Post LW	-0.487***	-1.151*	-1.129*	-0.046**	-0.092	-0.084
	(0.120)	(0.576)	(0.576)	(0.020)	(0.091)	(0.086)
Post LW X Org. $Complex_{2009}$		0.131	0.148		0.009	0.010
		(0.103)	(0.094)		(0.018)	(0.018)
Post LW X $GovPC1_{2009}$ X Org. $Complex_{2009}$			-0.027			-0.001
			(0.047)			(0.005)
Post LW X CEO $Duality_{2009}$ X Org. $Complex_{2009}$			-0.103			-0.018
			(0.088)			(0.020)
N	1120	1114	1114	1143	1137	1137
Adj. within-R2	0.39	0.40	0.41	0.82	0.82	0.82
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Banks	48	47	47	48	47	47

Table 9, continued: Risk Change around the DFA LW Guidance for organizationally complex banks

This table presents estimates of equation 3 using information around the passage of the Living Will guidance in 2012. The dependent variables are the following five measures of complexity: organizational complexity, business scope and dispersion, and geographic scope and dispersion. *PostLW* is an indicator variable equal to 1 after the LW became law in 2012Q3. *GovPC*1 is the first principal component of share of stocks owned by institutional owners, the share of independent directors of a bank, and CEO Duality. *CEO Duality* indicates whether the CEO is also the Chairman of the Board of Directors of the BHC. Bank controls capturing the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio are included. The estimations also include controls for GDP growth, the credit to GDP gap, and the VIX. The sample period is 2009Q2-2018Q2. All regressions include bank fixed effects and standard errors clustered at the bank level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Dynamic Beta			SRISK			LIBOR-OIS Beta		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Post LW	0.021	-0.277*	-0.248*	-4.404**	18.089*	18.933**	0.051***	0.077**	0.081**
	(0.036)	(0.159)	(0.133)	(1.689)	(9.442)	(8.674)	(0.008)	(0.034)	(0.031)
Post LW X Org. Complex_{2009}		0.059*	0.061**		-4.409**	-4.164**		-0.005	-0.004
		(0.031)	(0.028)		(2.095)	(1.939)		(0.006)	(0.006)
Post LW X GovPC1_{2009} X Org. Complex_{2009}			0.002			-0.637*			-0.002
			(0.007)			(0.358)			(0.002)
Post LW X CEO Duality_{2009} X Org. Complex_{2009}			-0.067*			-1.924			-0.008
			(0.036)			(2.690)			(0.010)
N	1082	1076	1076	1082	1076	1076	1143	1137	1137
Adj. within-R2	0.55	0.56	0.56	0.24	0.29	0.30	0.10	0.10	0.10
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Banks	44	43	43	44	43	43	48	47	47

Appendix

A1 Construction of Complexity Variables and Principal Components

Table A1: Definitions of Complexity Variables

Variable	Definition
Organizational	
$Count_{b,t}$	Total Count of subsidiaries held by BHC
Business	
$BPC1_{b,t}$	Business scope The first principal component over the following BHC-specific measures:
Nonfinancial Count Share$_{b,t}$	Share of non-financial affiliates
$CountB_{b,t}$	Total count of business types (commercial banks, mutual/pension funds, insurance, other financial, non-fin management firms, other nonfinancial)
$BHHI_{b,t}$	$\frac{CountB}{CountB-1}\left(1-\sum_{j=1}^{B}\left(\frac{count_j}{\sum_{j=1}^{B} count_j}\right)^2\right)$ where B are business types and $count_j$ is the number of BHC's subsidiares that are classified in accordance with each business type j.
$CountN_{b,t}$	Number of 4-digit NAICS industries
Non-interest income share$_{b,t}$	Share of income from non-interest sources
Geographic	
$GPC1_{b,t}$	Geographic scope The first principal component over the following BHC-specific measures:
$CountC_{b,t}$	Count of countries spanned by BHC's affiliates
$CHHI_{b,t}$	$CountCHHI = \frac{CountC}{CountC-1}\left(1-\sum_{c=1}^{C}\left(\frac{count_c}{\sum_{c=1}^{C} count_c}\right)^2\right)$ where C is the set of countries and $count_c$ is the count of subsidiaries in each country c.
Share of foreign office claims$_{b,t}$	Share of foreign office claims in total assets, by bank
$CountNDT_{b,t}$	Count Net Due to Positions, countries, by bank

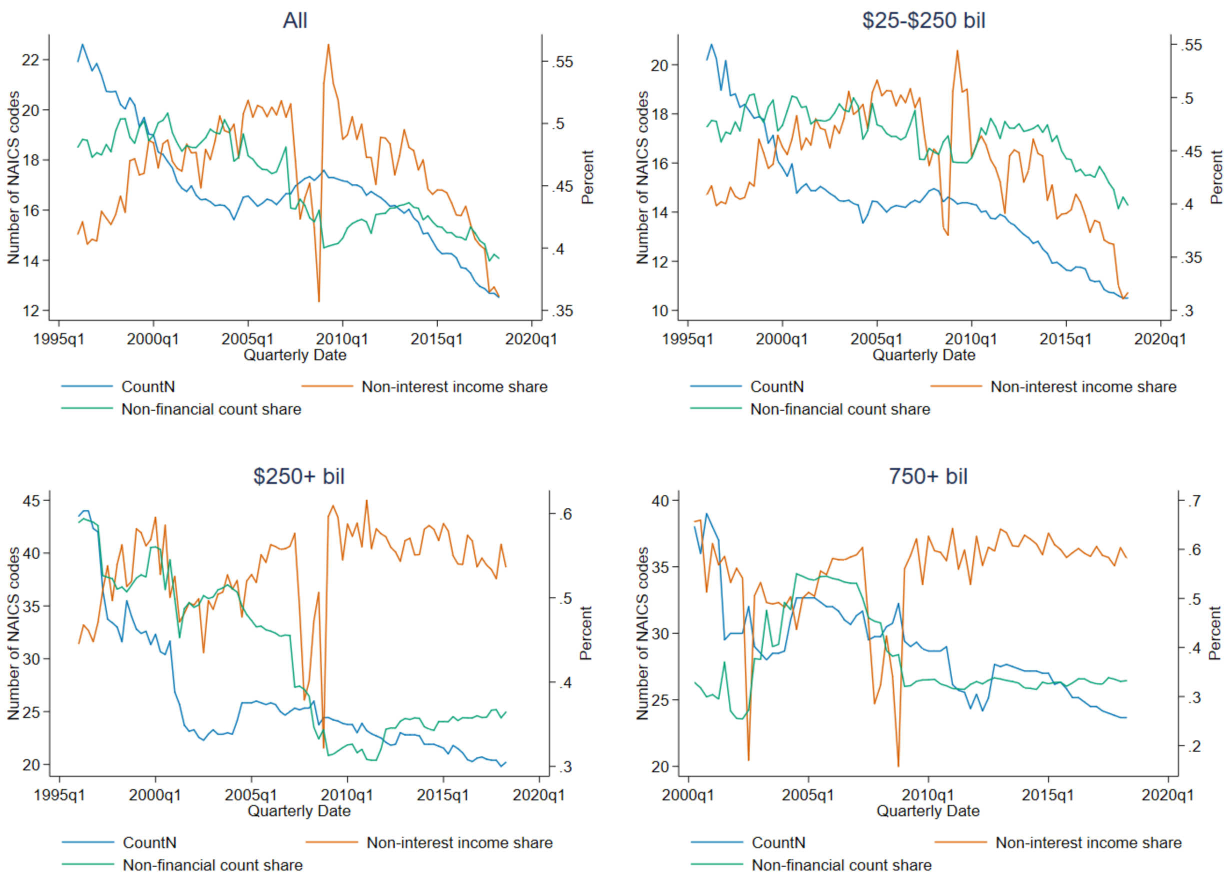
As there are multiple measures of Business Complexity and Geographic Complexity, we perform principle components analysis to reduce the data dimensionality. The first two principle components across the Business Complexity measures, BPC1 and BPC2, respectively account for 43 percent and 25 percent of the variation across the broader range of measures. Based on observing the correlations between these principle components and the original series, we view BPC1 as representing business scope and BPC2 as representing business diversity or dispersion. The first two principle components, GPC1 and GPC2, respectively account for 78 percent and 13 percent of the variation across the broader range of geographic complexity measures. Based on observing the correlations between these principle components and the original series, we view GPC1 as representing geographic scope and GPC2 as representing geographic diversity or dispersion.

The Table A2 provides the PCA of the respective complexity variables and the first two principle components.

Table A2: PCA of Complexity Variables

	Comp1	Comp2
Business Complexity (BPC)		
Non-Financial Count Share	0.14	-0.76
$CountB$	0.55	0.23
$CountBHHI$	-0.41	0.46
$CountN$	0.54	-0.02
Non-interest Income Share	0.47	0.39
Fraction of variance explained	0.598	
Geographic Complexity (GPC)		
$CountC$	0.52	-0.28
$CountCHHI$	0.46	0.77
Share of foreign office claims in total assets	0.51	0.14
Count Net due to positions	0.51	-0.55
Fraction of variance explained	0.911	
Governance (GovPC)		
Total Inst. Ownership, Percent of Shares Outstanding	0.71	0.71
Share of independent directors	0.71	-0.71
Fraction of variance explained	1	

Figure 1: Business Complexity Measures across BHCs, average by BHC asset size categories



Note: This figure presents average business complexity measures by date across the BHCs within each asset size category.

Table A3: Correlations between Business Scope Components

	Corr(CountN, Non-Int Inc Sh)	Corr(Count Fin Sh, CountN)	Corr(Non-Int Inc Sh, Count Fin Sh)
Full sample			
All BHCS	.067	.268	-.029
$25-$100 bil	.35	-.047	-.426
$100-$750 bil	.199	.151	-.248
$750+ bil	.017	.423	.073
Pre-Crisis			
All BHCS	.218	.243	-.389
$25-$100 bil	.148	.359	-.109
$100-$750 bil	-.093	.243	-.337
$750+ bil	.052	.22	-.495
Post-Crisis			
All BHCS	-.05	.238	-.437
$25-$100 bil	.005	-.085	.38
$100-$750 bil	-.055	.195	-.392
$750+ bil	-.124	.271	-.256