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Bank Complexity, Governance, and Risk

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Abstract

Bank holding companies (BHCs) can be complex organizations, conducting multiple lines of business through many distinct legal entities and across a range of geographies. While such complexity raises the costs of bank resolution when organizations fail, the effect of complexity on BHCs' broader risk profiles is less well understood. Business, organizational, and geographic complexity can engender explicit trade-offs between the agency problems that increase risk and the diversification, liquidity management, and synergy improvements that reduce risk. The outcomes of such trade-offs may depend on bank governance arrangements. We test these conjectures using data on large U.S. BHCs for the 1996-2018 period. Organizational complexity and geographic scope tend to provide diversification gains and reduce idiosyncratic and liquidity risks while also increasing BHCs' exposure to systematic and systemic risks. Regulatory changes focused on organizational complexity have significantly reduced this type of complexity, leading to a decrease in systemic risk and an increase in liquidity risk among BHCs. While bank governance structures have, in some cases, significantly affected the buildup of BHC complexity, better governance arrangements have not moderated the effects of complexity on risk outcomes.

Key words: bank complexity, risk taking, regulation, too big to fail, liquidity, corporate governance, agency problem, global banks, diversification

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To view the authors' disclosure statements, visit https://www.newyorkfed.org/research/staff_reports/sr930.html.

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 have 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). 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, 2020). Our study focuses on the important knowledge gap in the analysis of the relationship between complexity and different types of bank risk. We also study how regulatory changes induce complexity changes and alter the risks BHCs face.[1]

Alternative conjectures underlie the potential competing risk effects of complexity. We posit that, 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. 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, 2018), and may reduce their exposures to liquidity risk (Cetorelli and Goldberg, 2016) and sovereign stress (Baggatini, Fecht and Weber, 2018). Alternatively, complexity may instead increase the idiosyncratic risk profile if agency problems, internal to the organization, dominate the consequences of complexity. Adverse effects can arise if managers pursuing an unchecked "empire building" strategy generate an excessively complex structure, with resulting lapses in risk management. A weak corporate governance environment, incentivized by external factors such as implicit subsidies from the government (as denoted in Freixas, Loranth and Morrison, 2007) could exacerbate this likelihood.

We posit that the optimization problem of the BHC entails balancing the benefits of income diversification through more complex structures with the costs associated with agency problems. The net effect of these opposite forces is constructed to depend on the strength of monitoring and corporate governance. We provide the econometric testing approaches that explore the average association between BHC complexity, diversification and risk over time using panel techniques, including a set of tests following an instrumental variables approach. We then focus more specifically on the roles of regulation and corporate governance, as drivers of the development of banking organization complexity. We test for the relation between complexity and bank risk by using the

[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.

change in the effective cost of complexity after the introduction of the living will provision of the DFA. We also test how BHC size and governance strength alter outcomes for the different types of risk metrics.

Our analysis explores these hypotheses across all US BHCs larger than $25 billion (in 2012 prices) and using quarterly data that spans 1996 through 2018. We compute measures of three types of complexity for these US BHCs: organizational, business, and geographic. BHCs have 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, Jacobides and Stern, 2017). As noted in Goldberg and Meehl (2020), these three areas of complexity decreased for some of the largest BHCs after the GFC. We also construct a broad spectrum of BHC-specific risk measures, covering idiosyncratic risk, systematic or market risk, liquidity risk, and systemic risks. As we conjecture that both realizations and effects of complexity 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 our 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, which have a more explicit causal interpretation. We posit that bank complexity reduces the risk profile of banks if it is accompanied by increased diversification of income streams and improved liquidity management. We further conjecture that these outcomes are more likely for better governed organizations. In terms of regulatory drivers, our primary tests explore whether 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 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 resolution. The DFA liquidity requirements raised the costs of some forms of complexity by taking into account potential ring fencing, made capital requirements more sensitive to the risks 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 results shows that increases in BHC organizational and geographic complexity are associated with better income diversification, and with lower BHC idiosyncratic and liquidity risks. In contrast, BHCs with more organizational and geographic complexity have greater systematic and systemic risks. These results are economically significant, especially for the largest BHCs (more than $750 billion in assets). For example, a one standard deviation increase in organizational (equivalent to adding 1,000 legal entities) and geographic complexity is associated with an almost four standard deviation increase in income diversification and a reduction in idiosyncratic risks of roughly three standard deviations. The changes in systematic and liquidity risks are of lesser magnitude, but still economically significant. The results for smaller BHCs are still economically meaningful, but an order of magnitude smaller than for the larger BHCs. These findings suggest that as BHCs increase organizational and geographic complexity, they trade off the beneficial reductions in idiosyncratic and liquidity risks for greater exposures to systematic or market risks and systemic risks.

Another important finding is that BHC complexity increases with better governance, supporting the hypothesis that better governed banks pursue more complex arrangements to achieve gains in income and liquidity diversification. The alternative hypothesis, of agency problems dominating risk outcomes due to complexity, is not empirically supported. While we also find some spillbacks from BHC risk levels back to organizational and geographic complexity, these effects are economically smaller.

Our second set of results address the consequences of regulatory changes and show substantial effects on both BHC complexity and risk. BHCs reduced organizational complexity after being required to submit living wills. The risk profiles of US BHCs also changed. Banks' balance sheet income diversification increased, on average, translating into a drop in idiosyncratic risks. An interesting finding is that these gains were smaller for those banks that *ex ante* had more complex organizational structures. The introduction of this resolution tool was associated with a decrease in systemic risks for the largest and more complex banks, consistent with the objective of this regulation. As in the first set of results, the decrease in organizational complexity was associated with an increase in liquidity risk for the banks affected by the regulation. A consequence of these findings, possibly not highly visible in prior literature, is that regulators can face trade-offs when actions targeted at reducing complexity may increase some risks that are reduced from more complex structures (e.g., liquidity risk), while reducing risks(e.g., systemic risk).

This novel analysis contributes to three important literatures. First, we contribute to the significant advances are being made in measuring BHC complexity (Cetorelli and Goldberg 2014, Cetorelli and Goldberg 2016, Flood et al. 2020, Carmassi and Herring 2016, Barth and Wihlborg 2017, and Goldberg and Meehl 2020). 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. (2020) use network concepts that group entities in the BHC through which communication and coordination is relatively easy. Our contributions toward measurement of complexity stem from also using principle component analysis to extract key features from a range of distinct measures of business and geographic complexity. Included in these components are balance sheet data for BHCs, alongside bank structure information.

Second, our work adds a new set of insights to the rich literature on bank risk taking (Berger et al., 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 or geographic expansion in financial conglomerates (Laeven and

Levine, 2007, Goetz, Laeven and Levine, 2013), and bank governance and risks (Laeven and Levine, 2009, Brewer and Jagtiani, 2013). Generally, size is viewed as generating the too-big-to-fail subsidies that lower the cost of funding for the largest and systemically important institutions. Yet, increases in business scope across banks have been found to be driven by leaders in the banking sector, with associated changes in equity returns and funding costs. Geographic diversification within the United States has been linked to lower BHC valuations (Goetz, Laeven and Levine, 2016), while living will regulation increase banks' cost of capital, especially for banks that were systemically important before the crisis (Cetorelli and Traina, 2018). Our work starts with the observation that BHCs optimize over a set of different types of risks. We show that living will regulation reduced organizational complexity, raised liquidity risks, and reduced systemic risks. This analysis is consistent with the evolution of market's view of sources of systemic risk, from an exclusive focus on size prior to the crisis, to post-crisis additional consideration of complexity and interconnectedness (Antill and Sarkar, 2018).

Third, and relatedly, we contribute to the literature on the consequences of post-global financial crisis bank reforms. Regulations that cover bank liquidity, bank capital and bank resolution are likely to influence the optimal degree of BHC complexity, altering the trade-offs among the risks that BHCs internalize and the externalities associated with systemic risks. An extensive literature addresses the consequences of liquidity and capital regulations. The literature directly related to complexity includes documenting how the lengthy bankruptcy process and complexity of Lehman Brothers slowed resolution and magnified costs (Fleming and Sarkar, 2014). Some banks may have transformed their organizational structure to minimize the impact of regulatory costs (Flood et al., 2020). However, BHCs also may have used a variety of legal entities, such as Asset Backed Commercial Paper vehicles, to arbitrage regulations and increase risk-taking (Gong, Huizinga and Laeven, 2018). Our contribution around U.S. BHCs is a systematic exploration of trade-offs among types of risks that can be altered by complexity, and by related regulatory drivers. In our section of discussion, for example, we argue liquidity regulations that reduce BHC exposure to liquidity risk will have the unanticipated consequence of reducing the benefits to BHCs from pursuing geographic and organizational complexity. Living wills and resolution planning push firms to better internalize the costly contributions of complexity to systemic risk and generate lower organizational complexity. Bank capital regulations can either raise or lower optimal complexity depending on the relative effects on the costs of different types of BHC risks.

The remainder of this paper proceeds as follows. First, Section 2 presents the key hypotheses on the relationships between complexity, governance, and risk. Section 3 introduces the concepts for BHC complexity, governance, and risk, and presents key patterns in these metrics for large US BHCs (in excess of $25 billion in total assets), for 1996Q1 through 2018Q2. Section 4 provides the results of econometric tests of key hypotheses, starting with estimates of the average relationships between complexity, risk, and governance. The tests respectively present the consequences for BHC diversification gains, idiosyncratic risk, liquidity risk, market risk, and systemic risk using systems of equations with and without instrumental variables. This section then tests for changes around living will provisions of the DFA, and concludes with tests of robustness. Section 5 concludes with a discussion of the ramifications of our results for regulatory frameworks, as organizational and geographic complexity for better governed BHCs may lower the probability of an idiosyncratic or liquidity BHC stress event while possibly increasing the severity of stress consequences of market stresses when they occur. The trade-offs imply that BHC-specific reductions in idiosyncratic and liquidity risks may come at the expense of an increase in systematic and systemic risks, reducing the benefits of complexity from a societal perspective. The balance of risks, we argue, is relevant for regulatory approaches - beyond just the systemic risk consequences. Moreover, different tools used in regulation and supervision alter the individual BHC versus societal welfare disconnects.

2 Complexity Drivers, hypotheses and testing

This section overviews the regulatory developments in recent years that have directly shaped the complexity of BHCs and then turns to hypotheses on how more complex organizations might inherently take more risks. 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.

2.1 Determinants of bank complexity: regulations and governance

Banking organizations have evolved rapidly over the past 30 years, expanding size, corporate complexity, and business scope that covers new areas of financial intermediation as well as nonfinancial activities. Moreover, the international footprints of banking organizations have evolved, both with branch and subsidiary networks expanding for banks (Claessens and Horen, 2014a; Claessens and Horen, 2014b) and with notable increases in internationally-located nonbank entities (see Cetorelli, McAndrews and Traina (2014) and Goldberg and Meehl (2020) for US evidence; Cetorelli and Goldberg (2014) and Carmassi and Herring (2016) for international evidence).

This evolution in the United States process has been influenced by changes in regulations, financial innovation, and competitive pressures. The slow phase-out of restrictions on banks' nontraditional activities, such as securities underwriting imposed by the Glass-Steagall Act (GSA), began in the late 1980s and early 1990s (Chernobai, Ozdagli and Wang, 2020). This trend culminated with the passage of the 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] Asset securitization changed the technology of intermediation, while allowances in risk and liquidity management and tax codes and financial secrecy changes also may have driven some dynamics. 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 directly takes into account the complexity of banking organizations in the regulatory capital framework, with the most visible tool being the global systemically important bank (GSIB) capital surcharge. Basel III makes complexity more costly, as the externality generated by BHC complexity is internalized by the new capital surcharges or additional capital regulations partially aimed at pricing the cost of risks due to complex structures.[3]

The 2010 DFA passed by the U.S. Congress directly addressed the theme of resolvability of systemic financial institutions. As large size and complexity of some financial institutions makes them especially difficult to resolve in periods of stress, some BHCs are viewed as having benefited from too-big-to-fail (TBTF) or too-complex-to-fail firms' implicit government bailout subsidies. 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 will on an annual basis. These living wills should ultimately reduce systemic risks from systemically important financial institutions by providing a road map to liquidating these institutions in the event of their failure. Resolution rules also include guidance for the simplification of banks' organizational structures, with the 2016 "Guidance for 2017 165(d) Annual Resolution Plan Submission" including criteria for banks to rationalize their legal entities and facilitate the banks' preferred resolution strategy.

2.2 Average relation between bank complexity, governance, and risk

The levels of complexity at banking conglomerates should be determined by regulation, corporate governance, and business models. Some complexity may be beneficial to the organization as the diversification of revenue streams can enhance the resilience of institutions to some configurations of shocks. However, complexity may also increase risk at the BHC level, for example if the agency problem related to empire building incentives of managers is exacerbated by a less transparent organizational structure and poor corporate governance.

Organizational and business structures reflect the trade-offs in manager optimization problems (Ragu and Zingales 2001, Stein 2002). Within banking organizations, a higher degree of complexity may take the form of more legal entities, broader spans of business activities, or wider geographic

[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.

locations of BHC affiliates. The more complex banking organizations may have a higher share of non-financial income and more diversified sources of income (Laeven and Levine, 2007). The benefits of diversification arising from complexity should depend on the correlation of cash flows across businesses and geographies, which the are traded off against the exposure to systemic risk and the monitoring and operational costs of managing a complex organization. International structures could have added challenges due to the information costs related to operating in different jurisdictions and cultures and with adhering to a fractured regulatory landscape (Buch, Koch and Koetter, 2013). Some of this complexity may also arise from managers engaging in actions to reduce taxation or increase opacity through affiliate placement (Goldberg and Meehl, 2020).

Complexity choices could also facilitate the specialization of entities within the full organization and change the pattern of exposures to risk. Luciano and Wihlborg (2018) analyze theoretically how financial synergies through internal insurance arrangements can drive complexity, with internal capital markets allowing synergies in managing liquidity across the entities within a banking organization. If liquidity holdings at the banking units are made available to meet the needs of the nonbank affiliates, the banking unit might be more liquid than would otherwise be the case, and the exposure of the rest of the organization to liquidity risk is reduced. Cetorelli and Goldberg (2016) document such intra-organizational reallocations for the branches of foreign complex banks operating in the United States. Synergies also arise if the banks are differentially able to manage risk exposures because of the related nonbank entities in the organization. Baggatini, Fecht and Weber (2018) show that German universal banks shifted risky sovereign holdings from banking units to related mutual funds in the European sovereign debt crisis. Synergies from liquidity risk sharing complemented diversification, and reduced the exposure of the full BHC to fire sale risk.

Complex organizations are nonetheless 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 idiosyncratic risk may increase. Berger et al. (2017) find that internationalization has been associated with higher idiosyncratic bank risk in US commercial banks, but also with higher capitalization. Agency problems have been typically associated with institutions that are considered TBTF, which may lead to risk-taking behavior incentivized by the status of these banks. Given the difficulty of resolving these banks, they may accumulate risks, grow beyond optimal scale, gamble on government support in times of distress, and benefit from an implicit TBTF subsidy that lowers funding costs (Balasubramnian and Cyree, 2014; Acharya, Anginer and Warburton, 2016). Increased exposure to tail risk (Arteta, Carey, Correa and Kotter, 2019; Berger et al., 2017), divisional rent seeking and inefficient investment (Scharfstein and Stein, 2000) are possible "dark sides" of complexity. While more complex organizational structures may lead to riskier banking organizations, riskier organizations also may seek more complex organizational structures. Managers may be incentivized to pursue riskier strategies and greater complexity through specific compensation arrangements (Coles, Daniel and Naveen, 2006; DeYoung, Peng and Yan, 2013).

These types of compensation arrangements may be most prevalent in less well-governed firms. Our first set of hypotheses on complexity and organizational risk profile directly address these trade-offs:

Hypothesis 1a: *Bank complexity reduces the risk profile of banks if its accompanied by an increase in the diversification of banks' income streams and improved liquidity management.*
Hypothesis 1b: *Increased bank complexity is more likely to reduce risks for banks with stronger corporate governance.*

We test these hypotheses by estimating both single equations and also systems of equations which relate respective measures of diversification or risk at the banking organization level with respective measures of organizational, business, and geographical complexity. Formally, we estimate the following system:

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

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

where b denotes the individual BHCs and t denotes time. $Y_{b,t}$ is either a proxy for $Diversification_{b,t}$, such as the standard deviation of BHCs return on assets or of idiosyncratic stock returns, or for a measure of $Risk_{b,t}$. Analyses focus on four different types of risk: idiosyncratic (z-score, market z-score), liquidity (betas on liquidity cost spreads), systematic (dynamic conditional betas per Engle, 2016), and systemic (SRISK per Brownlees and Engle, 2016). $C_{b,t}$ reflects one of three alternative measures of complexity: organizational, business, or geographic. BHC governance is introduced as $G_{b,t}$. Tests control for other bank characteristics ($Z_{b,t-1}$) that are viewed as determining the risk profile of banks and macro environmental characteristics (X_t). Standard corporate governance measures, denoted by $G_{b,t}$, used in these specifications include the share of institutional ownership, the share of independent directors, and the absence of CEO duality with the Board Chair role.

We estimate this system of equations using 2SLS, with and without instrumenting for the respective endogenous variables. Standard errors are clustered at the level of the BHC. Specifications include either time fixed effects λ_t or X_t to capture common factors that impact all BHCs at time t.[4] BHC fixed effects δ_b and κ_b account for unobserved heterogeneity. In system estimation, $Z_{b,t-1}$ and $W_{b,t-1}$ are the instruments for $C_{b,t}$ and $Y_{b,t}$, respectively. The instrument for $Y_{b,t}$ is the market to book ratio of the bank, which proxies for the BHC's charter value, and the VIX$_t$, which captures

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

general risk appetite in the economy. The instrument for $C_{b,t}$ is BHC size. These explanatory variables are lagged by one period in order to address issues of simultaneity.

A positive estimate of θ^1 in equation (1) using diversification as a dependent variable signals that more complex structures enhance diversification of revenue streams. A similar positive coefficient for the estimation with a risk proxy as the dependent variable instead signals that greater complexity is associated with higher BHC risk. In equation (2) we test the reciprocal argument, whether the manager's appetite for risk produces different complexity outcomes. Time-varying governance measures are taken as pre-determined. Other coefficients of interest, β, capture the the effect of governance on both complexity and risk (diversification). A negative value for β^1 in risk specification with a positive for β^2 would imply that better governance allow banks to increase complexity without detrimental risk consequences. All of these specifications generate average relationships between variables over time, which we interpret as strongly indicative.

2.3 Regulatory changes and the relation between bank complexity and risk

The second testing approach more explicitly considers direct causality between complexity and BHC risk. Identifying a causal relation between complexity and risk-taking uses changes in the regulatory environment, as demonstrated by Brandao-Marques, Correa and Sapriza (2018), DeYoung, Peng and Yan (2013) and Laeven and Levine (2009). Our primary focus is on the new regulatory frameworks for systemic banks proposed in the Dodd-Frank Act (DFA) of 2010, implemented starting in July 2012, including the guidelines for resolution planning published in 2016.[5]

Our second hypothesis addresses the direct link between regulatory changes in the post-crisis period and complexity, focusing on 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. Alternatively, per hypothesis 1, complexity also could have had more nuanced consequences, depnding on the type of complexity considered and the type of risk metrics. By targeting the organizational structure of banks to facilitate their resolvability, new resolution frameworks may have reduced bank complexity, force banks to rationalize their organizational structure, and ultimately altered risk taking.The following testable hypothesis sets up the first part of our difference-in-difference estimation:

Hypothesis 2a: *Tighter regulatory restrictions on participation in non-traditional banking activities and enhanced recovery and resolution regimes should decrease BHCs' complexity.*

However, as previously noted, complex corporate structures also may be driven by weak gover-

[5] We also explore results around the 1999 passage of the Graham-Leach-Bliley Act, which are available upon request.

nance arrangements. As noted in standard agency theories of the corporation (Jensen and Meckling, 1976; Shleifer and Vishny, 1989) under weak governance managers pursuing their self interest may build empires focusing on investments that facilitates their entrenchment in the firm (Xuan, 2009). Stronger corporate governance arrangements may push back against these incentives of managers, limiting their "empire building" activities (Shleifer and Vishny, 1997). Better corporate governance arrangements may limit the increase in complex structures when these provide no tangible benefits to the overall firm. If tangible benefits take in the form of income diversification or liquidity risk reduction, organizations with stronger governance arrangement may reduce complexity to a lesser degree with the more restrictive regulations. We formalize this argument in the following hypothesis:

Hypothesis 2b: *Under tighter regulations complexity should decrease less for banks with stronger corporate governance.*

For our formal tests of these hypotheses, we test for the change in complexity after living wills were enacted, comparing firms with weaker and stronger governance arrangements.[6] For each estimation, we focus on the three years before and after the passage of the regulatory requirements. We expect the coefficient β to be negative, and thus ϕ to have a positive sign if BHCs with better governance have a less pronounced decline in complexity after the regulatory tightening.

We estimate the following equation with and without corporate governance terms:

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

In equation (3), with $d_{b,t}$ representing the date of implementing more restrictive policies around complexity for affected banks, β is expected to be negative. 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. The indicator for the date of implementation of living wills, $d_{b,t}$, varies by the size of the bank, as these requirements were phased in over a period of about two years. 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. Governance measures enter our specifications with a lag τ. The corporate governance measures are dated to 2009.[7]

Finally, the counterpart on risk outcomes is that, *ceteris paribus*, the BHCs faced with the most

[6] We take corporate governance measures as given because they are slow moving.

[7] For the GLBA period, the governance proxies are measures as of 1996, when scope regulations under the Glass-Steagall Act (GSA) were still binding (Chernobai, Ozdagli and Wang, 2020). The variable d_t is an indicator equal to 1 after 1999Q4, and zero otherwise, for the GLBA. These results are available upon request.

extensive tightening and *ex ante* with the most dominant moral hazard outcomes should observe the greatest declines in risk profiles.

Hypothesis 3: *More stringent regulatory frameworks, including recovery and resolution regimes, could lead to more improved risk profiles for BHCs 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. The treatment group includes banks that are directly affected by the regulatory policy. The control group consists of domestic banks that are less directly impacted by the regulatory policy. The identification of the two groups depends on banking characteristics, including complexity measures. For the introduction of living wills, the changes in complexity for BHCs that are affected by these resolution planning guidelines are compared to those that are not, with the treatment timing introduced as BHC-specific.[8]

3 Banking data: Complexity, governance, and risk

Complexity, risk, and governance data are defined at the level of the BHC. As US banking organizations under \$25 billion in asset size tend to have low complexity (Goldberg and Meehl 2020), the analysis focuses on the universe of BHCs with US parentage (top-holder) and at least \$25 billion in total assets, and the period 1996Q1 through 2018Q2.

The average number of BHCs that satisfy these inclusion criteria is 33 across all the quarters. The total number of BHCs by quarter 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.[9] The size distribution shifted towards larger institutions over time: indeed, only 2-7 BHCs are in the over \$250 billion category before 2000, and this grows to 11 in the later quarters.

The summary statistics over the variables for the bank holding companies included in the estimation sample are presented in Table 1. The upper panel of this table presents the distribution of variables across BHC-quarter observations, showing the distribution of total assets, deposit share in funding, loans relative to assets, and total equity capital to assets.

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

[9] Our data includes the new BHCs that were required to filed the FR-Y9C after 2009Q1. These banks were Goldman Sachs, Morgan Stanley, American Express, CIT Group, Ally Financial, Discover Financial Services, and Metlife.

3.1 BHC Complexity

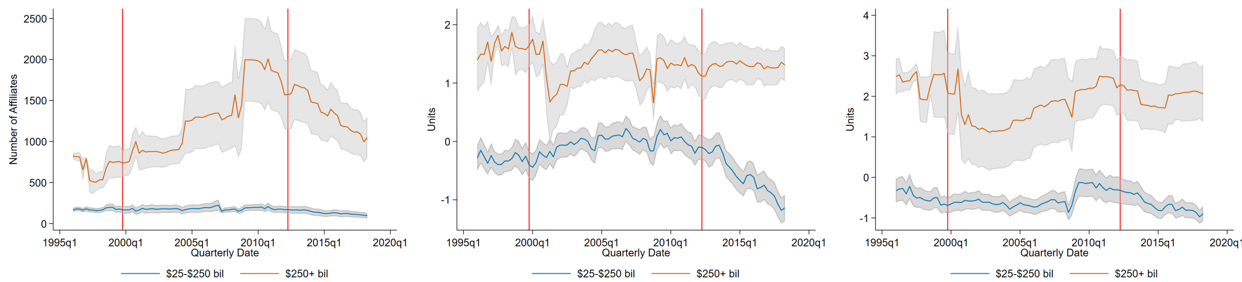
Large BHCs often have significant ownership positions or controlling interests in a range of legal entities (alternatively referred to as affiliates or subsidiaries). The complexity measures we construct utilize information on the structure, number, location, and industry type of bank and non-bank affiliates under each BHC with this information contained in regulatory reporting. Conceptual foundations are in Cetorelli and Goldberg (2014), the database for US BHCs in Cetorelli and Stern (2015), and refinements of concepts and evidence for large US BHCs in Goldberg and Meehl (2020). 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. One innovation in this current paper is that we introduce principal component analysis over alternative pieces of information relevant for types of complexity, including additional information that informs other aspects of business or geographic complexity.[10] Organizational, business, and geographic complexity indices are both BHC b and time t specific. Subscripts distinguish the number and characteristics of the legal entities within each BHC. Organizational complexity is computed as the total number of legal entities within the BHC, $Count_{b,t}$.

Figure 1 shows the distribution of BHC organizational complexity by two broad BHC size categories, representing quarterly averages and standard deviation of complexity for BHCs in asset size bucket starting in 1996. The respective vertical lines are dates of the GLBA and DFA Living Will guidance. BHCs under $250 billion on average have around 120 legal entities, with considerable variation. Within this group, the largest and most complex BHCs can have thousands of legal entities, on average over 2000 since the mid-2000s, further detailed in Goldberg and Meehl (2020). While BHC size and organizational complexity are strongly positively correlated, these are different concepts. Importantly considerable variation is observed across BHCs and over time in all forms of complexity, even after accounting for BHC size.

Business complexity, reflecting the span of financial and nonfinancial businesses of a BHC, is constructed using principal component analysis over information on the industries and businesses of the entities within each BHC. These alternative inputs, described in Table A2, are type counts, Herfindahl-type indices reflecting higher values indicating more dispersion of businesses within the BHC, the portion of these legal entities that are outside the financial sector, the number of industrial categories spanned by the legal entities, the total number of broad business categories spanned by these legal entities, the dispersion of legal entities across these types of businesses, and the share of income derived from sources other than interest. The measures vary considerably over time and for the smaller versus larger US BHCs. We apply principal components techniques

[10]The construction approaches for the respective indices are presented in Table A1.

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.

to summarize the top two common elements that span these four business complexity series and reduce the dimensionality of the data. The resulting first principal component, $BPC1_{b,t}$ discussed further in Appendix A1, captures business scope. Business scope is considerably broader for the largest US BHCs relative to those under \$250 billion (Figure 1). The averages across this latter group of BHCs have trended downward in the years after the DFA. For the largest US BHCs, business scope has evolved over time with shifting mixtures of financial and nonfinancial business, but not markedly declined (Goldberg and Meehl, 2020).

Geographic complexity is measured using 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. Components include the count of countries spanned by a BHC's subsidiaries.[11], the dispersion of BHC affiliate locations across countries[12], and bank-specific quarterly reporting on US bank international exposures to related and unrelated counterparties. Such information is important as the aforementioned structure data can miss the pattern of foreign branch locations of US banks. The very largest BHCs, over \$750 billion in assets, exhibit substantially more geographic complexity than the other BHCs below \$750 billion, and with BHCs below \$250 billion generally having low geographic complexity. The dimensionality reduction across the measures of geographic complexity yields two principal components with the resulting first compo-

[11] 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.

[12] 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.

nent (Appendix A1), $GPC1_{b,t}$, capturing geographic scope of the BHC.

3.2 BHC Risk

The BHC optimizes over a frontier of different risks, not a single risk measure. While the hypotheses of Section 2 articulate the ways that BHC complexity and risk are related, our empirical specifications focus on four types of risk measures at the BHC-time level: idiosyncratic, liquidity, systematic, and systemic. This span reflects potential BHC complexity consequences optimized by assessing trade-offs across types of risk.

Idiosyncratic risk is proxied by measures commonly used in the literature (Berger et al., 2017; Lepetit et al., 2008). Both measures reflect BHC income diversification, so higher values reflect lower idiosyncratic risk. Components are constructed based on return on assets (RoA) and equity share, or are a comparison of firm average returns with its standard deviation $SD\_RoA_{b,t}$.

$$\text{Z-Score}_{b,t} = (AverageRoA_{b,t} + \frac{AverageEquity_{b,t}}{Assets_{b,t}})/SD\_RoA_{b,t}$$

$$\text{Market Z-Score}_{b,t} = (AvgReturns_{b,t} + 1)/SD\_StockReturns_{b,t}$$

Within Market Z-Score, $AvgReturns_{b,t}$ is the 120-day average BHC stock returns, and Idiosyncratic Returns ($SD\_StockReturns_{b,t}$) is the standard deviation of its BHC idiosyncratic stock returns (after extracting the market return, Fama-French factors, and a momentum factor). Increasing income diversification is associated with higher levels of risk and less net income diversification, while increasing z-score is associated with lower levels of risk.

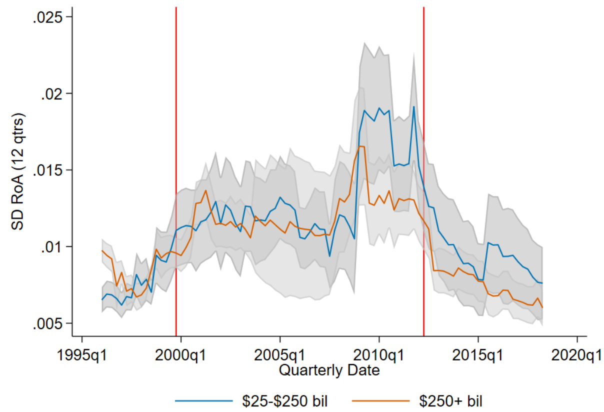
We inform the issue of whether complexity provides diversification benefits by also directly examining the standard deviation of returns on assets and of the idiosyncratic stock returns. Figure 2 shows patterns over time of these metrics. In the post-crisis period, the largest BHCs had more stable RoA, while market-based idiosyncratic variation tended to be more similar.

BHC liquidity risk is proxied by a LIBOR-OIS beta, which is computed from regressing the BHC returns on the LIBOR-OIS spread over a 180-day window. A BHC with higher liquidity risk exposure has lower returns when liquidity costs rise.[13]

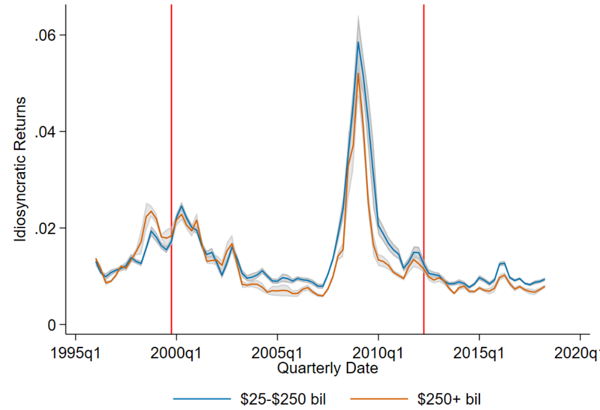
Systematic risk exposures of the BHC are proxied by the dynamic beta developed by Engle (2016). The advantage of this measure is that it does not rely on ad-hoc rolling windows for its calculation, as is the case for the commonly used measures of beta (Fama and MacBeth, 1973; Bali, Engle and Tang, 2017). The data to calculate this variable comes from CRSP and Kenneth French's

[13] 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 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.

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



(a) Income Diversification



(b) 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.

online data library. Exposure 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). [14]

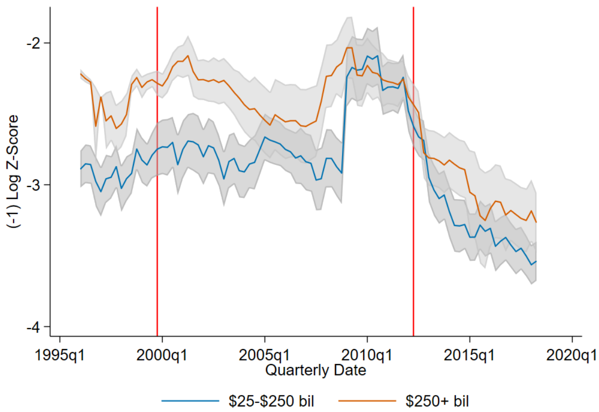
Visualizations of average values for BHCs sorted by size bucket and over time are provided in Figures 2 and 3. Through the end of 2018, measures of BHC return volatility on average have declined in the post DFA living will periods for all size categories of (large) US BHCs. Exposure to systemic risk (Figure 3 panel d) especially declined for the larger BHCs, and particularly diminished on average for BHCs with assets greater than \$750 bil.

3.3 BHC Governance

The strength of BHC governance is proxied by measures that assume stronger governance arises from better shareholder monitoring and transparency. The first governance proxy is the share of institutional ownership of each bank, measured using data we collected from Thomson Reuters. As institutional owners are considered informed investors that can monitor firm managers, larger shares of institutional owners should lead to fewer agency problems (Gaspar, Massa and Matos, 2005).

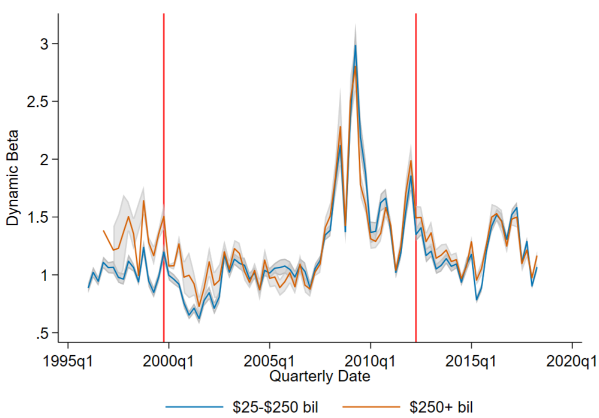
[14] This measure is computed using publicly available stock return information from CRSP and BHC balance sheet information from Compustat. The code to compute SRISK and the dynamic conditional beta was kindly shared by the Volatility Laboratory (V-Lab) at New York University.

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

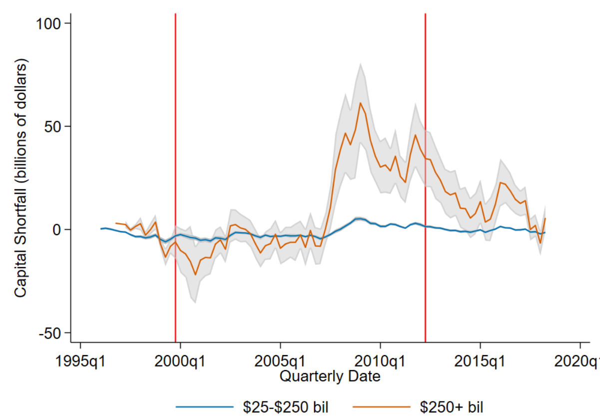


(a) (-1) Log Z-score

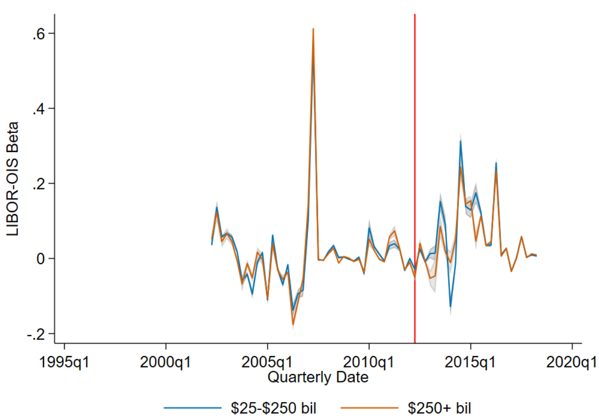
(b) (-1) Log Market Z-score



(c) Dynamic Conditional Beta



(d) *SRISK*

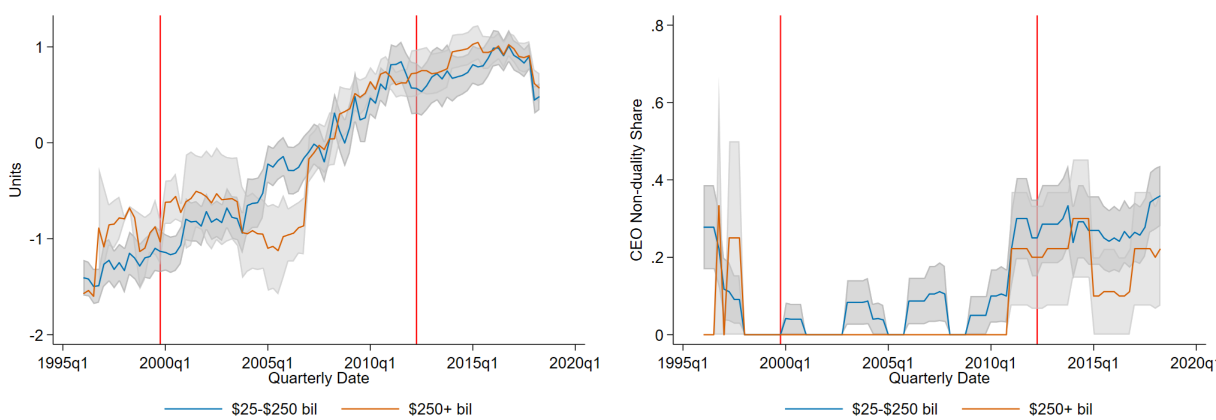


(e) LIBOR-OIS Beta

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.

The second governance proxy collected is the absence of CEO duality, with duality arising when 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, Melumad and Meng, 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. A third governance proxy is the share of independent directors, expected to be positively correlated with the degree of monitoring of the CEO by shareholders. This information is collected from Capital IQ and Refinitiv's ESG indicators. We computed the principle component over institutional ownership shares, denoting $GovPC1_{b,t}$ as a measure to capture better agency governance. Visualizations of average values of $GovPC1_{b,t}$ and CEO non-duality for BHCs sorted by size bucket and date are provided in Figure 4. On average, the years following the DFA LW showed governance improvements in $GovPC1_{b,t}$ that continued pre-DFA trends as institutional owners broadened their holdings of BHC stocks. Patterns across shares of independent directors were less clear by size category and relatively similar in the post GFC period. Independent direct shares rose discretely post-crisis and in advance of the DFA.

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



(a) GovPC1: 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.

3.4 Macroeconomic Controls

The controls for general economic and financial conditions in some regression specifications include US real GDP growth, 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). For robustness tests, we use an alternative metric, the Bekaert, Engstrom and Xu (2017) risk index, to specifically capture risk sentiment.

4 Empirical Results

4.1 The Average Relationship Between Complexity, Diversification, and Risk

On average, is complexity associated with BHC diversification and risk, and how does governance influence these outcomes? Our first set of test results use the system of equations described in specifications (1) and (2). Each complexity measure is explored through a separate regression specification, as is each distinct risk or return diversification measure. We estimate each of these equations separately in a panel setup and also estimate them jointy using 2SLS with instrumental variables for risk and complexity on the right hand side. For the latter specifications, 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.[15] In equation (2), we follow DeYoung, Peng and Yan (2013) and instrument the risk measures with the market to book ratio of each individual BHC, the nonperforming loans ratio, and by the VIX. The system of equations uses data between 1996q1 and 2018q2. All specifications have BHC fixed effects and standard errors clustered at the BHC level.

Table 2 summarizes the sign and significance patterns from a series of regressions on the respective complexity and diversification or risk variables. Each cell of this table represents the key result relevant for hypothesis 1a or 1b, each drawn from a separate regression. For each entry in the table we report only the sign and significance of the coefficient of the respective complexity or diversification (risk) variable. The full specification results are reported in the online appendix. The columns on the left show the results from specifications without any instrumental variables, while those on the right instrument for both diversification (risk) and complexity variables in respective

[15] 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.

equation.

The single equation estimations (without instrumental variables) show the significant associations between complexity, diversification and risk. The standard deviation of idiosyncratic returns is negatively and significantly associated with more organizational and business complexity. The standard deviation of RoA is negatively and significantly associated with geographic complexity. Market Z-Score measures of BHC idiosyncratic risk reflect these diversification benefits, as organizational and business complexity are associated with lower Market Z-Scores.

The better identified system of equations using instrumental variables, shown in the right columns of Table 2, provide more compelling evidence of causal relationships. We estimate separate systems of equations for each complexity measure while respectively instrumenting for the lagged complexity and diversification measures.[16] In these estimations, our instruments are not weak for the complexity variables, as captured by the KPWF statistic. Organizational complexity and the geographic scope of BHCs are associated with lower variability of RoA. The lower panel on the drivers of diversification shows that complexity is only marginally associated with the variability of RoA, although the instruments for this diversification measure are weak. Specifications that instead use the standard deviation of stock returns as the dependent variable find no average relation between complexity driving this type of idiosyncratic return measure based on equity prices. However, BHCs with more volatile idiosyncratic stock returns appear to contract business scope. Overall, it is both organizational complexity and the geographic scope of BHCs that dampen the variation on banks' balance sheet returns.

Tests for the average relation between risk and complexity without instruments are based on the same system of equations as for the diversification measures. The entries on the left show the results without instrumenting risk and complexity, while those on the right instrument those variables.

The systems of equations show that organizational complexity and business scope are associated with lower idiosyncratic risk, as measured by the market z-score. At the same time, organizational and geographic complexity are associated with higher systemic risk (as measured by SRISK), with more geographic complexity also associated with higher systematic risk. These same complexity traits are associated with less liquidity risk exposure. US BHCs appear to be using organizational and geographic complexity to reduce idiosyncratic and liquidity risks, but at the cost of an increasing systematic and systemic risks.

The results of the system of equations with instrumental variables show consistent findings. In general, more organizational and geographic complexity lowers idiosyncratic and liquidity risks,

[16] 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.

and raises systematic and systemic risk exposures. The bottom panel shows a partial a feedback effect between complexity and risk. Higher BHC systematic and systemic risk exposures are also more complex. Interestingly, BHCs with higher liquidity risks tend to lower geographic complexity.

The quantitative importance of the relation between complexity, diversification, and risk is high, especially for the largest BHCs (more than $750 billion in assets). For example, using the IV estimations, a one standard deviation increase in organizational complexity, equivalent to a change of about 1,000 legal entities, would lead to a 4 standard deviation increase in income diversification, as measured by the RoA, and to a 3 standard deviation change in the z-score. Similarly, a one standard deviation increase in geographic complexity would lead to a 1.1 standard deviation decline in liquidity risk exposure. Equivalent increases in organizational and geographic complexity are associated with a 1.3 and 1.7 standard deviation increases in systematic risks. For the smaller BHCs, these changes range in the order between 1 and 1.5 standard deviations. The association between geographic complexity and liquidity risk is not economically significant, as a 1 standard deviation increase in geographic complexity is just associated withe a 0.6 standard deviation decrease in liquidity risks.

The economic significance of the reverse relation, from diversification and risk on changes in complexity, is low. A one standard deviation change in the statistically significant risk measures are only associated with changes in complexity that are just a fraction of their standard deviations. This applies to both the large and small BHCs.

In sum, the results from the these estimations lead us to nuance the conclusions around **Hypothesis 1a**, which was crafted for general risk and complexity conclusions. Instead, we document a rich tradeoff. 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.

Hypothesis 1b conjectured that BHCs with better governance arrangements might be able to increase complexity without increasing their risk exposures. We test this using the same specifications reported in Table 2, but now focus on the β coefficients from equations (1) and (2) that highlight direct roles of both governance variables, alternatively captured by $GovPC1_{b,t}$ (the first principal component encapsulating institutional ownership and board independence) and the CEO non-duality.

Table 3 shows the sign and significance of the coefficients for these governance measures in each one of the diversification and risk regressions. Better governance in BHCs, as as captured $GovPC1_{b,t}$ and shown in panel A, is only associated with larger idiosyncratic and liquidity risk exposures. However, better governance is robustly associated with more organizational and business complexity. These results appear to reject **Hypothesis 1b**: better governed banks are the ones that increase complexity as they seek more diversified income streams. Panel B provides corresponding results using absence of CEO duality to capture governance. Similar results arise as with the first prinicipal component of institutional ownership and board independence, but weaker. Altogether, some governance traits may help banks to navigate an increase in complexity while at the same time controlling the levels of risk of the organization.

Overall, the results suggest that BHC organizational complexity enhances income diversification and reduces idiosyncratic risk exposures. This result is driven by BHCs with better governance arrangements that push for more complex organizational structures. However, although more complex organizational structures may reduce idiosyncratic risks, the same complex organizational structures increase the systematic risks of BHCs, making them vulnerable to large coordinated events.

4.2 Complexity, Governance, and BHC Living Wills

As changes in the regulatory environment are partially targeted at BHC complexity, the next set of results focus on the consequences of introduction of LWs in 2012.[17] First, tests assess whether BHC complexity changed when these regulatory actions were implemented per **Hypothesis 2a**. Second, tests focus on **Hypothesis 2b**, establishing whether the BHCs with weaker governance arrangements then exhibited the larger changes in complexity. As discussed around equation (3), these empirical tests work like difference in difference tests using a sample period of about 3 years before and 3 years after the regulatory change.

The dependent variables are the levels of organizational complexity, business scope, and geographic scope. $d_{b,t}$ is an indicator variable equal to 1 after the staggered introduction of LWs in mid-2012. The window between 2009q2 and 2018q2 is considered to assess the impact of this regulation. All regressions include as controls BHC (log of real) assets, the loans to assets ratio, the deposits to assets ratio, the liquid assets ratio, and equity to assets, and aggregate measures (GDP growth, the credit to GDP gap, and the VIX) with all lagged by one quarter. The regressions also include BHC fixed effects and standard errors clustered at the BHC level. In Table 3 columns (2)-(3), (5)-(6), and (9)-(10), $d_{b,t}$ is interacted with an indicator variable equal to 1 for BHCs with assets above $750 billion. The coefficient on this interaction term allows us to assess whether the impact of this regulation was larger for those BHCs with a larger 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 had a notably larger number of affiliates prior to the introduction of LWs. Other measures of complexity do not change significantly either for the average BHC or for the largest BHCs.

Columns (3), (6), and (9) provide estimates from a similar set of regressions that include

[17]We present similar test for the passage of the GLBA in 1999, which is available upon request.

interactions between $d_{b,t}$ and two governance measures, in addition to the size indicator. The values for these governance measures are as of 2009. **Hypothesis 2b** posits BHC with better governance will adjust less to regulatory loosenings, as these are the ones where complexity is more likely to have diversification motives dominate "empire building" motives.

The table show that governance did not, on average, influence the change of complexity after the introduction of LWs. Organizational complexity was most affected by the change in regulation, and the largest BHCs reduced complexity of their organizations more (and also were much more organizational complexity *ex ante*). The BHCs with better governance did not adjust their structure significantly differently than other BHCs. In addition the specification for geographic complexity shows a coefficient for the interaction between $d_{b,t}$ and our CEO Non-Duality indicator as negative and weakly significant. BHCs with non-dual roles for the CEO decreased their geographic complexity by somewhat more after the introduction of LWs.

The results confirm that regulations affect specific aspects of complexity, as described in **Hypothesis 2a**, especially those types of complexity directly targeted by those regulations. In the case of LWs, the legal entity rationalization guidance 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. However, we do not find support for **Hypothesis 2b**, as the BHC governance measures in general are not associated with a differential change in complexity following the introduction of new regulations. In this case, regulatory changes substitute for governance in limiting organizational complexity. Section 4.4 returns to these issues with a more conceptual discussion of liquidity regulation and capital regulations also could alter the BHC complexity and risk trade-offs.

We have conducted standard tests to assess the validity of these difference-in-difference estimators, following Atanasov and Black (2016). Figure OA.1 in the Online Appendix show the tests for parallel trends for our sample of treated (living wills reporters) and non-treated BHCs. We plot the coefficient on the interaction between the indicator of those BHCs subject to LWs and a set of time dummies. Parallel trends generally characterize all the measures of complexity and, in particular, organizational complexity as the main variable of interest. We also run a set of placebo tests using the passage of the DFA as the indicator of interest. In these specifications, we only use the pre-living wills period, between 2009 and 2012. This set of regressions, presented in figure OA.4 in the Online Appendix, does not indicate a significant change in complexity in the post-DFA treatment period.

4.3 Living Wills, Diversification, and Risk

In this section we test whether the living will regulatory actions that affect banks' complexity are associated with changes in the diversification of banks' income streams and their risk profiles.

However, as noted in Section 2, the DFA also included other provisions to increase the resilience of banking organizations, with specific and well documented emphasis on those BHCs and activities 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. As research has explored the effects of these changes on BHC risks, identification of the specific role of living wills is also challenging.

The first set of tests, reported in Table 4, focus on the change in banks' diversification after the staggered introduction of LWs starting in mid-2012. As shown in column (1), the introduction of LWs was associated with a general reduction in RoA variability. However, this decrease in the standard deviation of RoA was not associated with the the size of the BHCs or their governance traits, as shown in columns (2) and (3). In columns (4)-(6) we present results for the same specification, but with the standard deviation of BHC idiosyncratic returns as the dependent variable. 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 $d_{b,t}$ 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. We expect that the specific role of LWs is difficult to isolate in such specifications.

Next, we analyze the relation between complexity, governance, and bank risk after the introduction of LWs. These specifications target **Hypothesis 3**, regarding whether more stringent regulatory frameworks lead to lower 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 may achieve relatively more risk reduction with tighter regulations.

Table 5 provides results with columns corresponding to the respective risk measures as dependent variables: idiosyncratic risk of BHCs (z-score and market z-score), systematic risk (dynamic beta), systemic risk (SRISK), and the BHCs' liquidity risk. This setup allows us to assess whether changes in regulations that alter complexity shift banks' risk profiles, with BHCs engaging in strategies that may reduce one type of risk but increase another one.

As shown in columns (1)-(3) and also (4)-(6), the introduction of LWs is associated with a decrease in the z-score for BHCs after they started reporting LWs (negative and statistically significant coefficient for $d_{b,t}$). In general, neither BHC size nor governance measures are consistently associated with a change in idiosyncratic risk in this period. The only exception is $GovPC1_{b,t}$ with better governed BHCs having a larger reduction of liquidity risk after the introduction of LWs.

The next panel of results cover systematic, systemic, and liquidity risks. The reporting of LWs do not appear to be associated with an increase in banks systematic risk on average, as the coefficients on $d_{b,t}$ are mostly not significant. As shown in column (4), SRISK decreased, on average, after banks started reporting LWs. Importantly, columns (5) and (6) show that, in general, SRISK decreased more markedly for the largest BHCs. 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. 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.

As with the previous results based on difference-in-difference estimations, we conduct tests to assess the validity of this technique for our specifications (see figures OA.2, OA.3, OA.5, and OA.6 in the Online Appendix). For our statistically significant results, such as for systemic and liquidity risks, these tests show that trends are parallel in general in the pre-event period. In addition, placebo tests with the passage of the DFA do not yield any significant changes. 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**. The decline in systemic risk was stronger for larger BHCs. Liquidity risks exhibited the opposite pattern, as BHCs increased in this type of risk exposure, especially for smaller BHCs. The regulatory change influenced the risk profile of both larger and smaller BHCs.

Next, we test whether those changes were larger for BHCs 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 6 reports the results for the diversification measures and Table 7 for the risk measures. In these specifications we replace the size indicator variable with the level of organizational complexity of each BHC as of 2009. We expect that BHCs with higher organizational complexity prior to the introduction of LWs made adjustments that were associated with more significant changes in income diversification and overall risk profiles. In addition, triple interaction terms between the $d_{b,t}$ indicator variable, the governance measures, and the level of organizational complexity are used to assess whether BHCs with weaker governance adjusted by more after the adoption of the new LW rules.

The results show that income variation for more organizationally complex BHCs decreased by less than their peers after the introduction of LWs. This result is consistent with the average result that complexity was associated with better income diversification. As more organizationally complex BHCs reduced their organizational complexity, risk diversification suffered relative to other BHCs. The results for other risk metrics show that organizationally complex banks did not alter idiosyncratic risk exposures differently than BHCs 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 interpretation is more consistent with the other result that complexity is associated with lower levels of idiosyncratic risk exposure. We find mixed results on systematic and systemic risks. Consistent with the other results, more organizationally complex BHCs had a larger decrease in systemic risk after the introduction of LWs. In contrast, these BHCs had smaller declines in systematic risk. Within this group, BHCs with better governance, as measure by CEO non-duality, effectively reduced systematic risk relative to their less complex peers.

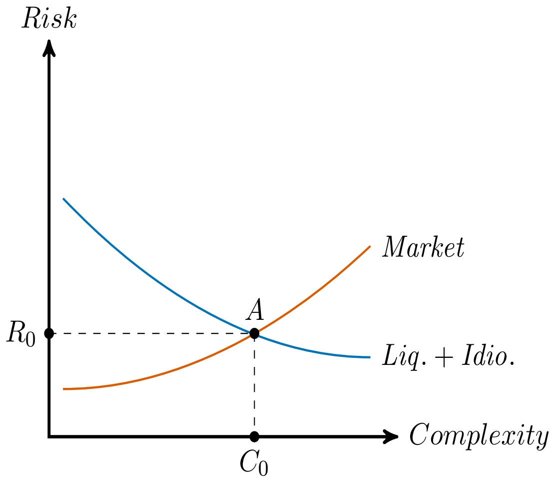
In sum, some of the changes after the introduction of LWs are consistent with the average relations documented in Section 4.1. In those cases where that is not the case, other factors not associated with complexity likely drove the changes in risk profiles.

4.4 Potential Effects of Enhanced Liquidity and Capital Regulation

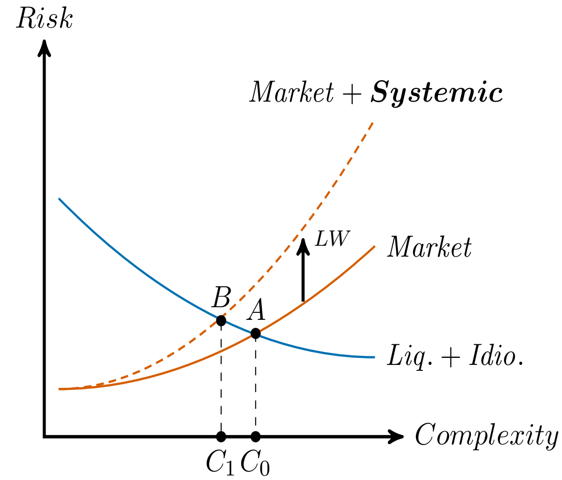
A simple set of graphical illustrations provide intuition around how other types of regulation alter the dynamics between complexity, living wills, and risk profiles. Consider first a simple illustration of the empirical findings from Section 4.1, with Figure 5 panel a showing the positive relationship between complexity (organizational and geographic) and BHC market risk, and a negative relationship with idiosyncratic risk from diversification and liquidity risk from utilizing internal capital markets and management at a conglomerate level. Under this partial equilibrium setting, the BHC chooses a level of complexity, for example C_0, that captures the trade-offs as complexity rises along the horizontal axis. Initial levels of systematic market risk, idiosyncratic risk, and liquidity risk all are normalized to R_0.

The other three panels consider the effects of resolution frameworks (panel b), tighter liquidity requirements (panel c) and tighter capital requirements like those arising from Basel III higher minimum capital ratios and stress testing (panel d). Under LWs, the BHC internalizes more of the externalities associated with systemic risk exposures. Instead of exclusively considering the upward sloping market risks, the trade-offs on the increasing risk side also consider the systemic risk exposures 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 (2018). 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.

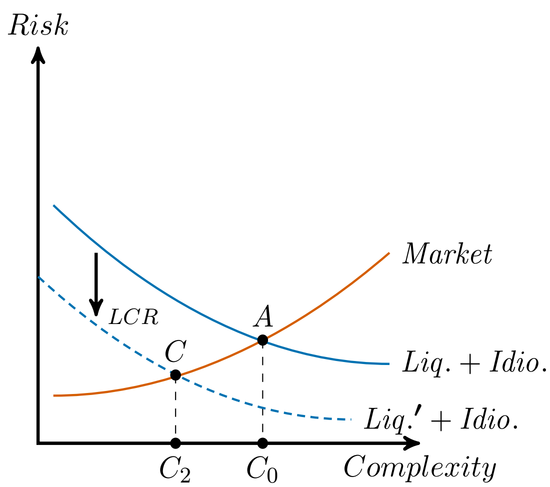
Figure 5: Illustration of Risk and Complexity Relationships, with Regulation Shifts



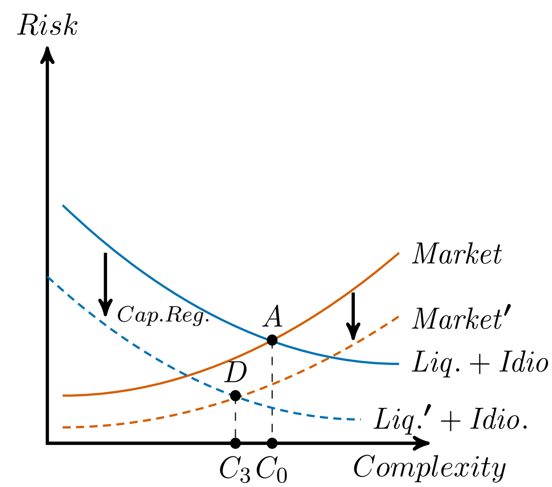
(a) Baseline



(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.

5 Conclusion

The links between BHC complexity and risk became apparent during the global financial crisis. Large and complex BHCs had significant systemic risk exposures and, given their systemic importance, were very difficult to resolve during the crisis. The TBTF phenomenon was also a too complex to fail phenomenon, underscoring extensive post crisis efforts to make BHCs more resilient so that failure probabilities would decline, and make banks less complex, so that externalities from failures would have fewer costly externalities.

A starting point of this paper has been that the broader relationship between types of BHC complexity and the frontier of types of BHC risks has not been well understood. Agency problems weigh against diversification gains in driving risk outcomes. We show that the regulatory actions taken after the global financial crisis, specifically living wills guidance, were associated with significant declines in organizational complexity among US BHCs with over $25 billion in assets. These changes translated into reductions in BHCs' idiosyncratic and systemic risks, partially explained by a decrease in BHCs' income variability.

BHC governance and regulatory changes can 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, reaping benefits in their income diversification and reducing their exposures to idiosyncratic risks and liquidity risks. Although new regulations have decreased idiosyncratic and systemic risks through changes in complexity, liquidity risk (and less so for systematic risk) exposures increased. This finding is consistent with average results measured over a longer horizon between profiles of BHC risk and types of organizational, business, and geographic complexity. These organizational, business, and geographic complexity types go well beyond the more balance sheet and opacity based constructs more regularly used in international policy circles to describe complexity. The ability of BHCs 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 BHCs.

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Table 1: Summary Statistics of Variables

	mean	sd	min	p25	p50	p75	max	count
BHC Sample								
Assets ($2012 billions)	258	458	23	48	91	202	2542	3659
Loans to Assets Ratio	0.58	0.19	0.02	0.52	0.65	0.71	0.87	3658
Deposits to assets ratio	0.63	0.18	0.00	0.58	0.66	0.74	0.94	3538
Liquid assets ratio	0.26	0.15	0.00	0.16	0.22	0.31	0.82	3652
Equity to assets ratio	0.09	0.03	0.03	0.07	0.09	0.11	0.22	3659
Number of BHCs	33	6	23	29	32	34	49	3659
BHC Complexity								
Total affiliate count	382.35	672.69	4	58	115	388	4494	3601
BPC1: Business Scope	0.00	1.28	-3.57	-1.03	-0.17	1.06	3.27	3593
CountB	5.22	0.55	3	5	5	6	6	3601
CountN	17.19	8.16	4	12	14	20	53	3601
Non-Financial Count Share	0.45	0.18	0.05	0.32	0.42	0.55	0.97	3601
BHHI	0.75	0.16	0.08	0.68	0.79	0.85	1.00	3601
Non-interest income share	0.45	0.19	0.00	0.31	0.41	0.53	1.00	3651
GPC1: Geographic Scope	0.00	1.77	-1.53	-1.35	-0.74	1.19	6.53	3601
CountC	14.78	18.10	1	2	6	22	87	3601
Count Net due to positions	11.66	18.07	1	1	3	16	100	3659
CHHI	0.31	0.29	0.00	0.04	0.21	0.60	0.94	3601
Share of foreign office claims in total assets	0.08	0.12	0.00	0.00	0.01	0.13	0.52	3659
BHC Diversification								
Income Diversification	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								
(-1) Log Z-Score	-2.81	0.84	-5.89	-3.37	-2.77	-2.22	-0.57	3467
(-1) Market Z-Score	-4.04	0.47	-5.14	-4.36	-4.12	-3.80	-1.79	3565
Dynamic Beta	1.16	0.43	0.17	0.90	1.09	1.34	4.38	3111
SRISK	1.79	16.44	-68.09	-2.34	-0.16	1.90	142.64	3111
LIBOR-OIS Beta	-0.03	0.11	-0.87	-0.05	-0.01	0.02	0.40	2151
BHC Governance								
GovPC1: Bank Ownership Governance	-0.00	1.20	-4.07	-0.76	0.12	0.98	2.41	2450
Total Inst. Ownership, Pct. Shares Outstanding	0.64	0.17	0.00	0.52	0.63	0.76	1.94	2960
Share of independent directors	0.78	0.12	0.29	0.71	0.80	0.88	1.00	2703
CEO duality	0.13	0.33	0				1	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 and Risk, Average Long Run Relationship

This table presents signs and significance of estimates of equations (1) and (2) without IV. The first panel uses the regression with diversification or risk measures on the left hand side and complexity on the right hand side, with bank and macro controls. The second panel uses the regression with complexity measures on the left hand side and diversification or 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**		
Diversification (Risk) as Dependent Variable	Org.	Bus. Scope	Geo. Scope	Org.	Bus. Scope	Geo. Scope
Income Diversification	–	+	–**	–***	–	–***
Idiosyncratic Returns	–**	–**	+	–	–	–
(-1) Log Z-score	+	+	–	–**	–	–***
(-1) Log Market Z-score	–***	–***	+	–	–*	+
LIBOR-OIS Beta	–***	–	–**	–	–	–**
Dynamic Beta	+	–	+***	+**	+	+***
SRISK	+*	+	+**	+***	+**	+**
Complexity as Dependent Variable	Org.	Bus Scope	Geo. Scope	Org.	Bus Scope	Geo. Scope
Income Diversification	–	+	–	+	–	+*
Idiosyncratic Returns	–*	–**	+	–	–**	+
(-1) Log Z-score	+	+	–	+	–	+**
(-1) Log Market Z-score	–**	–***	+	–	–**	+
LIBOR-OIS Beta	–***	–*	–**	–	+	–**
Dynamic Beta	+	–	+***	+**	+	+***
SRISK	+***	+	+*	+***	+	+**

Table 3: 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. The first panel 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. The second panel 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:**		
Diversification (Risk) as Dependent Variable	Org.	Bus. Scope	Geo. Scope	Org.	Bus. Scope	Geo. Scope
Income Diversification	+	+	+	+*	+	+*
Idiosyncratic Returns	+	+	+	+	+	+
(-1) Log Z-score	+	+	+	+*	+	+
(-1) Log Market Z-score	+***	+***	+**	+***	+***	+**
LIBOR-OIS Beta	+**	+**	+**	+**	+**	+**
Dynamic Beta	+***	+***	+***	+*	+	+*
SRISK	+	+	+	−	−	−
Complexity as Dependent Variable	Org.	Bus Scope	Geo. Scope	Org.	Bus Scope	Geo. Scope
Income Diversification	+**	+***	+	+**	+***	+
Idiosyncratic Returns	+*	+***	+	+*	+***	+
(-1) Log Z-score	+**	+***	+	+**	+***	+
(-1) Log Market Z-score	+**	+***	+	+**	+***	+
LIBOR-OIS Beta	+	−	+	+	−	+**
Dynamic Beta	+**	+***	+	+*	+***	+
SRISK	+**	+***	+	+*	+***	+

Table 3, 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. The first panel 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. The second panel 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**		
Diversification (Risk) as Dependent Variable	Org.	Bus. Scope	Geo. Scope	Org.	Bus. Scope	Geo. Scope
Income Diversification	+**	+**	+**	+**	+*	+**
Idiosyncratic Returns	−**	−**	−***	−***	−***	−***
(-1) Log Z-score	+	+	+	+*	+	+
(-1) Log Market Z-score	−	−*	−**	−*	−	−**
LIBOR-OIS Beta	+	+	+	+	+	+
Dynamic Beta	+	+	+	−	+	−
SRISK	+	+	+	−	−	−
Complexity as Dependent Variable	Org.	Bus Scope	Geo. Scope	Org.	Bus Scope	Geo. Scope
Income Diversification	+**	+	+	+	+	+
Idiosyncratic Returns	+**	+	+	+**	+	+
(-1) Log Z-score	+**	+	+	+**	+*	+
(-1) Log Market Z-score	+**	+	+	+**	+	+
LIBOR-OIS Beta	+*	+	+*	+*	+	+**
Dynamic Beta	+	+	+	+	+	+
SRISK	+	+	+	+	+	+

Table 3: 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 three measures of complexity: organizational complexity, business scope, and geographic scope. $d_{b,t}$ is an indicator variable equal to 1 after the LW became law in 2012Q3 for affected banks. *GovPC*1 is the first principal component of share of stocks owned by institutional owners and the share of independent directors of a bank. *CEO Non-Duality* indicates when the CEO is not also the Chairman of the Board of Directors of the BHC. $750^{+}_{b,2009}$ is an indicator variable for BHCs greater than $750 billion in assets. BHC controls capture the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio, lagged one quarter. 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 BHC fixed effects and standard errors clustered at the BHC level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	Log Total Count			BPC1: Business Scope			GPC1: Geographic Scope		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$d_{b,t}$	-0.160***	-0.115*	-0.119*	-0.053	-0.083	-0.054	-0.070	-0.088	-0.021
	(0.049)	(0.062)	(0.063)	(0.085)	(0.104)	(0.081)	(0.062)	(0.057)	(0.067)
$d_{b,t}$ X $750^{+}{}_{b,2009}$		-0.230**	-0.233**		0.048	0.056		0.082	0.096
		(0.112)	(0.112)		(0.118)	(0.123)		(0.167)	(0.153)
$d_{b,t}$ x GovPC1$_{b,2009}$			-0.020			0.031			0.039
			(0.084)			(0.079)			(0.062)
$d_{b,t}$ x CEO Non-Duality$_{b,2009}$			0.081			-0.288			-0.605*
			(0.210)			(0.331)			(0.350)
N	1183	1140	1140	1183	1140	1140	1183	1140	1140
Adj. within-R2	0.27	0.30	0.30	0.11	0.11	0.11	0.24	0.25	0.28
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	47	43	43	47	43	43	47	43	43

Table 4: 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 two measures of diversification: Income Diversification and Idiosyncratic Returns. $d_{b,t}$ is an indicator variable equal to 1 after the LW became law in 2012Q3 for affected banks. $GovPC1$ is the first principal component of share of stocks owned by institutional owners and the share of independent directors of a bank. *CEO Non-Duality* indicates when the CEO is not also the Chairman of the Board of Directors of the BHC. $750^{+}_{b,2009}$ is an indicator variable for BHCs greater than $750 billion in assets. BHC controls capture the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio, lagged one quarter. 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 BHC fixed effects and standard errors clustered at the BHC 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)
$d_{b,t}$	-0.004***	-0.004***	-0.004*	0.001	-0.000	0.001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
$d_{b,t}$ x $750^{+}{}_{b,2009}$		0.003	0.003		0.004**	0.004***
		(0.002)	(0.002)		(0.002)	(0.001)
$d_{b,t}$ x $GovPC1_{b,2009}$			0.001			0.000
			(0.004)			(0.001)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$			-0.004			-0.006**
			(0.003)			(0.003)
N	1120	1085	1085	1143	1100	1100
Adj. within-R2	0.24	0.25	0.25	0.62	0.63	0.64
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	48	44	44	48	44	44

Table 5: 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 risk: (-1) Log Z-Score, (-1) Log Market Z-Score, Dynamic Beta, SRISK, and LIBOR-OIS Beta. $d_{b,t}$ is an indicator variable equal to 1 after the LW became law in 2012Q3 for affected banks. *GovPC*1 is the first principal component of share of stocks owned by institutional owners and the share of independent directors of a bank. *CEO Non-Duality* indicates when the CEO is not also the Chairman of the Board of Directors of the BHC. $750^+_{b,2009}$ is an indicator variable for BHCs greater than $750 billion in assets. BHC controls capture the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio, lagged one quarter. 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 BHC fixed effects and standard errors clustered at the BHC level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	(-1) Log Z-Score			(-1) Log Market Z-Score		
	(1)	(2)	(3)	(4)	(5)	(6)
$d_{b,t}$	-0.487***	-0.500***	-0.414**	-0.046**	-0.056***	-0.050*
	(0.120)	(0.136)	(0.175)	(0.020)	(0.020)	(0.027)
$d_{b,t}$ x $750^+{}_{b,2009}$		0.110	0.122		0.044	0.045
		(0.246)	(0.222)		(0.059)	(0.058)
$d_{b,t}$ x $GovPC1_{b,2009}$			-0.090			0.001
			(0.239)			(0.026)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$			-0.441			-0.043
			(0.296)			(0.091)
N	1120	1085	1085	1143	1100	1100
Adj. within-R2	0.39	0.39	0.40	0.82	0.82	0.82
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	48	44	44	48	44	44

	Dynamic Beta			SRISK			LIBOR-OIS Beta		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$d_{b,t}$	0.021	-0.010	0.032	-4.404**	0.507	1.317	0.051***	0.058***	0.069***
	(0.036)	(0.037)	(0.034)	(1.689)	(1.429)	(1.926)	(0.008)	(0.008)	(0.009)
$d_{b,t}$ x $750^+{}_{b,2009}$		0.118	0.121		-21.333***	-21.378***		-0.028**	-0.027*
		(0.106)	(0.098)		(7.766)	(7.556)		(0.014)	(0.016)
$d_{b,t}$ x $GovPC1_{b,2009}$			0.002			-2.187			-0.011
			(0.029)			(1.361)			(0.008)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$			-0.311*			-1.645			-0.061
			(0.167)			(6.569)			(0.038)
N	1082	1039	1039	1082	1039	1039	1143	1100	1100
Adj. within-R2	0.55	0.56	0.56	0.24	0.35	0.35	0.10	0.10	0.10
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	44	40	40	44	40	40	48	44	44

Table 6: 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. $d_{b,t}$ is an indicator variable equal to 1 after the LW became law in 2012Q3 for affected banks. $GovPC1$ is the first principal component of share of stocks owned by institutional owners and the share of independent directors of a bank. *CEO Non-Duality* indicates when the CEO is not also the Chairman of the Board of Directors of the BHC. $750^{+}_{b,2009}$ is an indicator variable for BHCs greater than $750 billion in assets. BHC controls capture the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio, lagged one quarter. 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 BHC fixed effects and standard errors clustered at the BHC 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)
$d_{b,t}$	-0.004***	-0.012**	-0.011**	0.001	-0.005**	-0.004**
	(0.001)	(0.006)	(0.006)	(0.001)	(0.002)	(0.002)
$d_{b,t}$ x Org. $Complex_{b,2009}$		0.002	0.002*		0.001**	0.001***
		(0.001)	(0.001)		(0.000)	(0.000)
$d_{b,t}$ x $GovPC1_{b,2009}$ x Org. $Complex_{b,2009}$			0.000			-0.000
			(0.001)			(0.000)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$ x Org. $Complex_{b,2009}$			-0.001			-0.001***
			(0.001)			(0.000)
N	1120	1114	1114	1143	1137	1137
Adj. within-R2	0.24	0.26	0.26	0.62	0.63	0.63
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	48	47	47	48	47	47

Table 7: 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. $d_{b,t}$ is an indicator variable equal to 1 after the LW became law in 2012Q3 for affected banks. *GovPC*1 is the first principal component of share of stocks owned by institutional owners and the share of independent directors of a bank. *CEO Non-Duality* indicates when the CEO is not also the Chairman of the Board of Directors of the BHC. $750^{+}_{b,2009}$ is an indicator variable for BHCs greater than \$750 billion in assets. BHC controls capture the log of real assets, the liquid assets ratio, loans to deposits ratio, equity to assets ratio, lagged one quarter. 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 BHC fixed effects and standard errors clustered at the BHC level. * denotes statistically significant results at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

	(-1) Log Z-Score			(-1) Log Market Z-Score		
	(1)	(2)	(3)	(4)	(5)	(6)
$d_{b,t}$	-0.487***	-1.151*	-1.135*	-0.046**	-0.092	-0.085
	(0.120)	(0.576)	(0.571)	(0.020)	(0.091)	(0.086)
$d_{b,t}$ x Org. $Complex_{b,2009}$		0.131	0.150		0.009	0.010
		(0.103)	(0.093)		(0.018)	(0.018)
$d_{b,t}$ x $GovPC1_{b,2009}$ x Org. $Complex_{b,2009}$			-0.028			-0.001
			(0.047)			(0.005)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$ x Org. $Complex_{b,2009}$			-0.106			-0.019
			(0.087)			(0.019)
N	1120	1114	1114	1143	1137	1137
Adj. within-R2	0.39	0.40	0.41	0.82	0.82	0.82
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	48	47	47	48	47	47

	Dynamic Beta			SRISK			LIBOR-OIS Beta		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$d_{b,t}$	0.021	-0.277*	-0.253*	-4.404**	18.089*	19.010**	0.051***	0.077**	0.080**
	(0.036)	(0.159)	(0.135)	(1.689)	(9.442)	(8.530)	(0.008)	(0.034)	(0.031)
$d_{b,t}$ x Org. $Complex_{b,2009}$		0.059*	0.062**		-4.409**	-4.126**		-0.005	-0.004
		(0.031)	(0.028)		(2.095)	(1.902)		(0.006)	(0.006)
$d_{b,t}$ x $GovPC1_{b,2009}$ x Org. $Complex_{b,2009}$			0.001			-0.677*			-0.002
			(0.007)			(0.372)			(0.002)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$ x Org. $Complex_{b,2009}$			-0.065*			-2.279			-0.008
			(0.035)			(2.638)			(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
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	44	43	43	44	43	43	48	47	47

Appendix

A1 Constructing 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 $\text{Share}_{b,t}$	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 $\text{share}_{b,t}$	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 $\text{claims}_{b,t}$	Share of foreign office claims in total assets, by bank
$CountNDT_{b,t}$	Count Net Due to Positions, countries, by bank

Organizational complexity is computed as the total number of legal entities within the BHC, $Count_{b,t}$. Industry type is indexed by i based on NAICS code, 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,

Table A2: PCA of Complexity Variables

	Comp1	Comp2
Business Complexity ($BPC1_{b,t}$)		
Non-Financial Count Share	0.14	-0.76
CountB	0.55	0.23
BHHI	-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 ($GPC1_{b,t}$)		
CountC	0.52	-0.28
CHHI	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 ($GovPC1_{b,t}$)		
Total Inst. Ownership, Percent of Shares Outstanding	0.71	0.71
Share of independent directors	0.71	-0.71
Fraction of variance explained	1	

Other Nonfinancial);[18] 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.

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

[18]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.