Bank Complexity, Governance, and Risk*

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October 2020

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, geographic, and organizational 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 balance of outcomes may depend on the strength of bank governance. We test these conjectures using data on large U.S. BHCs for the 1996-2018 period. Business, geographic, and organizational complexity provide diversification benefits and some reduced idiosyncratic and liquidity risk exposure. Geographic and organizational complexity, on average, also increase BHC systemic risks. Regulatory tightening focused on complexity reduced organizational complexity, also curtailing systemic risk while increasing liquidity risk. Better governance tends to reduce the adverse effects of geographic complexity on risk.

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

JEL Classification: G21, G28, G32.

*We appreciate the thoughtful comments of the editor Thorsten Beck, two anonymous references, Iñaki Aldasoro, Allen Berger, Robert DeYoung, Krzysztof Gajewski, Kose John, Lukasz Kamil Kurowski, Katheryn Russ, Giovanni dell'Ariccia, and seminar participants at the European Central Bank, George Mason University, the IBEFA Annual Meeting in San Diego, MoFiR, the Villanova WiFi seminar, the Bank of Italy and Bocconi 2020 conference on financial stability, and workshop participants at the 4th Annual Chapman Conference on Money and Finance and the 2019 IBRN meeting. Mary Chen, Sarah Ngo Hamerling, Janavi Janakiraman, and Kevin Lai provided excellent research assistance. Scott Okrent provided invaluable help in computing the systemic risk measures using the code facilitated by the VLab at New York University. The views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System, the Federal Reserve Bank of New York, or of any other person associated with the Federal Reserve System.

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1 Introduction

Large and complex banking organizations in the United States have received considerable regulatory scrutiny after the global financial crisis (GFC), with a focus on improving their resilience and reducing the costly externalities that could occur when these organizations fail. Bank size and balance sheet structures have garnered extensive analytical attention in too-big-to-fail (TBTF) and risk discussions (Gandhi and Lustig, 2015). However, relatively little analytical work has focused on the implications of bank complexity, mainly oriented toward 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, broader business and geographic scope can provide a BHC with a form of insurance against default risk, as posited by (Luciano and Wihlborg, 2018) and may reduce its exposure to liquidity risk (Cetorelli and Goldberg, 2016) and sovereign stress (Baggatini et al., 2018). Alternatively, complexity may instead increase the idiosyncratic risk profile if agency problems within the organization dominate. Such 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 (Freixas, Loranth and Morrison, 2007) could exacerbate this likelihood.

We posit that the optimization problem of the BHC entails balancing the benefits of income and return diversification through more complex structures with the costs associated with agency problems. The net effect of these opposite forces may depend on the strength of monitoring and corporate governance. We provide tests of the average association between BHC complexity, diversification, and risk over time using instrumental variables techniques. We then focus more specifically on the roles of regulation and corporate governance as drivers of bank organizational complexity, and the associated risks. We test for the relation between complexity and bank risk using the increase in the effective cost of complexity after the introduction of 2010 Living Will

[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.

(LW) guidance of the Dodd-Frank Consumer Protection Act (DFA). We also test whether stronger BHC governance alters outcomes for the different types of risk metrics.

Our analysis explores these hypotheses across all U.S. 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 U.S. BHCs: business, geographic, and organizational. These three areas of complexity decreased for some of the largest BHCs after the GFC, although business scope tended to remain more stable (Goldberg and Meehl (2020)). In addition to constructing measures of return diversification by BHC and over time, we construct a range of BHC-specific risk measures in order to observe whether risk trade-offs occur, covering idiosyncratic, systematic risk, liquidity, and systemic risks. BHC governance proxies use data on institutional investor ownership shares, the absence of duality of CEO and Chair of the Board of Directors roles, and the share of independent directors.

We test our hypotheses on the complexity-risk-governance nexus using panel instrumental variables (IV) specifications, which establish the average relations between complexity and risk over time, and using difference-in-difference estimations around a relevant regulatory tightening for a more explicit causal interpretation. We posit that BHC complexity reduces part of the risk profile of banks if it is accompanied by increased diversification of income streams and improved liquidity management. This may imply a trade-off with increases in other risk exposures. We further conjecture that these outcomes are more likely for better governed organizations. In terms of regulatory drivers, we explore whether the introduction and accompanying regulations of the LW guidance altered the relationship between bank risk and complexity. The DFA's BHC resolution planning elements and, in 2017, guidance on legal entity rationalization required 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, business, 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 systemic risks, and more systematic risk in the case of geographic complexity. These results are economically significant. For example, a one standard deviation increase in geographic complexity is associated with a 0.7 standard deviation increase in income diversification and a 0.6 standard deviation decrease in liquidity risk for BHCs. In contrast, this same increase in geographic complexity is associated with a 1.1 standard deviation increase in systematic risk and a 2.5 standard deviation increase in systemic risk. These findings suggest, in particular, that as BHCs increase organizational and geographic complexity, they trade off the beneficial reductions in idiosyncratic and liquidity risks for greater exposures to systematic and systemic risks.

Another important finding is that the strength of the BHC complexity effects are not changed in a consistent way with better governance. These results do not provide support for two of our conjectures about the role of governance. We do not find consistent evidence that better governed banks pursue more complex arrangements to achieve gains in income and liquidity diversification. We also do not find support for the hypothesis of agency problems dominating risk outcomes due to complexity under weak governance. It is possible that these weak results are influenced by the specific governance proxies used combined with the instrumentals variables approach applied.

Our second set of results address the consequences of regulatory tightening for both BHC complexity and risk. We show that BHCs significantly reduced organizational complexity after being required to submit living wills. The variability of return on assets declined on average, while the variability of idiosyncratic returns did not change. The *ex ante* better governed BHCs on average had diversification gains on idiosyncratic returns while the worse governed firms had diversification losses. The BHC balance sheet income diversification increases translated into a drop in idiosyncratic risks. Liquidity risk exposure rose on average, while systemic risk on average declined in U.S. BHCs. Market risk declined on average for the better governed BHCs.

However, these average effects for market risk and systemic risk mask important differences when BHC consequences are differentiated by both *ex ante* organizational complexity and governance, reinforcing the importance of using micro data for hypothesis testing. Market risk declined for both less complex BHCs and for the complex BHCs that are better governed. Systematic risk exposure actually increased for the most complex and less well governed BHCs. Systemic risk may have increased for low complexity BHCs, and otherwise the declines were most pronounced for the better governed and more complex organizations.

The introduction of this resolution tool was associated with a decrease in systemic risks for the 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 is that regulators can face trade-offs when actions targeted at reducing complexity may increase some risks associated with lower complexity (e.g., liquidity risk), even while reducing others (e.g., systemic risk). Better governance delivered more risk reduction in conjunction with the introduction of the resolution framework, even if this governance did not actually lead to greater declines in BHC organizational complexity.

Our analytics build on three important literatures. First, significant advances are being made in measuring BHC complexity (Avraham et al. 2012, 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 are relatively easy. Our contributions toward measurement of complexity stem from using structural features of the organization along with other metrics, and then applying principle component analysis to extract key features from the range of distinct inputs for business and geographic complexity. Included in these components are balance sheet data for BHCs, alongside bank structure information.

Second, we add careful insights about complexity to a 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 (Afonso et al., 2014; 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; Santos and Wilson, 2017). 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 also 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 increased banks' cost of capital, especially for banks that were systemically important before the crisis (Cetorelli and Traina, 2018). Our work starts with the perspective 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 for the more complex BHCs, with some results dependent on the strength of BHC governance. Complexity concepts are sometimes correlated with size, but we show that these relationships are quite diverse. These findings are also interesting, as market views of sources of systemic risk have evolved from an exclusive focus on size prior to the crisis to post-crisis additional consideration of complexity and interconnectedness (Antill and Sarkar, 2018). That research shows that since 2007 a BHC (organizational) complexity factor accounts for more than half of the total implicit subsidies computed on the basis of equity prices and systemic risk.

Third, and relatedly, we contribute to the important literature on the consequences of post-global financial crisis bank reforms. Regulations that cover bank liquidity, bank capital and bank resolution are likely to alter the trade-offs among the risks that BHCs internalize. Within an extensive literature that addresses the consequences of liquidity and capital regulations, the lengthy bankruptcy process and complexity of Lehman Brothers clearly 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; Carmassi and Herring, 2016). Measures constructed for a sample of Euro Area banks between 2007 and 2014 shows that these banks increased their number of subsidiaries, while not increasing the diversification of subsidiaries across regions and business types (Krause et al., 2017). Some of the growth in complexity may have arisen as BHCs 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). Tax considerations come up in different ways, whether around creating entities to generate tax benefits from community housing subsidies in the U.S. (Cetorelli and Wangl, 2016) or low tax foreign jurisdictions (Goldberg and Meehl, 2020). Our contribution to the literature on U.S. BHCs shows the trade-offs among types of risks from changing types of complexity, and establishes post-global financial crisis regulatory drivers. We also provide a conceptual discussion arguing that liquidity regulations that reduce BHC exposure to liquidity risk will have the unanticipated consequence of reducing the benefits to BHCs from pursuing geographic complexity. Likewise, living wills and resolution planning can 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 attributes for large U.S. 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 instrumental variables. This section then tests for changes around living will provisions of the DFA. Section 5 concludes with a discussion of the conceptual importance of different regulations for complexity choices, and then turns to the ramifications of our results for regulatory frameworks, as complexity for better governed BHCs may lower the probability of an idiosyncratic or liquidity BHC stress event while possibly increasing the severity of 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.

2 Complexity Drivers, hypotheses and testing

This section describes the regulatory developments that have directly shaped the complexity of U.S. BHCs in recent years and then turns to describe hypotheses on how more complex organizations might inherently take more risks. The section also 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 their size, corporate complexity, and business scope, which now covers new areas of financial intermediation and non-financial activities. Moreover, the international footprints of banking organizations have evolved, with branch and subsidiary networks expanding for BHCs (Claessens and Horen, 2014a; Claessens and Horen, 2014b) and with notable increases in internationally-located nonbank legal entities (see Cetorelli, McAndrews and Traina (2014) and Goldberg and Meehl (2020) for U.S. evidence; Cetorelli and Goldberg (2014) and Carmassi and Herring (2016) for international evidence).

The evolution in the complexity of U.S. BHCs has been influenced by changes in regulations, financial innovation, and competitive pressures (Cetorelli et al., 2014). The slow phase-out of restrictions on banks' non-traditional activities such as securities underwriting, imposed by the Glass-Steagall Act (GSA), began in the late 1980s and early 1990s . This trend culminated with the passage of the Gramm-Leach-Bliley Act (GLBA) in 1999, which repealed the GSA and allowed banks to engage in investment banking activities and also to expand into the insurance business (Chernobai, Ozdagli and Wang, 2020).[2] Asset securitization changed the technology of intermediation, while allowances in risk and liquidity management, with changes in tax codes and financial secrecy, 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 the 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 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

[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.

or more in assets to submit living wills on an annual basis. These living wills should ultimately reduce systemic risks from systemically important financial institutions by providing a road map for 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

As noted before, the levels of complexity at banking conglomerates should be influenced by competition, innovation, and the regulatory environment. 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 managers' optimization problems (Rajan 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 locations of BHC affiliates. 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 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 banking units are made available to meet the needs of nonbank affiliates, banking units 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 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. In this case, synergies from liquidity risk sharing complemented business 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 U.S. 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, 2020; 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.

Given these relations outlined in the literature, we pose our first set of hypotheses that directly address the trade-offs between complexity, diversification, and risk:

Hypothesis 1a: *Bank complexity reduces the risk profile of banks if 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.*

To test **Hypothesis 1a** we estimate a system of equations which relates measures of diversification or risk at the banking organization level with measures of organizational, business, and geographic complexity. This system of equations takes into account the possibility that complexity and risk are simultaneously determined. Formally, we estimate the following system:

$$Y_{b,t} = \alpha^1 + \theta^1 \cdot C_{b,t-1} + \gamma^1 \cdot X_t + \psi^1 \cdot W_{b,t-1} + \delta_b + \epsilon_{b,t} \tag{1}$$

$$C_{b,t} = \alpha^2 + \theta^2 \cdot Y_{b,t-1} + \gamma^2 \cdot X_t + \psi^2 \cdot W_{b,t-1} + \kappa_b + \omega_{b,t} \tag{2}$$

where b denotes the individual BHCs and t denotes time. $Y_{b,t}$ is either a measure for $Diversification_{b,t}$, such as the standard deviation of return on assets or of idiosyncratic stock returns, or for a measure of $Risk_{b,t}$. Our main tests 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.

In the system of equations, we instrument for $C_{b,t}$ and $Y_{b,t}$ using two sets of distinct instruments. The instrument for $C_{b,t}$, the complexity measures, are the natural logarithm of the number of BHC employees in each quarter, an indicator variable equal to 1 between the passage of the GLBA in 1999 and the DFA in 2010, and the level of complexity of other banks in the same size tercile as bank b. Starting with the relevance conditions for these instruments, banks with more employees should be in general more complex, as the number of employees could signal participation across more legal entities, businesses, or geographies. The regulatory indicator equals one for a period where BHCs were allowed to expand their scope of business activities and delve into asset securitization markets with fewer restrictions (Acharya et al., 2013). As noted in Cetorelli et al. (2014), the regulatory environment influences banks' decisions to become more complex, and the particular period captured by the indicator variable is associated with fewer limits on banks' scope to become complex. Lastly, the competitive environment may also influence banks to become complex. If competitors in the same size range increase their level of complexity, they may influence the bank's decision to follow similar strategies. Thus, the level of complexity of competitors should be associated to the degree of complexity of each bank.

In terms of the exclusion restriction, the level of employment of a given bank by itself should not necessariliy be related to the level of risk or diversification of a bank. It should influence those variable only through the organizational structure, businesses, and geography of where those employees are located. For example, banks with more employees are more risky if those employees are allocated to a broader set of geographies or function in a more complex organizational structure. In the case of the regulatory indicator, the GLBA was particular in affecting the activities in which banks could operate, a feature directly captured by our complexity measures. In general, studies have found an inconclusive link between this regulatory event and risk measures (Filson and Olfati, 2014). Thus, we pose that this regulatory change is only likely to influence risk depending on the complexity structure of analyzed banks. Last, the degree of complexity of competitors is only likely to influence a bank's risk levels if the bank decides to follow its competitors into adjusting their degree of complexity. It is unlikely that the complexity of competitors would influence BHCs' risk characteristics directly.

The instruments for $Y_{b,t}$, the diversification and risk measures, are the market-to-book ratio of each bank, which proxies for the BHC's charter value, the VIX_t, which captures general risk appetite in the economy, and the nonperforming loan ratio. With regards to the relevance restriction of these instruments, lower franchise value has typically been associated with more risk-taking behavior by banks (Demsetz et al., 1996), while the VIX is a broad measure of risk appetite that should also be associated with BHC risk. Similarly, the quality of BHC loan portfolios, as captured by the nonperforming loan ratio, should reflect the riskiness of BHCs. The exclusion restriction also applies to these variables. The market to book ratio and the VIX should only influence the degree of complexity of BHCs through the risk-taking behavior of banks, as captured by the risk proxies. As noted previously, the factors that affect complexity are competition, innovation, and some aspects of the regulatory environment. Similarly, the nonperforming ratio should affect complexity only through the risk proxies.

We also control in these specifications for other bank characteristics ($W_{b,t-1}$) that are viewed as determining the risk or complexity profile of banks. In particular, we include an indicator variable equal to one for banks that were deemed global systemically important in 2012, as well as the ratios of deposits, loans, and liquid assets to total assets for each bank. The specifications also control for macro environmental characteristics (X_t), captured by GDP growth and the credit-to-GDP gap. All explanatory variables are lagged by one period in order to address issues of simultaneity.

We estimate the system of equations using limited-information maximum likelihood, as this method is more robust to the presence of weak instruments. Standard errors are clustered at the level of the BHC. Specifications include fixed effects δ_b and κ_b account for unobserved time-invariant BHC heterogeneity.

A negative estimate of θ^1 in equation (1) using diversification as a dependent variable signals that more complex structures enhance diversification of revenue streams (the diversification proxies are defined such that lower values imply more diversified income streams). A 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. Given these relations, we would reject Hypothesis 1a if banks' return variability does not decrease with complexity and if the proxies for risk are positively associated with complexity.

To test Hypothesis 1b we follow a similar strategy as in equations (1) and (2), but introduce measures of corporate governance at the BHC level and interaction terms between these variables and the complexity and diversification (risk) measures. Concretely, we estimate the following system of equations:

$$Y_{b,t} = \alpha^1 + \theta^1 \cdot C_{b,t-1} + \beta^1 \cdot G_{b,t-1} + \eta^1 \cdot C_{b,t-1} \cdot G_{b,t-1} + \gamma^1 \cdot X_t + \psi^1 \cdot W_{b,t-1} + \delta_b + \epsilon_{b,t} \qquad (3)$$

$$C_{b,t} = \alpha^2 + \theta^2 \cdot Y_{b,t-1} + \beta^2 \cdot G_{b,t-1} + \eta^2 \cdot Y_{b,t-1} \cdot G_{b,t-1} + \gamma^2 \cdot X_t + \psi^2 \cdot W_{b,t-1} + \kappa_b + \omega_{b,t} \qquad (4)$$

As noted in standard agency theories of the corporation (Jensen and Meckling, 1976; Shleifer and Vishny, 1989), under weak corporate governance arrangements, managers pursuing their self interest may build empires that focus on investments facilitating 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 increases 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.

BHC governance is introduced as $G_{b,t}$. 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 in the CEO and Board Chair role. The first two variables are aggregated using a principal component analysis, of which we use the first factor. This variable captures the governance characteristics associated with the shareholders of the banks. As in the Anglo-Saxon model of corporate governance, stronger governance is associated with providing shareholders more control to maximize the value of their investments (Macey and O'Hara, 2003). The share of institutional ownership and of independent directors proxy for that control, with higher values indicating more shareholder power. Similarly, CEO non-duality, or the separation of the CEO and Board Chair roles, measure the relative control of management compared to shareholders (Krause et al., 2014), with more control assigned to the CEO in cases when it performs both roles. CEO Non-Duality is viewed in the literature as limiting CEOs from exerting excessive power over the Board, and also improving the amount of information filtered to shareholders (Baldenius et al., 2014). This information may reduce agency problems within the BHC and improve its risk profile.

Under the null hypothesis, the positive link between complexity and risk should weaken if stronger governance at banks limits the "empire building" incentives of managers when more complex structures are pursued. However, as noted by Laeven and Levine (2009), stronger governance traits, at least focusing on shareholder power, do not necessarily lead to lower risk and could support a rejection of the null hypothesis. In this context, to test **Hypothesis 1b**, we focus on the η^1 coefficients. Positive values for these coefficients would lead us to reject the null hypothesis, as stronger governance would be associated with more risk.

In our estimation strategy, we take governance measures as pre-determined, given their slow moving nature. Thus, we use the same set of instruments from (1) and (2) in this specification, but we also instrument for the interaction terms. Importantly, BHC fixed effects included in the specifications ensure that our identification comes from changes in the governance measures around their mean value for the sample period.

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 can use changes in the regulatory environment, as demonstrated by Brandao-Marques et al. (2020), DeYoung et al. (2013) and Laeven and Levine (2009). Our primary focus is on the new regulatory frameworks for systemic banks proposed in the DFA of 2010, implemented starting in July 2012, including the guidelines for resolution planning published in 2016.[4]

Our second hypothesis addresses the link between complexity and risk by focusing on the new regulatory framework targeting complexity through resolution rules for systemic financial institutions. Complexity may have allowed banks to take on more risk through their involvement in low capital-cost riskier activities, or through enhancing the public-sector subsidy implicitly received by these institutions. Alternatively, per Hypothesis 1a, complexity also could have more nuanced consequences, depending on the types of complexity and risk metrics considered. By targeting the organizational structure of banks to facilitate their resolvability, new resolution frameworks may have reduced bank complexity, forced banks to rationalize their organizational structure, and ultimately altered risk taking. The following testable hypothesis sets up the first part of our difference-in-differences estimation:

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

As previously noted, complex corporate structures also may be driven by governance arrangements. We assess whether this particular regulatory change had a differential effect for banks with different governance. 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 assessment of these hypotheses, we test for the change in complexity after living wills were enacted, comparing firms with weaker and stronger governance arrangements.[5] For each estimation, we focus on the three years before and after the passage of the regulatory requirements. We estimate the following equation with and without corporate governance terms:

$$C^i_{b,t} = \alpha + \beta \cdot d_{b,t} + \phi \cdot d_{b,t} \cdot G_{b,2009} + \gamma \cdot X_t + \psi \cdot W_{b,t-1} + \delta_b + \epsilon_{b,t} \quad (5)$$

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

[5] Importantly, corporate governance are unlikely to move under this particular window of time, especially as living wills did not target these characteristics directly. Thus, we can assume that governance is pre-determined in this setting.

In equation (5), $d_{b,t}$ represents the date of implementing more restrictive policies around complexity for affected banks. 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.

Equation (5) includes three macroeconomic-level controls (X_t): GDP growth, the credit to GDP gap, and the VIX. We also include time-varying bank controls ($Z_{b,t}$) intended to capture bank level characteristics that may affect banks' decision to change its complexity level. In particular, we include the log of real assets (in 2012 dollars) of the banks and their ratios of deposits, equity, liquid assets, and loans to assets. We also include fixed effects at the bank level captured by δ_b.

The corporate governance measures are dated as of 2009 and are composed of the same governance measures used in (3), namely, the first principal component of the shares of institutional owners and independent directors across banks, and an indicator variable for CEO non-duality. Governance measures are defined as of 2009. Given that we include fixed effects, the main entry of the governance variables drops out of the equation.

A negative coefficient on β would imply that we cannot reject Hypothesis 2a and that tighter regulations do reduce complexity, as measured by the three types of complexity characteristics analyzed. Similarly, a positive coefficient on ϕ would imply that BHCs with better governance have a less pronounced decline in complexity after the regulatory tightening, consistent with Hypothesis 2b.

Finally, the counterpart on risk outcomes is that, *ceteris paribus*, the BHCs faced with the most extensive tightening and *ex ante* with the most dominant moral hazard outcomes should observe the greatest declines in risk profiles. We state this in the following hypothesis:

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 (5), where we compare bank diversification and 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.[6] Formally, we estimate:

$$Y_{b,t}^{i} = \alpha + \beta \cdot d_{b,t} + \phi \cdot d_{b,t} \cdot G_{b,2009} + \gamma \cdot X_t + \psi \cdot W_{b,t-1} + \delta_b + \epsilon_{b,t} \tag{6}$$

Where variables are defined as in equation (5). In this particular equation, our interest again is on β and ϕ. A negative value for β and positive for ϕ would lead us not to reject the null that more stringent regulatory frameworks focused on complexity are likely to reduce the risks of BHCs, especially for those with weaker governance, and increase their diversification.

We take this analysis one step further by looking at the change in diversification and risk for banks that were *ex ante* more organizationally complex. We focus on this type of complexity, because it was directly targeted by the living wills rules, especially those focused on rationalizing the number and structure of legal entities. We estimate the following variation of equation (6):

$$\begin{aligned} Y_{b,t}^{i} =& \alpha + \beta \cdot d_{b,t} + \phi \cdot d_{b,t} \cdot G_{b,2009} + \theta \cdot d_{b,t} \cdot OrgComp_{b,2009} \\ &+ \eta \cdot d_{b,t} \cdot G_{b,2009} \cdot OrgComp_{b,2009} + \gamma \cdot X_t + \psi \cdot W_{b,t-1} + \delta_b + \epsilon_{b,t} \end{aligned} \tag{7}$$

In this case, we would expect those banks with more *ex ante* complexity to have a stronger response to the regulatory change, implying a negative value for θ. Consistent with Hypothesis 3, we would expect the coefficient on η to be positive. That is, *ex ante* more complex banks with better governance arrangement are less likely to have big changes in their diversification or risk variables. This test should provide a complementary framework to asses Hypothesis 3.

3 Banking data: Complexity, governance, and risk

Complexity, risk, and governance data are defined at the level of the BHC. As U.S. 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 U.S. parentage (top-holder) and at least $25 billion in total real assets (calculated in real terms as of 2012), and the period 1996Q1 through 2018Q2.[7]

The summary statistics over the variables for the BHCs included in the estimation sample are presented in Table 1. The upper panel of this table presents the distribution of standard variables across BHC-quarter observations, showing the BHC distributions of total assets, deposit share in funding, loans relative to assets, liquid assets, and total equity capital to assets. The next section has data corresponding to BHC complexity characteristics, including the component pieces behind the main complexity variables used in our empirical tests. BHC diversification, risk, governance,

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

[7]Goldberg and Meehl 2020)spans U.S. BHCs that have more than $1 billion in assets and a U.S. topholder for 2007Q2 in contrast with 2017Q2. As a small number of BHCs under $25 billion can be complex according to the metrics we are using, we calculate some robustness tests including these few additional BHCs. The results show that these extra BHC observations do not qualitatively alter our main results. Results are available upon request.

and variables used as instruments follow. The table concludes with quarterly macro variables. A description of each variable used in our analysis is reported in Table A1 in the appendix.

The average number of BHCs that satisfy our inclusion criteria is 36 across all the quarters. The total number of BHCs by quarter is a minimum of 26 and rises to a maximum of 46 in later quarters. Nearly one quarter of the BHC-quarter observations are over $250 billion, and nearly half are below $100 billion.[8] The size distribution shifted towards larger institutions over time.

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 from regulatory reporting on the structure, number, location, and industry type of bank and non-bank affiliates under each BHC. We build on the conceptual foundations in Cetorelli and Goldberg (2014), the database for U.S. BHCs in Cetorelli and Stern (2015), and refinements of concepts and presentation of evidence for large U.S. BHCs in Goldberg and Meehl (2020). Those studies have organizational, business and geographic complexity metrics that 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 our current paper is the use of principal component analysis over both structural and balance sheet information that inform other aspects of business or geographic complexity.[9] Organizational, business, and geographic complexity indices are both BHC b and time t specific.

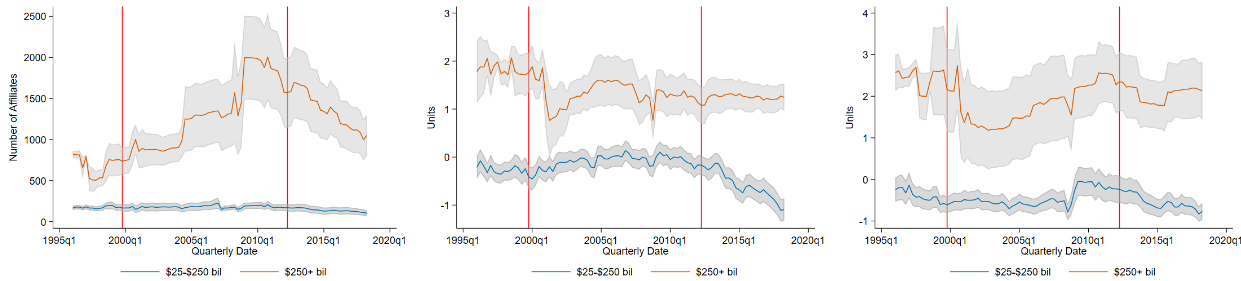
Organizational complexity is computed as the total number of legal entities within the BHC, $Count_{b,t}$. Figure 1 panel (a) shows the distribution of BHC organizational complexity by two broad BHC size categories, representing quarterly averages and standard deviation of complexity for BHCs in asset size bucket starting in 1996. The respective vertical lines are dates of the GLBA and DFA Living Will guidance. BHCs over $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. The maximum BHC-quarter observation is nearly 4500 legal entities under a single BHC. As 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.

Our measure for business complexity reflects the scope of financial and nonfinancial businesses of a BHC. We construct this metric using principal component analysis over information on the

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

[9] The construction approaches for the respective indices are presented in Tables A1 and A2.

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.

industries and businesses of the entities within each BHC. The respective inputs, with additional details provided in Table A2, are the total number of broad business categories spanned by these legal entities, the dispersion of legal entities across these types of businesses as captured by a herfindahl index BHHI, the portion of these legal entities that are outside the financial sector, the number of industrial categories spanned by the legal entities, and the share of income derived from sources other than interest. The measures vary considerably over time and for the smaller versus larger U.S. BHCs. We apply principal components techniques to summarize the top two common elements that span these four business complexity series and reduce the dimensionality of the data. The resulting first principal component, $BPC1_{b,t}$ discussed further in Appendix **??**, captures business scope. Business scope is considerably broader for the largest U.S. BHCs relative to those under $250 billion (Figure 1 panel (b)). The averages across this latter group of BHCs have trended downward in the years after the DFA. The largest U.S. BHCs' evolution in business scope in part tracked their shifting mixtures of financial and nonfinancial business (Goldberg and Meehl, 2020), with other analyses focused on consequences of mergers and acquisitions as well as competition in new services (Cetorelli et al., 2017).

Geographic complexity is measured using information on locations of 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[10], the dispersion of BHC affiliate locations across countries[11], bank-specific quarterly reporting on U.S. bank international exposures to related and unrelated counterparties, and the share of bank foreign office claims relative to total bank assets. This supplementary balance sheet information adds potentially important perspective, as the aforementioned structure data, including only information about subsidiaries, can miss the pattern of foreign branch locations of U.S. banks. The most geographically complex BHCs have affiliates in over 20 countries, and can have upwards of 10 percent of their balance sheets dedicated to foreign claims. The largest BHCs, with over $750 billion in assets, exhibit substantially more geographic complexity than the other large BHCs, and BHCs below $250 billion generally have much lower geographic complexity. Our work on dimensionality reduction across these measures of geographic complexity yields two principal components with the resulting first component (Appendix **??**), $GPC1_{b,t}$, capturing geographic scope of the BHC. The second principle component captured substantially less of the cross-sectional and time-series variation in geographic complexity for U.S. BHCs.

3.2 BHC Risk

Our analytics take the perspective that 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 two return diversification measures and four types of risk measures at the BHC-time level: idiosyncratic, liquidity, systematic, and systemic. 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 $SD\_RoA_{b,t}$.

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

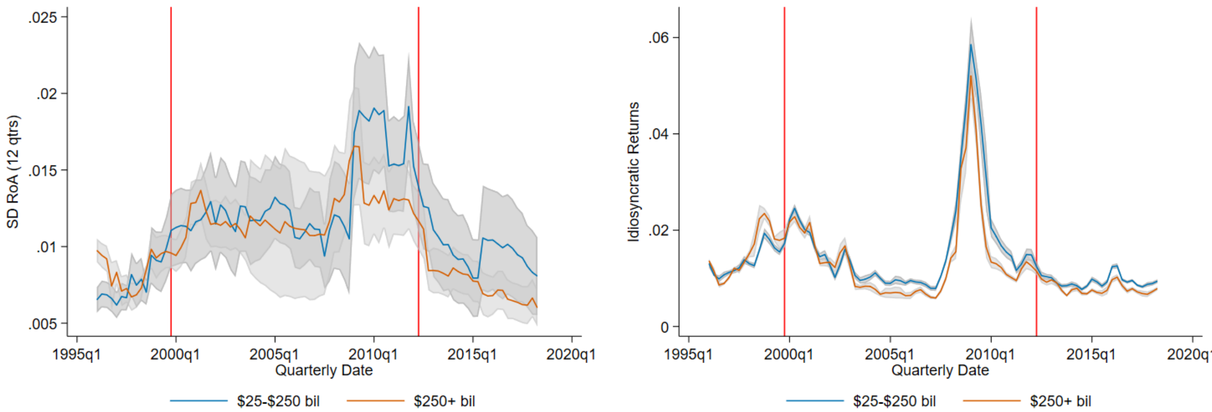
$$\text{Market Z-Score}_{b,t} = (AvgReturns_{b,t} + 1)/SD\_StockReturns_{b,t}$$

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

[10]CountC includes domestic affiliates of the BHC, so takes a value of one if the BHC has zero foreign affiliates. A variant of this measure could be the counts of locations spanned by banking subsidiaries and branches. Moreover, if appropriate data is available, balance sheet and income data for the BHC could be used to construct additional metrics.

[11]These 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.

Figure 2: Diversification Measures across BHCs, Average by BHC Asset Size Categories



(a) Std Dev Return on Assets

(b) Std Dev Market Returns

Note: This figure presents 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.

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.

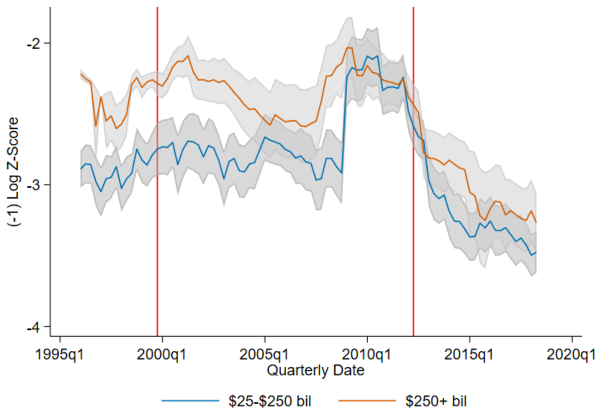
We inform the issue of whether complexity provides diversification benefits by directly examining the standard deviation of returns on assets and the standard deviation of idiosyncratic stock returns. The lower the standard deviation of returns, all else equal, the greater the balance sheet diversification. Figure 2 shows patterns over time of these diversification metrics. In the post-crisis period, the largest BHCs tended to have more stable RoA, compared with BHCs in the $25 to $250 billion size bucket. Market-based idiosyncratic variation tended to be more similar, but still with larger BHCs having lower variation on average.

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.[12] Liquidity risk exposures of the two groups of large U.S. BHCs tightly track each other and are overlapping.

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,

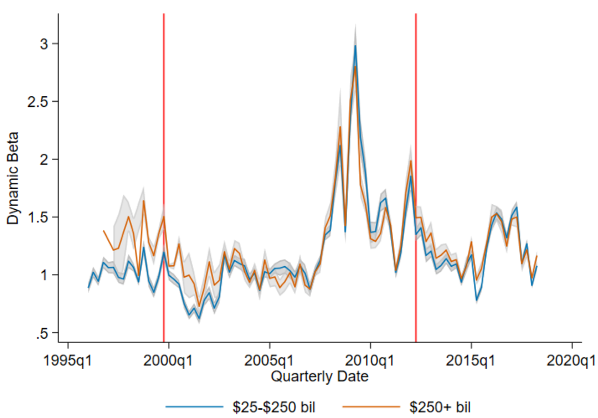
[12]The balance sheet data are accounting data from the FR Y9C report. Stock return information is sourced from the Center for Research in Security Prices (CRSP). Given the skewness in the distribution of the Z-score, the econometric specifications use log Z-score values. The LIBOR-OIS spreads are from Bloomberg.

Figure 3: Risk Measures across BHCs, Average by BHC Asset Size Categories

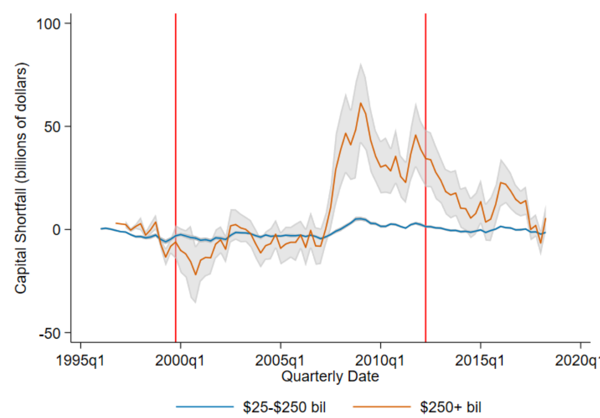


(a) (-1) Log Z-score

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



(c) Systematic Risk



(d) *SRISK*

(e) Liquidity Risk

Note: This figure presents 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.

Engle and Tang, 2017). The data to calculate this variable come from CRSP and Kenneth French's online data library, with the resulting computed exposure of the BHC to systemic risk proxied by $SRISK_{b,t}$. This measure is a prediction of a BHC's capital shortfall conditional on a severe market decline per the methodology of Brownlees and Engle (2016). [13]

Comparing the visualizations of average values for BHCs sorted by size bucket and over time (Figures 2 and 3), measures of BHC return volatility have declined on average in the post DFA living will periods for both size categories of (large) U.S. 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 (not shown).

3.3 BHC Governance

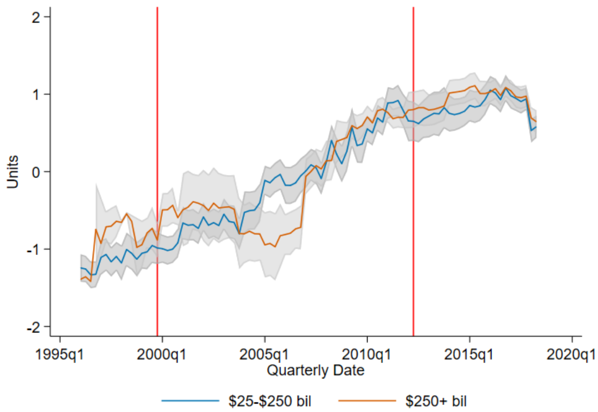
The strength of BHC governance is proxied by measures that assume stronger shareholder control, including through monitoring and transparency. Our first indicator is the share of institutional ownership of each bank, measured using data collected from Refinitiv. As institutional owners are considered informed investors that can monitor firm managers, larger shares of institutional owners should lead to fewer agency problems (Gaspar, Massa and Matos, 2005). A second indicator 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 compute the first principal component over these two indicators, which we denote as $GovPC1_{b,t}$, with more information about the inputs described in the Appendix (Table A2). Larger values of this measure indicates better agency governance.

The second governance proxy collected is the absence of CEO duality, with non-duality arising when the CEO is not also the Chair of the Board of Directors of the BHC. CEOs with dual roles may exert excessive power over the Board, limiting the amount of information filtered to shareholders (Baldenius et al., 2014). This may exacerbate agency problems within the bank and potentially lead to a riskier profile. We collect information on CEO roles from S&P's Execucomp and Capital IQ.

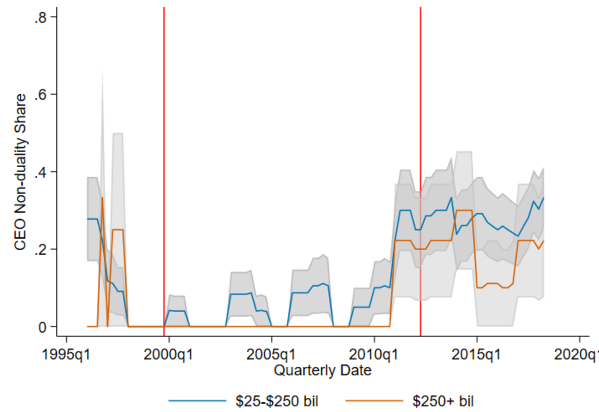
Visualizations of average values of $GovPC1_{b,t}$ and CEO non-duality for BHCs sorted by size bucket and date are provided in Figure 4. On average, the years following the DFA LW showed governance improvements in $GovPC1_{b,t}$ that continued pre-DFA trends as institutional owners broadened their holdings of BHC stocks. Patterns across shares of independent directors were less clear by size category and relatively similar in the post GFC period. Independent director shares rose discretely post-crisis and in advance of the DFA.[14]

[13]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

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 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 Instrumental Variables and Macroeconomic Controls

As noted in section 2.2, we use a set of variables as instruments in our system of equations relating complexity and risk. Summary statistics for those instruments are reported in Table 1. Of note, the regulatory indicator equals one for the period between the passage of the GLBA in 1999 and the DFA in 2010. The values for the complexity of competitors are calculated as the average complexity of BHCs in the tercile where the analyzed BHC is placed in a given quarter. Employment and the nonperfoming loan ratio are extracted from the FR Y-9C report, while the market-to-book ratio is calculated using information from S&P Compustat.

The controls for general economic and financial conditions in some regression specifications include U.S. 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)[15].

by the Volatility Laboratory (V-Lab) at New York University.

[14]Changes in governance metrics have been prompted by different regulations and rules. For example, Pathan and Faff (2013) argue that the Sarbanes-Oxley Act of 2002 and rules made by stock exchanges, including the New York Stock exchange, led to a changes in corporate governance at large publicly traded firms, including the BHCs in our sample. Some of those changes included a requirement for more independent directors, which is captured in the GovPC1 measure.

[15]The VIX is used in some specifications as an instrument and in others as a control.

4 Empirical Results

4.1 The Average Relationship Between Complexity, Diversification, and Risk

In this section we report tests focusing on the average associations between BHC complexity, diversification and risk, while assessing how governance influence these relations. Our first set of results use the system of equations described in specifications (1) and (2), around **Hypotheses 1a and 1b**. 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 using instrumental variables for risk and complexity on the right hand side of the specifications. As discussed in section 2.2, the measures of complexity in equation (1) are instrumented using: the log number of employees in each BHC and quarter, 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.[16] In equation (2), we follow the existing literature that describes some of the determinants of bank risk and instrument the risk measures with the market to book ratio (DeYoung, Peng and Yan, 2013) and nonperforming loans ratio of each BHC, as well as the VIX. The systems of equations use quarterly data between 1996q1 and 2018q2. All specifications have BHC fixed effects and standard errors clustered at the BHC level, and are estimated using limited information maximum likelihood, as this technique is more robust than 2SLS to weak instruments.

Table 2 summarizes the values and significance patterns of the main coefficients of interest from a series of regressions on the respective complexity and diversification or risk variables. Each cell of this table represents the values of coefficients θ^1 and θ^2 in equations (1) and (2), respectively, each from a distinct regression. These are the key results relevant for testing Hypothesis 1a.[17]

Panel A presents the results for our proxies for income diversification, which are the standard deviation of the return on assets and the standard deviation of idiosyncratic returns. Panel B shows the results for the five risk measures: two for idiosyncratic risks, and one each for liquidity risk, systematic risk, and systemic risk. The columns on the left show the results from the specifications with income variation or risk as regressands, while those on the right have complexity as the regressand.

Starting with income diversification in Panel A, all three complexity measures are associated with significantly lower variability of idiosyncratic equity returns, but not with lower variability in the return on assets. In these estimations, our instruments are not weak for the complexity

[16] As described in Section 2, regulations are one of the 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.

[17] The full specification results are reported in the online appendix, including the first stage regressions. In the online appendix, we also report the Kleiberger-Paap Wald F (KPWF) statistic as the measure for weak identification of the instruments in each regression.

variables, as captured by the KPWF statistic. The right columns on the drivers of diversification shows that complexity is only marginally associated with income and stock return variability, although the instruments for this diversification measure are weak. Overall, Panel A results show that an increase in BHCs complexity dampen the variation on banks' equity returns, a potential sign of more income diversification, but we do not find a similar improvement in income diversification using income returns.

Panel B reports test results for the average relation between complexity and risk. The table has the same structure as for income diversification, but instead focuses on the five risk measures. First, results show that greater organizational and business complexity are each associated with lower levels of idiosyncratic risk, as captured by the market z-score. These results are not surprising, as market z-score is closely associated with the lower variability of idiosyncratic returns for complex BHCs described in the results of Panel A. More geographic complexity is shown to reduce liquidity risks. Geographic complexity may allow banks to use diversified sources of liquidity, which could mitigate the effect of funding stresses in particular geographies on the overall liquidity of the BHCs (Goetz et al., 2016) (Cetorelli and Goldberg, 2016). However, more complexity organizational, business, and geographic - is associated with higher systemic risk (as measured by SRISK) and more geographic complexity specifically is associated with higher systematic risk. These patterns demonstrate the potential trade offs faced by BHCs and regulators, as the pursuit of more complex arrangements may increase some types of risks while reducing others.[18]

The right columns of Panel B show the relationships between complexity and risk, but using complexity as the regressand. There is a partial feedback effect between the two sets of variables. Higher BHC systematic risk is associated with higher levels of organizational and geographic complexity. Interestingly, BHCs with higher liquidity risks tend to have lower geographic complexity. The effects of idiosyncratic risks on business and geographic complexity are more mixed, with opposite results for regular z-scores and market z-scores.

The quantitative importance of the relation between complexity, diversification, and risk is high. For example, a one standard deviation increase in geographic complexity is associated with a 0.7 standard deviation increase in income diversification, as measured by the variation in idiosyncratic equity returns, and a 0.6 standard deviation decrease in liquidity risk. This change in geographic complexity is also associated with a 1.1 standard deviation increase in systematic risk and 2.5 standard deviation increase in systemic risk. Similarly, one standard deviation increases in orga-

[18]As shown in section 1 of the online appendix, in almost all specifications we can reject the null hypothesis that the instruments used in the estimations are weak, as captured by the KPWF statistic. The only exception is for the estimation that has liquidity risk as the regressand and business complexity as the regressor. Given the shorter time series for our liquidity risk measure, the instruments become weak in our specification. In section 3 of the online appendix, Tables OA.15 and OA.16, we present results using the liquidity betas using the TED spread as an alternative measure of liquidity stress. That measure has a slightly longer time series. In those specifications, the instruments are no longer weak.

nizational and business complexity complexity are associated with increases of about 0.5 standard deviations in income diversification and decreases of the same magnitude in idiosyncratic risk, as captured by the market z-score. The same changes in organizational or business complexity are also associated with a 0.5 increases in systemic risks, again highlighting the magnitude of trade-offs present across the different types of risk exposures faced by BHCs as complexity expands.

By contrast, the economic significance of the reverse relationships, from diversification and risk to complexity, are low. A one standard deviation change in the statistically significant risk measures are only associated with changes in complexity that are less than a half of their respective standard deviations.

The results from these estimations for U.S. BHCs lead us to nuance the conclusions around **Hypothesis 1a**, which was crafted for general risk and complexity conclusions. Instead, the results present a rich tradeoff. More complex and diversified BHCs appear to have lower idiosyncratic and liquidity risks, but these dimensions of risk improvements come at the expense of having higher systematic and systemic risks.

In **Hypothesis 1b**, we had conjectured that BHCs with better governance arrangements might be able to increase complexity without increasing their risk exposures. We test this using the specifications reported in Table 3, but now focus on the η coefficients from equations (3) and (4), which are associated with the interaction term between the governance proxies and the respective complexity, diversification, or risk measures. As noted previously, this analysis utilizes two governance variables: $GovPC1_{b,t}$ (the first principal component encapsulating institutional ownership and board independence) and an indicator variable equal to one if the CEO and Chair of the Board positions are occupied by different people (CEO non-duality). A higher value for this governance measures implies greater control for shareholders, which is commonly associated with better performance outcomes. To not reject the null of **Hypothesis 1b**, the η^1 coefficients would need to be negative and significant. In that case, better governed BHCs should be more diversified and less risky as complexity increases.

Table 3 shows the sign and significance of the η^1 coefficients for these interaction terms for each of the governance measures in the respective diversification and risk regressions. Panel A presents the results for the income diversification specifications, while Panel B provides results for the risk measures. It is important to note that the instruments as weaker in this specification, as we not only have to instrument for the main complexity, diversification, and risk variables, but also for the interaction terms between these variables and the governance measures. The specifications for geographic complexity have particularly weaker instruments. With this caveat, only a few specifications have significant coefficients. Better governance in BHCs, as captured by $GovPC1_{b,t}$, is associated with larger idiosyncratic and systemic risk exposures as business complexity increases. In contrast, the interaction between $GovPC1_{b,t}$ and geographic complexity has a negative and significant coefficient for the specification with systematic risk as a regressand, although the instruments for the endogenous regressors are weak. We do not find any significant results associated with CEO non-duality.

These results appear to reject **Hypothesis 1b**: either governance does not play a role in intermediating the relationship between complexity and risk, or better governed banks are the ones that increase their risk profiles as they increase business complexity. The findings, while consistent with Laeven and Levine (2009), may be the result of the particular governance measures used or are an empirical puzzle for future research.

Overall, the results across the average relationships for U.S. BHCs provide partial confirmation for **Hypothesis 1a**, with a nuanced interpretations across the different types of complexity, diversification, and risk. Our findings broadly reject **Hypothesis 1b** as the average role for corporate governance in changes in banks complexity and risk decisions is weak.

4.2 Complexity, Governance, and BHC Living Wills

As changes in the regulatory environment in the post-GFC period partially targeted BHC complexity, the next set of results focus on the consequences of the introduction of LWs in 2012.[19] First, as discussed in section 2.3, our tests assess whether BHC complexity changed when these regulatory actions were implemented per **Hypothesis 2a**. A second set of tests focus on **Hypothesis 2b**, establishing whether BHCs with weaker governance arrangements then exhibited larger changes in complexity. In particular, we estimate equation (5), which uses a difference-in-difference approach with a sample period of about three years before and three years after the regulatory change. $d_{b,t}$ is an indicator variable equal to 1 after the staggered introduction of LWs starting in mid-2012. The window between 2009q2 and 2018q2 is considered to assess the impact of this regulation.

The dependent variables in the first set of these tests are the levels of organizational, business, and geographic complexity. All regressions include bank-level controls such as BHC (log of real) assets, the loans to assets ratio, the deposits to assets ratio, the liquid assets ratio, and the equity to assets ratio, in addition to aggregate control 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.

The results for these estimations are provided in Table 4. Columns (1), (3), and (5) report specifications that only include the indicator $d_{b,t}$ and the bank and aggregate controls. Columns (2), (4), and (6) provide the coefficient estimates from a similar set of regressions that also include interactions between $d_{b,t}$ and the two governance measures, with values for these governance measures as of 2009. This approach allows us to take governance as predetermined and assess the change in

[19]We conduct similar tests for the passage of the GLBA in 1999, which is available upon request.

complexity as a result of the regulatory change conditional on the level of those governance metrics.

Table 4 results show that the introduction of LWs had a significant effect on BHCs' organizational complexity. Columns (1) and (2) show that the overall number of affiliates within BHCs decreased after the introduction of LWs. The average decrease captured by the coefficient in column (1), -0.159, represents about one-tenth of a standard deviation of our proxy for organizational complexity, the log of the total count of legal entities of each BHC. Although this result seems small for the overall sample, for the largest banks, those with assets above $750 billion, the decrease represents more than one-fourth of the standard deviation of this same variable, which is not negligible. Other measures of complexity do not change significantly for the average BHC, reinforcing the finding that LW regulations had a more intensive impact on organizational complexity, which should facilitate the resolvability of these BHCs.

Hypothesis 2b posits that BHC with better governance will adjust less to regulatory tightenings, as these are the BHCs where complexity is more likely to have diversification motives dominate "empire building" motives. The table shows that governance did not, on average, influence the change of complexity after the introduction of LWs. The BHCs with better governance did not adjust their structure significantly differently than other BHCs. The only exception is the specification for geographic complexity, which shows a negative and significant coefficient for the interaction between $d_{b,t}$ and the CEO Non-Duality indicator. In this case, better governed BHCs those with non-dual roles for the CEO - decreased their geographic complexity by somewhat more after the introduction of LWs. The change is not negligible, as the reduction in geographic complexity for well governed BHCs represents about one third of the standard deviation of this variable. This result goes against **Hypothesis 2b**.

In sum, these results across U.S. BHCs 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 specifically targeted the organizational structure of banks. Accordingly, BHCs reduced their number of affiliates following the regulation. However, **Hypothesis 2b** is not supported, as the BHC governance measures in general are not associated with a differential change in complexity following the introduction of new regulations. Regulatory action in the form of living wills, not the better governance of some BHCs, was the driver of reduced organizational complexity of these U.S. BHCs.[20]

[20] 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 shows the tests for parallel trends for our sample of treated (LWs 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

The next results focus on **Hypothesis 3**, examining whether the LW regulatory actions that affect banks' complexity are associated with changes in the diversification of banks' income streams and their risk profiles. The first set of tests, reported in Table 5, focus on the change in BHCs' diversification after the staggered introduction of LWs starting in mid-2012. Specifically, equation 6 is estimated using two diversification measures as dependent variables. Column (1) shows that 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 governance traits of the BHCs, as shown in column (2). Columns (3) and (4) instead use with the standard deviation of BHC idiosyncratic returns as the dependent variable. BHCs' variability of returns did not decrease, on average, after the introduction of LWs. However, the variability of these returns was lower for the BHC with non-dual CEOs compared to those BHCs where the CEOs acted as Board Chairs, as shown by the negative and significant for the coefficient on the interaction term between $d_{b,t}$ and the indicator variable for this governance measure. 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.

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 a BHC with weaker governance may achieve relatively more risk reduction with tighter regulations. These results, shown in Table 6, are based on the estimation of equation 6 using as respective dependent variables the five measures of risks: 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 also shift banks' risk profiles, with BHCs engaging in strategies that may reduce some types at the expense of increases in other types of risk.

Columns (1) through (3) show that the introduction of LWs is associated with a decrease in the z-score measures for BHCs after they started reporting LWs (negative and statistically significant coefficient for $d_{b,t}$). The governance measures do not consistently alter the degree of average change in idiosyncratic risk.

The next set of results cover systematic, systemic, and liquidity risks. The reporting of LWs do not appear increase in BHCs systematic risk on average, as the coefficients on $d_{b,t}$ are mostly not significant. However, systematic risk for better governed banks, as measured by CEO non-duality, actually decreased after the introduction of LWs, which hints at a potential role for governance in the mediation between complexity and risk through regulatory changes.

Columns (3) and (4) show that SRISK decreased, on average, after banks started reporting LWs, while liquidity risk increased on average. The increase in liquidity risk is weaker for BHCs with more institutional owners and independent directors. These findings are consistent with the results shown in the system of equations reported in Table 2. A reduction in complexity and declines in systemic risk may come at the expense of larger liquidity risk exposures of U.S. BHCs. [21]

This set of results on risk 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**. Liquidity risks exhibited the opposite pattern, as BHCs increased in this type of risk exposure, consistent with our interpretation of trade-offs along a set of risk frontiers from different forms of complexity.

Next, we test whether this pattern of results differs for BHCs that were more complex in the dimension that was most affected by the introduction of LWs, organizational complexity. Table 7 reports the results for the diversification measures and Table 8 for the risk measures. In these specifications, we report estimates of equation 7 where we use the level of organizational complexity of each BHC as of 2009 as an interaction term. BHCs with higher organizational complexity prior to the introduction of LWs are expected to make greater adjustments in income diversification and risk profiles. 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 the 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, their income diversification improved to a lesser extent relative to other BHCs. Of note, better governance may have muted this distinction, as complex BHCs with non-dual CEOs were able to reduce their variation in idiosyncratic stock returns at almost the same pace as non-complex BHCs.

The results for other risk metrics, provided in Table 8, 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 decline in idiosyncratic risk may have been driven by other conditions or policies, including from changes to BHC capital requirements. This interpretation is more consistent with the other result that complexity is associated with lower levels of idiosyncratic risk exposure.

[21] 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.

Governance and complexity interact in interesting ways around systematic and systemic risks. Consistent with the other results, more organizationally complex BHCs had larger decreases in systemic risk after the introduction of LWs. This systemic risk reduction was even stronger for BHCs with better governance, as captured by the first principal component measuring institutional ownership and board independence. In contrast, these organizationally complex BHCs had smaller declines in systematic risk. Within this group, the BHCs with better governance, as measured by CEO non-duality, more effectively reduced systematic risk relative to their less complex peers.[22]

The results we have presented in this section are robust to changes in the estimation sample to focus only on BHCs closer to the regulatory threshold ($50 billion in assets), that is, using only BHCs with assets between $25 billion and $100 billion (27 BHCs). In this robustness check (available upon request), the sample of treated banks encompasses BHCs with assets between $50 and $100 billion, which had to report living wills at the end of 2013. With the exception of the results on systematic risk, where changes are no longer significant when adding governance variables, we find that the pattern of significance and coefficient signs are broadly consistent between the full sample and this restricted sample.

Our findings are also robust to expanding the BHC sample to include smaller but more complex BHCs. For this robustness check, we created the different complexity measures for a sample of banks with assets between $1 and $25 billion, and added observations for these BHCs to specifications when they had specific forms of complexity at least as high as the 50th percentile (just one example) of values for the larger BHC sample in the paper. Our results are largely unchanged if we add these additional BHCs.

In sum, some of the changes in BHC risk profiles after the introduction of LWs are consistent with the average relations documented in Section 4.1. In those cases where results differ, other factors not associated with complexity likely played a role in the changes in risk profiles. BHC governance plays a role, serving mostly as a complement to stricter regulations around complexity in reducing correlated risks (systematic) and systemic risks as organizational complexity contracted.

5 Concluding Observations

The links between BHC complexity and risk became particularly apparent during the GFC. Large and complex BHCs had significant systemic risk exposures and were very difficult to resolve during the crisis, generating externalities. The too-big-to-fail phenomenon was also a too-complex-to-fail phenomenon, underscoring the importance of extensive post crisis efforts aimed both at making BHCs more resilient so that failure probabilities would decline, and making banks less complex, so

[22] We do not view the two proxies for governance as sufficiently separating the channels for governance effects, and view significance of either measure as an agglomeration of improved monitoring and transparency, limitations of CEOs from exerting excessive power over the Board, and improving the amount of information filtered to shareholders.

that the externalities from failures would be substantially reduced.

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 from complexity can weigh against diversification and liquidity risk gains in driving outcomes. We have shown average relationships over time, and have focused attention on the regulatory actions taken after the GFC, specifically living wills guidance of the DFA. Living wills were associated with significant declines in organizational complexity among U.S. 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. Better governance was associated with better risk outcomes among organizationally complex BHCs.

Of course, the DFA also included other provisions to increase the resilience of banking organizations, with 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.

While we have not explored the effects of other regulations on complexity and risk, conceptually other types of regulation might alter the dynamics between complexity, living wills, and risk profiles. The effects of resolution frameworks might differ under tighter liquidity requirements or tighter capital requirements like those arising from Basel III higher minimum capital ratios and stress testing. Under LWs, the BHC internalizes more of the externalities associated with systemic risk exposures. Instead of exclusively considering systematic risks, the trade-offs on the increasing risk side also include the systemic risk exposures which expand with complexity, generating a potentially lower level of complexity chosen by the BHC. Regulations that reduce BHC exposure to liquidity risk reduce some benefits to the forms of complexity that deliver liquidity risk benefits, such as geographic complexity. Tighter bank capital requirements can either raise or lower optimal complexity from the vantage point of the BHC depending on how these respectively change different forms of BHC risk exposures. Financial technologies also can change the incentives for the distinct forms of complexity, shifting the trade-offs between different forms of risk.

Importantly, our research, which uses data for large and complex U.S. BHCs, has demonstrated that both BHC governance and regulatory changes can jointly influence BHCs' risk profiles. Our hypotheses had conjectured that BHCs with weak governance would change the most, as they would be pushed to take actions that improve their risk profiles. We conjectured that BHCs with better governance would be able to navigate complex structures, reaping benefits in their income diversification and reducing their exposures to idiosyncratic risks and liquidity risks. These particular hypotheses were not supported in our analysis of large U.S. BHCs. The average relationships between BHC risk profiles and complexity were not significantly altered by governance, consistent with the results of Laeven and Levine (2009). This is an interesting finding that we believe warrants further investigation. Alternative governance metrics might deliver different results, or competing mechanisms might be at play. However, in complex BHCs, better governance delivered better risk outcomes in the aftermath of living will guidance.

Our work emphasizes the importance of structural complexity with roles for organizational, business, and geographic complexity. These types of complexity are important and distinct from the balance sheet and opacity-based constructs that are more regularly used in international policy circles to characterize 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. Improving governance may help BHCs use complexity to lower the probability of an idiosyncratic or liquidity BHC stress event while also limiting the of consequences of market stresses when they occur. The trade-offs that we have documented imply that BHC-specific reductions in complexity have the desirable effects of reducing systematic and systemic risks exposures, but many come at the cost of some expanded idiosyncratic and liquidity risks exposures. The costs of these latter exposures are more likely to be internalized by well governed BHCs, instead of the types of risks that are associated with greater social costs.

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Table 1: Summary Statistics

	mean	sd	min	p25	p50	p75	max	# obs
BHC Sample								
Assets ($2012 billions)	278	487	25	43	91	221	2542	3187
Loans to Assets	0.58	0.19	0.02	0.50	0.65	0.71	0.86	3186
Deposits to Assets	0.61	0.18	0.00	0.57	0.65	0.72	0.93	3077
Liquid Assets to Assets	0.26	0.15	0.00	0.15	0.21	0.32	0.82	3181
Equity to Assets	0.10	0.03	0.03	0.08	0.09	0.11	0.22	3187
Number of BHCs	35.41	4.33	26	32	36	39	46	90*
BHC Complexity								
Total Affiliate Count	404.44	715.55	4	48	104	416	4494	3124
Log Total Affiliate Count	4.94	1.41	1.39	3.87	4.64	6.03	8.41	3124
BPC1: Business Scope	-0.07	1.31	-3.59	-1.11	-0.20	0.98	3.41	3115
CountB (count of business types, maximum 6)	5.24	0.58	3	5	5	6	6	3124
CountN (count of NAICS industries)	16.38	7.36	4	12	14	18	51	3124
Non-Financial Count Share	0.45	0.19	0.05	0.31	0.41	0.55	0.97	3124
BHHI (affiliate business type herfindahl)	0.73	0.16	0.08	0.66	0.77	0.84	1.00	3124
Non-Interest Income Share	0.46	0.20	0.00	0.31	0.41	0.56	1.00	3178
GPC1: Geographic Scope	-0.07	1.75	-1.51	-1.35	-0.82	0.81	6.39	3124
CountC (count of countries)	14.10	18.10	1	2	6	20	87	3124
Count Net Due to Positions	11.62	18.94	1	1	2	15	100	3187
CHHI (affiliate country count herfindahl)	0.29	0.29	0.00	0.03	0.16	0.57	0.93	3124
Foreign Office Claims to Total Assets	0.07	0.12	0.00	0.00	0.01	0.10	0.52	3187
BHC Diversification								
Std Dev Return on Assets	0.010	0.012	0.000	0.004	0.006	0.012	0.078	2997
Std Dev Market Returns	0.014	0.010	0.004	0.008	0.011	0.016	0.159	3083
BHC Risk								
(-1) Log Z-score (12 qtr)	-2.85	0.87	-5.88	-3.44	-2.84	-2.23	-0.56	2997
(-1) Market Z-score	-4.04	0.49	-5.14	-4.37	-4.11	-3.78	-1.79	3084
Liquidity Risk	-0.03	0.11	-0.87	-0.05	-0.01	0.02	0.40	2175
Systematic Risk	1.15	0.45	0.15	0.88	1.08	1.34	4.38	2820

Table 1: Summary Statistics (continued)

	mean	sd	min	p25	p50	p75	max	# obs
SRISK	1.58	17.26	-68.09	-2.78	-0.69	1.29	142.64	2820
BHC Governance								
GovPC1: Bank Ownership Governance	-0.11	1.24	-4.40	-0.88	-0.01	0.90	2.41	2580
Total Inst. Ownership, Pct. Shares Outstanding	0.63	0.18	0.00	0.51	0.64	0.77	1.94	2705
Independent Directors Share	77.66	12.56	22.22	71.43	80.00	87.50	100.00	2849
CEO Non-Duality Share	0.13	0.33	0.00	0.00	0.00	0.00	1.00	2849
Instrumental Variables								
Log BHC Employment	9.94	1.15	7.39	9.12	9.82	10.65	12.92	3186
Regulatory Indicator	0.46	0.50	0.00	0.00	0.00	1.00	1.00	3187
Org. Complexity Competitors	4.94	1.08	3.11	3.99	4.70	5.90	7.27	3124
Bus. Complexity Competitors	-0.07	0.90	-2.11	-0.79	-0.11	0.79	1.63	3115
Geo. Complexity Competitors	-0.07	1.02	-1.45	-0.92	-0.37	0.54	2.87	3124
Market-to-Book (Regulatory) Ratio	1.92	1.14	0.03	1.09	1.76	2.45	12.05	3084
Non-Performing Loans to Assets	0.02	0.02	0.00	0.01	0.01	0.02	0.19	3089
Quarterly Macro Controls								
VIX	20.08	7.28	10.31	14.35	19.19	24.53	58.59	90
Credit to GDP Gap	-1.43	8.98	-16.10	-9.20	-0.20	7.20	12.20	90
Annualized Real GDP Growth	2.59	2.34	-8.40	1.50	2.60	3.80	7.50	90

* Count of BHCs by quarter.

Table 2: U.S. BHC Complexity, Diversification, and Risk Exposure: Average Long Run Relationship

Panels A and B report the results of 6 and 15 sets of instrumental variables specifications, respectively, corresponding to joint estimations using specific pairs of risk or return variation and complexity measures. The cell entries correspond to estimated θ^1 (when risk or return variation is regressand) and θ^2 (when complexity is regressand) of equations (1) and (2). *, **, *** denote statistically significant results at the 10, 5, and 1 percent levels. Specifications include macro controls (annualized real GDP growth, lagged credit to GDP gap), BHC-level fixed effects, and BHC controls (G-SIB dummy, lagged loans to assets, lagged deposits to assets, lagged liquid assets to assets).

Panel A: BHC Return Variation and Complexity

	Income variation as regressand			Complexity as regressand		
	Organizational	Business	Geographic	Organizational	Business	Geographic
Std Dev Return on Assets	-0.001	0.000	-0.003	49.673	-5.575	40.860*
Std Dev Market Returns	-0.003***	-0.004***	-0.004*	-3.325	-9.932**	2.912

Panel B: Risk and Complexity

	Risk exposure as regressand			Complexity as regressand		
	Organizational	Business	Geographic	Organizational	Business	Geographic
Z-score	-0.077	0.127	-0.330	0.229	-0.119	0.350*
Market Z-score	-0.147**	-0.200***	-0.156	-0.063	-0.147**	0.013
Liquidity Risk	-0.015	-0.033	-0.037**	-2.594	8.062	-8.013***
Systematic Risk	0.099	0.059	0.286**	0.354**	0.106	0.334***
SRISK	6.461*	7.407*	24.322*	0.021	0.012	0.014

Table 3: Governance Effects on Risk and Complexity, Average Long Run Relationship

Panels A and B report the results of 6 and 15 sets of instrumental variables specifications, respectively, corresponding to joint estimations using specific pairs of risk or return variation and complexity measures and including interactions with pairs of governance variables. The cell entries correspond to estimated η^1 (when risk or return variation is regressand) and η^2 (when complexity is regressand) of equations (3) and (4). Both interaction terms are within each IV specification. *, **, *** denote statistically significant results at the 10, 5, and 1 percent levels. Specifications include macro controls (annualized real GDP growth, lagged credit to GDP gap), BHC-level fixed effects, and BHC controls (G-SIB dummy, lagged loans to assets, lagged deposits to assets, lagged liquid assets to assets).

Panel A: BHC Return Variation and Complexity

	Income variation as regressand			Complexity as regressand		
	Organizational	Business	Geographic	Organizational	Business	Geographic
Std Dev Return on Assets						
× Governance PC1	-0.001	-0.001	0.000	-135.785	-144.639	-66.373
× CEO Non-Duality	-0.000	-0.001	-0.002*	-268.042	-311.512	-125.620
Std Dev Market Returns						
× Governance PC1	0.001	0.002*	0.001	2.185	-3.955	1.380
× CEO Non-Duality	-0.001	-0.001	-0.002	11.219	-0.159	-21.457

Panel B: BHC Risk and Complexity

	Risk exposure as regressand			Complexity as regressand		
	Organizational	Business	Geographic	Organizational	Business	Geographic
Z-score						
× Governance PC1	-0.029	-0.027	0.113	-1.110	-2.216	-0.425
× CEO Non-Duality	-0.088	-0.153	-0.354	-1.189	-1.115	-0.322
Market Z-score						
× Governance PC1	0.051	0.104*	0.012	0.092**	-0.015	0.030
× CEO Non-Duality	-0.054	-0.054	-0.100	-0.142	-0.190	-0.181
Liquidity Risk						
× Governance PC1	0.001	-0.010	0.018	-23.597	58.032	-8.708
× CEO Non-Duality	-0.007	0.014	-0.028	-46.192	103.791	-10.155
Systematic Risk						
× Governance PC1	-0.030	0.061	-0.202**	-0.479	-0.651***	-0.040
× CEO Non-Duality	-0.019	-0.102	0.158	-0.448	-0.244	-0.255
SRISK						
× Governance PC1	2.836	6.114*	-0.130	-0.045*	-0.045***	-0.007
× CEO Non-Duality	-1.124	-4.825	1.928	-0.014	0.002	-0.015

Table 4: Complexity Change around the DFA LW Guidance, with Size and Governance

This table presents estimates of equation (5) 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. $GovPC1$ 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. BHC controls capture the log of real assets, the liquid assets ratio, loans to assets ratio, equity to assets ratio, and deposits 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. *, **, *** denote statistically significant results at the 10, 5, and 1 percent levels.

	Organizational		Business		Geographic	
	(1)	(2)	(3)	(4)	(5)	(6)
$d_{b,t}$	-0.159***	-0.174***	-0.073	-0.056	-0.072	-0.001
	(0.049)	(0.061)	(0.082)	(0.062)	(0.062)	(0.079)
$d_{b,t}$ x $GovPC1_{b,2009}$		0.035		0.064		0.024
		(0.098)		(0.071)		(0.063)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$		0.026		-0.283		-0.585*
		(0.208)		(0.319)		(0.346)
N	1153	1153	1153	1153	1153	1153
Adj. within-R2	0.28	0.28	0.11	0.11	0.24	0.27
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	44	44	44	44	44	44

Table 5: Diversification Change around the DFA LW Guidance

This table presents estimates of equation (6) 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. BHC controls capture the log of real assets, the liquid assets ratio, loans to assets ratio, equity to assets ratio, and deposits 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. *, **, *** denote statistically significant results at the 10, 5, and 1 percent levels.

	Std Dev Return on Assets		Std Dev Market Returns	
	(1)	(2)	(3)	(4)
$d_{b,t}$	-0.004***	-0.004*	0.001	0.001*
	(0.001)	(0.002)	(0.001)	(0.001)
$d_{b,t}$ x $GovPC1_{b,2009}$		0.002		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	1090	1090	1113	1113
Adj. within-R2	0.24	0.25	0.62	0.63
BHC FE	Yes	Yes	Yes	Yes
Number of BHCs	45	45	45	45

Table 6: Risk Change around the DFA LW Guidance

This table presents estimates of equation (6) 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. *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. BHC controls capture the log of real assets, the liquid assets ratio, loans to assets ratio, equity to assets ratio, and deposits 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. *, **, *** denote statistically significant results at the 10, 5, and 1 percent levels.

	Z-score		Market Z-score	
	(1)	(2)	(3)	(4)
$d_{b,t}$	-0.485***	-0.430**	-0.046**	-0.040
	(0.121)	(0.175)	(0.020)	(0.029)
$d_{b,t}$ x $GovPC1_{b,2009}$		0.045		-0.003
		(0.263)		(0.025)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$		-0.501		-0.037
		(0.322)		(0.091)
N	1090	1090	1113	1113
Adj. within-R2	0.39	0.39	0.82	0.82
BHC FE	Yes	Yes	Yes	Yes
Number of BHCs	45	45	45	45

	Systematic Risk		SRISK		Liquidity Risk	
	(1)	(2)	(3)	(4)	(5)	(6)
$d_{b,t}$	0.021	0.061	-4.372**	-3.351*	0.050***	0.062***
	(0.036)	(0.042)	(1.689)	(1.766)	(0.008)	(0.010)
$d_{b,t}$ x $GovPC1_{b,2009}$		0.016		-2.517		-0.014*
		(0.033)		(1.740)		(0.007)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$		-0.324*		-2.224		-0.059
		(0.177)		(10.197)		(0.041)
N	1057	1057	1057	1057	1113	1113
Adj. within-R2	0.56	0.56	0.24	0.25	0.09	0.10
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	42	42	42	42	45	45

Table 7: Diversification Change around the DFA LW Guidance for Organizationally Complex Banks

This table presents estimates of equation (7) 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. BHC controls capture the log of real assets, the liquid assets ratio, loans to assets ratio, equity to assets ratio, and deposits 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. *, **, *** denote statistically significant results at the 10, 5, and 1 percent levels.

	Std Dev Return on Assets			Std Dev Market 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)	(0.005)	(0.001)	(0.002)	(0.002)
$d_{b,t}$ x Org. $Complex_{b,2009}$		0.002	0.001*		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	1090	1084	1084	1113	1107	1107
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	45	44	44	45	44	44

Table 8: Risk Change around the DFA LW Guidance for Organizationally Complex Banks

This table presents estimates of equation (7) 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. BHC controls capture the log of real assets, the liquid assets ratio, loans to assets ratio, equity to assets ratio, and deposits 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. *, **, *** denote statistically significant results at the 10, 5, and 1 percent levels.

	Z-Score			Market Z-Score		
	(1)	(2)	(3)	(4)	(5)	(6)
$d_{b,t}$	-0.485***	-1.149*	-1.128**	-0.046**	-0.092	-0.087
	(0.121)	(0.577)	(0.552)	(0.020)	(0.091)	(0.087)
$d_{b,t}$ x Org. $Complex_{b,2009}$		0.131	0.144		0.009	0.011
		(0.103)	(0.089)		(0.018)	(0.018)
$d_{b,t}$ x $GovPC1_{b,2009}$ x Org. $Complex_{b,2009}$			-0.007			-0.002
			(0.053)			(0.006)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$ x Org. $Complex_{b,2009}$			-0.114			-0.019
			(0.088)			(0.019)
N	1090	1084	1084	1113	1107	1107
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	45	44	44	45	44	44

	Systematic Risk			SRISK			Liquidity Risk		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$d_{b,t}$	0.021	-0.276*	-0.251*	-4.372**	18.158*	18.334**	0.050***	0.074**	0.075**
	(0.036)	(0.160)	(0.136)	(1.689)	(9.452)	(8.536)	(0.008)	(0.035)	(0.032)
$d_{b,t}$ x Org. $Complex_{b,2009}$		0.058*	0.061**		-4.416**	-3.963**		-0.005	-0.003
		(0.031)	(0.029)		(2.096)	(1.916)		(0.006)	(0.007)
$d_{b,t}$ x $GovPC1_{b,2009}$ x Org. $Complex_{b,2009}$			0.001			-0.663*			-0.002
			(0.007)			(0.359)			(0.002)
$d_{b,t}$ x CEO $Non\text{-}Duality_{b,2009}$ x Org. $Complex_{b,2009}$			-0.065*			-2.303			-0.007
			(0.036)			(2.632)			(0.010)
N	1057	1051	1051	1057	1051	1051	1113	1107	1107
Adj. within-R2	0.56	0.57	0.57	0.24	0.29	0.30	0.09	0.09	0.09
BHC FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of BHCs	42	41	41	42	41	41	45	44	44

Appendix

Table A1: Variable Definitions and Data Sources

	Variable Description & Source Information
BHC Sample	
Assets	FR Y-9C: BHCK2170
Loans to Assets	FR Y-9C: BHCK2122
Deposits to Assets	FR Y-9C: BHDM6631, BHDM6636, BHFN6631, BHFN6636
Liquid Assets to Assets	
post 01/31/2002	FR Y-9C: BHCK1754, BHCK1773, BHCK3545, BHDM987, BHCKB989
01/31/1997 - 12/31/2001	FR-Y9C: BHCK1754, BHCK1773, BHCK3545, BHCK1350
01/31/1994 - 12/31/1996	FR-Y9C: BHCK1754, BHCK1773, BHCK3545, BHCK0276, BHCK0277
pre 12/31/1993	FR-Y9C: BHDM6631, BHDM6636, BHFN6631, BHFN6636
Equity to Assets	FR Y-9C: BHCK3210
Log BHC Employment	FR Y-9C: RIAD4150
Market-to-Book (Regulatory) Ratio	Compustat: Price or Bid/Ask Average, Shares Outstanding; FR Y-9C: BHCK3210
Non-Performing Loans Ratio	FR Y-9C: BHCK5525, BHCK3506, BHCK5526, BHCK3507, BHCK2122
BHC Complexity	
BHC Affiliates	FFIEC National Information Center (NIC) database; All affiliate structure information is based on identifiers contained in BHC affiliate structures as described in Ceterolli & Stern (2015)
Organizational Complexity	Total Affiliate Count
Business Complexity	BPC1 or Business Scope is the first principal component over BHC quarterly data on:
CountB	Total count of business types (commercial banks, mutual/pension funds, insurance, other financial, non-financial management firms, other nonfinancial) spanned by BHC affiliates
CountN	Number of 4-digit NAICS industries spanned by BHC affiliates
Non-Financial Count Share	Count of nonfinancial affiliates relative to total affiliate counts
BHHI	$\frac{CountB}{CountB-1}\left(1-\sum_{j=1}^{B}\left(\frac{count_j}{\sum_{j=1}^{B} count_j}\right)^2\right)$ 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
Non-Interest Income Share	FR Y-9C: BHCK4079, BHCK4074
Geographic Complexity	GPC1 or Geographic Scope is the first principal component over BHC quarterly data on:
CountC	Count of countries spanned by BHC affiliates
Count Net Due to Positions	Count of countries with non-zero net due to/from positions
all dates	FFIEC 009: FCEX8595 $\neq 0$
pre 2006	FFIEC 009: FCEX8594 > 0
2006 & post 2006	FFIEC 009: FCEXC938, FCEXC939 > 0

Table A1: Variable Definitions and Data Sources (continued)

CHHI	$CountCHHI = \frac{CountC}{CountC-1}\left(1-\sum_{c=1}^{C}\left(\frac{count_c}{\sum_{c=1}^{C} count_c}\right)^2\right)$ where C is the set of countries and $count_c$ is the count of subsidiaries in each country c
Foreign Office Claims to Assets	FR Y-9C: BHCK2170 (Total Assets)
pre 2006	FR Y-9C: FCEX8580, FCEX8593
2006-2015	FR Y-9C: FCEXC915, FCEXC916, FCEXC917, FCEXC918, FCEXC919, FCEXC920
2016 & post 2016	FR Y-9C: FCEXC915, FCEXC916, FCEXM851, FCEXM852, FCEXM853, FCEXC918, FCEXC919, FCEXM854, FCEXM855, FCEXM856
BHC Diversification	
Std Dev Return on Assets (RoA)	12-month rolling standard deviation of the ratio of net income to average assets FR Y-9C: BHCK4340, BHCK4079, BHCK3368
Std Dev Market Returns	Standard deviaton of residuals of 180 day regression of excess returns on market returns and Fama-French factors (SMB, HML, and UMD) CRSP
BHC Risk	
(-1) Log Z-score (12 qtr)	$-Log[(AverageRoA_{b,t} + \frac{Equity_{b,t}}{Assets_{b,t}})/Std\,Dev\_RoA_{b,t}]$, CRSP
(-1) Market Z-score	$-Log[(AverageRoA_{b,t} + \frac{Equity_{b,t}}{Assets_{b,t}})/Std\,Dev\_MarketReturns_{b,t}]$, CRSP (market returns annualized over 252 trading days)
Liquidity Risk	180-day rolling beta of excess returns on LIBOR-OIS spread CRSP; Bloomberg
Systematic Risk	Dynamic conditional beta (Engle, 2016) Federal Reserve Board of Governors with New York University (NYU) VLab
SRISK	Brownless and Engle (2016) Federal Reserve Board of Governors with NYU VLab
BHC Governance	
Governance Measures	GovPC1 or Bank Ownership Governanceis the first principal component over BHC quarterly data on:
Total Inst. Ownership	Thomson Reuters Institutional Holdings 13F
Independent Directors Share	Compustat
CEO Non-Duality Share	Compustat
Quarterly Macro Controls	
VIX	Chicago Board Operations Exchange
Credit to GDP Gap	Bank for International Settlements
Annualized Real GDP Growth	Bureau of Economic Analysis

Table A2: PCA of Complexity Variables

Business Complexity	$BPC1_{b,t}$	$BPC2_{b,t}$	Cumulative
Non-Financial Count Share	0.17	-0.74	
$CountB$	0.56	0.26	
$BHHI$	-0.41	0.48	
$CountN$	0.58	0.02	
Non-interest Income Share	0.40	0.40	
Fraction of variance explained	0.349	0.282	0.631
Geographic Complexity	$GPC1_{b,t}$	$GPC2_{b,t}$	
$CountC$	0.53	-0.30	
$CHHI$	0.44	0.81	
Share of foreign office claims in total assets	0.51	0.11	
Count Net due to positions	0.51	-0.49	
Fraction of variance explained	0.789	0.136	0.925
Governance	$GovPC1_{b,t}$	$GovPC2_{b,t}$	
Total Inst. Ownership, Percent of Shares Outstanding	0.71	0.71	
Share of independent directors	0.71	-0.71	
Fraction of variance explained	0.707	0.293	1

This table presents the results of principle component analysis applied to inform business complexity, geographic complexity, and governance. This dimensionality reduction is performed over the variables provided in each section. The analysis within the main body of the paper uses the first principle components, respectively BPC1 for business complexity, GPC1 for geographic complexity, and GovPC1 for governance. The fraction of variance explained by each component is provided in the lower row of each table section.