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Does customer-base structure influence managerial risk-taking incentives? ☆

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ABSTRACT

We find strong evidence that when a firm's customer base is more concentrated, the firm's CEO receives more risk-taking incentives in her compensation package. This finding is robust to numerous alternative measures, alternative specifications, alternative subsamples, and different attempts that mitigate endogeneity concerns. Further, the positive effect of customer concentration on CEO risk-taking incentive provision is more prominent when the CEO is more reluctant to take risks, when the firm has more investment opportunities, and when the firm is more prone to the costs of losing large customers. These findings are consistent with the notion that boards provide additional risk-taking incentives to offset the CEO's aversion to the risk of non-diversified revenue streams, thereby preventing excessive managerial conservatism at the expense of value maximization.

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1. Introduction

Much of the literature on the standard moral hazard problem (Mirrlees, 1976; Holmstrom, 1979) and the design of managerial compensation focuses on the importance of

the sensitivity of CEO wealth to performance as an incentive alignment mechanism (Jensen and Murphy, 1990; Bizjak et al., 1993). Yet, the optimal structure of incentives is also a function of the exposure of CEO wealth to firm risk through convex payoffs (Guay, 1999; Core and Guay, 2002; Coles et al., 2006). Despite the significant operational and policy implications of managerial risk-taking incentives (Chava and Purnanandam, 2010; Armstrong and Vashishtha, 2012; Bakke et al., 2016), empirical work on how firms design manager pay convexity in relation to their decision making environment involving moral hazard remains limited (Coles and Li, 2020). This paper makes a step forward by examining the economic link between risk-taking incentives in managerial compensation and an important organizational feature in the firm's supply chain, namely, the concentration of its customer base.

Firms' dependence on major customers is a critical determinant of their values and corporate policies. Although

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forging enduring trade relationships could help a firm achieve a stronger competitive position (Patatoukas, 2012), relying on major customers for a large proportion of sales represents a significant source of risk for the supplying firm. For example, a supplier may incur significant losses when its major customers become financially distressed or declare bankruptcy, switch to a different supplier, or decide to change their products (Hertzel and Officer, 2012; Kolay et al., 2016; Dhaliwal et al., 2016). Further, developing and maintaining bilateral relationships with major customers requires customized supplier investments that are highly risky with low redeployability value outside of the relationship (Rauch, 1999; Kale and Shahrur, 2007). A strand of literature examines the role of customer concentration risk in determining corporate policies and outcomes.¹ In this paper, we extend this line of research by showing how customer risk affects CEOs' risk-taking incentives.

Why does customer risk influence CEO compensation? While diversified shareholders do not care much about the customer risk that is idiosyncratic and could be diversified away, risk-averse managers with undiversified human capital do. Hence, they may have incentives to invest conservatively and forgo risky but positive-NPV projects, accentuating moral hazard problems. As formalized in the theoretical model of Edmans and Gabaix (2011), when firm (customer) risk is higher, offering the CEO more pay convexity to offset her risk aversion and induce her to undertake value-creating risky projects is optimal. The pay convexity here refers to the sensitivity of CEO wealth to stock return volatility, or *vega*. A higher vega makes risk more valuable to managers, encouraging risk-taking behavior (Coles et al., 2006; Gormley et al., 2013). We therefore hypothesize that a positive relation exists between customer concentration and supplier CEO vega.

To test this hypothesis, we follow prior studies (e.g., Patatoukas, 2012; Dhaliwal et al., 2016; Campello and Gao, 2017) and measure customer concentration or customer risk with *Major customer sales*, which is the fraction of a firm's total sales to all corporate major customers, and *Customer HHI*, which is a Herfindahl-Hirschman index based on major corporate customer sales. Using both measures, we show customer concentration is positively associated with supplier CEO vega, lending support to our hypothesis. This finding is robust to alternative measures of risk-taking incentives and customer concentration, alternative model specifications, alternative sample periods, and alternative subsamples, as well as to controlling for cash and performance incentives in compensation contracts. In particular, our results do not change when we use a more comprehensive measure of vega incentives following the methodological approach of Bettis et al. (2018) that accounts for the recent trend of performance-vesting (p-v hereafter) stock grants displacing options.

¹ For example, recent evidence suggests suppliers with a more concentrated customer base are associated with stricter borrowing terms (Campello and Gao, 2017), more constrained access to external capital (Liu et al., 2018), higher cash holdings (Itzkowitz, 2013), and higher costs of equity (Dhaliwal et al., 2016).

An important concern with the above baseline results is that our estimates of the relation between customer concentration and CEO vega may tell us little about causality because of omitted variable and reverse causality concerns. Our customer concentration measures may not be exogenous, and hence the estimated positive relation could occur either because the same firm characteristics omitted from our analysis simultaneously drive both the customer-base structure and CEO vega, or because higher vega induces CEOs to choose a more concentrated customer base. To address these concerns and establish causality, we perform several tests.

First, we conduct a propensity score matching (PSM) algorithm, whereby firm-years with at least one major customer are matched with otherwise indistinguishable firm-years without major customers. This approach helps us control the effects of observable firm characteristics and pin down the effect of customer risk on CEO vega. We continue to observe a higher CEO vega for firms with higher customer risk.

Second, we focus on the concentration-vega relation for newly appointed CEOs to mitigate the concern that CEOs may have the ability to influence both the customer-base structure and their own pay. The results are robust in this analysis.

Third, we employ an instrumental variable approach to address the endogeneity concern. Following the existing literature (Campello and Gao, 2017; Gutiérrez and Philippon, 2017; Duan et al., 2019), we construct two instruments for customer concentration, namely, *Customer industry M&A*, which is a measure of the M&A intensity in customer industries, and *Customer regulation index*, which is an index capturing the level of aggregate regulatory restrictions in customer industries. Both instrumental variables could lead to changes in customer concentration and hence satisfy the relevance condition of the instrumental variable approach. However, evidence that these instruments could directly influence a supplier's CEO compensation package other than through their effects on the firm's customer-base structure is scant. Hence, the instruments reasonably satisfy the exclusion restriction of the instrumental variable approach. We once again find a positive and significant effect of (instrumented) customer concentration on CEO vega.

Fourth, we undertake tests to mitigate reverse causality concerns; that is, the structure of managerial incentives is determined to induce certain investment outcomes that might alter the concentration of customer firms' product markets, resulting in a positive concentration-vega relation. Specifically, we re-examine the effect of customer concentration on CEO vega after excluding the largest suppliers in terms of sales. Large firms are more likely to have the market power and incentive to actively influence customer firms' product markets and are more subject to this reverse causality concern. The fact that our results still hold after the exclusion suggests our findings do not appear to arise from reverse causation. In addition, following Cen et al. (2017), we exploit newly established major customer relationships and find a large and significant increase in CEO vega after the relationship establishment event, but the pattern is absent before the event. These ob-

servations confirm the positive concentration-vega relation is unlikely driven by reverse causation.

In summary, all of the above approaches and tests produce consistent evidence that increased customer concentration positively affects CEO vega. Although any approach and any piece of evidence is open to alternative interpretations, all the evidence taken together is difficult to reconcile with specific alternative arguments, and hence suggests a causal link between customer concentration and CEO vega.

Next, we examine the cross-sectional heterogeneity in the effect of customer concentration on CEO vega. The first set of tests explores how CEOs' and suppliers' characteristics alter our baseline results. As argued earlier, when exposed to undiversifiable customer risk, risk-averse CEOs could bypass risky but valuable investments. To encourage value-enhancing risk taking, CEO compensation should include more pay convexity. If customer concentration affects supplier CEO vega through such a channel, the effect should be stronger when the CEO is less open and/or more susceptible to risk-taking, and when supplier firms have higher investment opportunities so that the potential loss due to excessive CEO conservatism is larger. To test the above conjectures, we examine the cross-sectional heterogeneity of our main findings based on CEOs' risk attitudes and firms' investment opportunities. The existing literature proposes that young CEOs are more willing than old CEOs to take risks, due to career incentives (e.g., [Prendergast and Stole, 1996](#)). Relatedly, generalist CEOs are less likely than specialist CEOs to shy away from risk taking, given their broad outside options (e.g., [Custódio et al., 2013](#); [Mishra, 2014](#)). We construct two partition variables based on the above rationales to capture CEOs' risk attitudes. In addition, we use Tobin's q to measure a firm's investment opportunities, following the existing literature. Our analyzes show the effect of customer concentration is more pronounced for older CEOs and specialist CEOs, as well as for suppliers with higher investment opportunities. These results lend support to the notion that boards provide additional risk-taking incentives in CEOs' compensation packages to offset their aversion to the risk of non-diversified revenue streams, thereby preventing excessive managerial conservatism at the expense of value maximization.

Our second set of cross-sectional heterogeneity tests examines how characteristics of customer-supplier relationships alter our main results. Arguably, if major customers can switch suppliers at a relatively low cost or if the suppliers make more risky, relationship-specific investments (RSI), the customer risk is higher. Hence, customer concentration should have a more pronounced effect on CEO vega. Following [Dhaliwal et al. \(2016\)](#) and [Kale and Shahrur \(2007\)](#), we measure customers' costs of switching to other suppliers by the dependent supplier's industry market share, and measure supplier RSI by the supplier's intensity of research and development (R&D) activities. Consistent with our conjectures, we find the positive effect of customer concentration on CEO vega is more pronounced when customers' cost of switching suppliers is lower and when suppliers' RSI is higher. Overall, our heterogeneity tests provide further support to our inferences

of the positive effect of customer concentration on CEO vega, because coming up with an omitted variable that biases our results equally in all cross-sectional dimensions discussed above is hard.

In the final part of the paper, we examine the relation between a concentrated base of government customers and the supplier CEO's risk-taking incentives in her compensation package. While the focus of our paper is on corporate customers, suppliers could rely on governments for a large fraction of sales as well. Government customers differ considerably from corporate customers. In particular, they are much less likely to default or declare bankruptcy, and their purchases are typically longer-term and not completely profit-driven ([Banerjee et al., 2008](#); [Goldman et al., 2013](#)). As a result, government customers represent a more stable source of revenues that could help mitigate the risk associated with losing major customers. Hence, in the presence of a concentrated base of safer government customers, the risk of losing substantial future revenues from major customers is reduced; thus, the need for pay convexity to offset risk aversion is lower. Consistent with the above argument, interestingly, we find a negative relation between government customer concentration and supplier CEO vega. This finding is in contrast to the positive effect of corporate customer concentration on CEO vega. Together, the contrasting results between government and corporate customers provide further support to our hypothesis that the makeup of the customer base and, by implication, the stability of the revenue stream matter for the provision of risk-taking incentives to CEOs in their compensation packages.

Our study contributes to three strands of literature. First, it adds to the literature on the determinants of CEO risk-taking incentives. [Guay \(1999\)](#) and [Coles et al. \(2006\)](#) show that firms with substantial investment opportunities provide more risk-taking incentives in managerial compensation. [Ellul et al. \(2017\)](#) find that after unemployment benefits become more generous, boards increase CEO pay convexity to encourage risk taking. [Chang et al. \(2016\)](#) document that financial distress risk is positively associated with pay convexity of new CEOs. [Bakke et al. \(2020\)](#) show that an increase in product market competition brought about by heightened foreign entry leads to boards decreasing CEO risk-taking incentives. These studies, however, largely ignore the role played by a firm's customer base in CEOs' risk-taking incentive provisions. Our paper contributes to this line of inquiry by providing evidence that boards evaluate a firm's customer-base structure when determining CEO pay convexity.

Second, it adds to the growing literature on the role of customers as important firm stakeholders. Prior work shows that a firm's customer-base structure could influence various corporate policies.² Some studies provide evidence that customer concentration is an impor-

² For example, existing studies find that a firm's customer-base structure is related to its financial contracting ([Cen et al., 2016](#)), firm profitability ([Patatoukas, 2012](#); [Irvine et al., 2016](#)), capital structure ([Kale and Shahrur, 2007](#); [Banerjee et al., 2008](#)), accounting practices ([Hui et al., 2012](#)), earnings management ([Raman and Shahrur, 2008](#)), cash holdings

tant source of firm risk. For example, Campello and Gao (2017) show that the concentration of a supplier's customer base adversely affects its relations with creditors. Dhaliwal et al. (2016) find higher customer concentration risk is associated with higher costs of equity, and Liu et al. (2018) provide evidence that customer concentration risk hinders suppliers' ability to raise external funding through receivable securitization. Our findings enrich this stream of research by showing that customer concentration risk could have a significant effect on the supplier CEO's risk-taking incentives in her compensation package.

Third, our paper is related to a small group of studies documenting that considerations from firms in the same industry or in the supply chain affect the optimal structure of the firm in question. For example, Karuna (2007) finds that firms provide stronger performance incentives when competition from industry rivals is greater. Hertz et al. (2008) show that suppliers to bankruptcy-filing firms experience negative and significant stock price reactions around filing and pre-filing distress dates. Coles et al. (2018) find that the external pay gap between the CEO in question and the highest-paid CEO in the same industry provides tournament incentives that affect firm performance and risk. Harford et al. (2019) demonstrate that significant trade relationships and economic links incrementally explain firms' acquisition activities. Complementary to these studies, we examine how economic links along the supply chain affect managerial risk-taking incentives in the context of moral hazard. In turn, the fact that product market relationships are sufficiently important to be manifested in the design of managerial incentive schemes suggests an extended concept of the firm as a managed economic system that permeates a firm's formal boundaries, entailing system-wide considerations about incentive provision problems.

In a contemporaneous paper, Liu et al. (2021) study a similar question to ours. Exploiting import tariff reductions as an experimental setting, they also provide evidence that a firm's relationship with major customers can have a substantial effect on its managerial compensation structure. Yet, the two papers differ in important aspects. First, their construction of important customer relationships includes both major customers that account for at least 10% of the firm's total revenue and other voluntarily disclosed, non-major customers (i.e., contribute less than 10% of total sales). We, however, focus only on major customers and adhere to the objective cutoff rule to maintain uniformity.³ Also, note that our customer concentration risk argument relies primarily on the proportion of sales to major customers being sufficiently large: if such a customer removes its business from a supplier, this would be a serious disruption to that supplier. Second, Liu et al. (2021) restrict their sample to manufacturing firms and show that manufacturing firms with varying degrees of customer concentration adjust CEO vega differently in response to competition shocks. Our results, based on a full sample of

firms with information available on ExecuComp, suggest that CEO vega depends on customer concentration directly, allowing for greater generalizability and providing a more complete picture on the relation between customer relationship and CEO compensation.

The rest of the paper is organized as follows. Section 2 describes the sample and variable constructions. Section 3 discusses the main results and robustness tests. Section 4 addresses potential endogeneity issues. Section 5 examines the cross-sectional heterogeneity in the relation between customer concentration and CEO vega. Section 6 concludes.

2. Data sources, sample selection, and methodology

2.1. Data sources and sample selection

We investigate the relation between customer concentration and CEOs' incentive contracts in this paper. Hence, our starting point for constructing the sample is the universe of firms over the period 1992–2018 in the ExecuComp database that provides CEO compensation information. We then expand this information to include customer-supplier data from Compustat's Segment Customer files. Moreover, we obtain firm-level financial data from Compustat, stock price information from CRSP, and CEO characteristics from ExecuComp. All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the potential impact of outliers. We drop observations with missing values for the variables employed in the regressions. The final sample includes firms in the intersection of these databases, consisting of 38,366 firm-year observations for 3474 unique firms.

2.2. Empirical specification

To examine the relation between customer concentration and managerial risk-taking incentive provision at the supplier-year level, we estimate the following panel regression model:

$$\ln(1 + Vega)_{i,t} = + \beta \cdot Customer\ Concentration_{i,t} + \gamma \cdot Control_{i,t} + Industry * year_{i,t} + \epsilon_{i,t} \quad (1)$$

The measures of CEO risk-taking incentives and customer concentration are discussed in detail in the following subsections. *Control* represents a vector of firm and CEO characteristics that affect the CEO's incentive contracts following the existing literature. We include *Industry*year*, the industry-year interaction fixed effects, to mitigate any concern about omitted variables that are correlated with a firm's customer-base structure and vary within industries and years. Similar to prior studies (e.g., Dhaliwal et al., 2016; Campello and Gao, 2017; Cen et al., 2017), we do not include firm fixed effects in our regressions, due to limited within-firm variation in the customer concentration variables. We return to this issue shortly.

(Itzkowitz, 2013), innovation (Chu et al., 2019; He and Tian, 2018, 2020), misconduct (Chen et al., 2021), and tax strategies (Cen et al., 2017).

³ We discuss this issue in more detail in Section 2.3.

2.3. Measuring customer concentration

We identify firms' major customers using Compustat's Segment Customer database. This information is publicly available because SFAS No. 14 (before 1997) and FAS No. 131 (after 1997) require firms to report all customers that account for 10% or more of total firm revenues. The Segment database provides the type and name of a major customer, along with the dollar amount of annual revenues generated from each major customer. Although regulations only require suppliers to disclose customers representing at least 10% of revenues, suppliers could voluntarily report customers that account for less than 10% of revenues (i.e., nonmajor customers). We exclude these customers from our concentration calculations for two important reasons.⁴ First, voluntary disclosure choices in the context of information about customers are a result of the tradeoff between the benefits of reducing information asymmetry and the costs of being in a disadvantaged position relative to competitors (Ellis et al., 2012). Thus, the presence of nonmajor customers in the data would be endogenously determined, resulting in a sample selection problem. That is, if product market competition incentivizes firms to withhold information about sales (Dedman and Lennox, 2009), nonmajor customers are less likely to appear in competitive industries and in times of high competition, creating a bias that varies with the degree of competition faced by the firm. Second, a prerequisite for the customer concentration risk to be a major concern in a moral hazard context is that the proportion of sales to major customers must be sufficiently large in the sense that losing such customers would have a material adverse effect on the supplier. For both reasons, we adhere to the objective 10% cutoff rule and focus on major customers.

We use two measures to capture the extent to which a supplier's customer base is concentrated. For the first measure, we follow Banerjee et al. (2008) and Dhaliwal et al. (2016) and define *Major customer sales* as the fraction of a supplier's annual total sales captured by all major customers, where major customers are those that account for at least 10% of the supplier's annual revenues.

The second measure, *Customer HHI*, follows Patatoukas (2012), who constructs the customer concentration variable based on the notion of a Herfindahl-Hirschman Index of sales to major customers. Specifically, we measure supplier *i*'s customer concentration in year *t* across the supplier's *J* major customers as:

$$\text{Customer HHI}_{it} = \sum_{j=1}^J \left(\frac{\text{Sales}_{ijt}}{\text{Sales}_{it}} \right)^2$$

where Sales_{ijt} represents supplier *i*'s sales to major customer *j* in year *t*, and Sales_{it} represents supplier *i*'s total sales in year *t*. *Customer HHI* ranges between 0 and 1, with higher values indicating a more concentrated customer base. It takes a value of 0 when a supplier does not disclose sales to any major customers, and takes a value of 1 when a supplier depends on a single major customer for all of its annual revenues.

⁴ Our results are robust to including these customers.

Note that our main source of variation in the customer concentration variables comes from the cross section. To get a sense of the relative variation of the customer concentration measures in our sample, we calculate between- and within-firm variances in Panel A of Table 1. As one can see, these measures vary more across firms than within firms. The within-firm standard deviation of *Customer HHI* (*Major customer sales*) is 4.6% (9.5%). For comparison, the between-firm standard deviation of *Customer HHI* (*Major customer sales*) is 7.5% (17.3%). This observation is consistent with Dhaliwal et al. (2016), Campello and Gao (2017), and Cen et al. (2017), who also note that the limited within-firm variation in customer concentration variables may work against including firm fixed effects in regressions, and suggest using industry-year fixed effects instead, which we follow in our empirical specifications.⁵

2.4. Measuring risk-taking incentives

We follow the existing literature and measure managerial risk-taking incentives by the sensitivity of CEO wealth to stock return volatility, or *Vega*, defined as the change in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return (Guay, 1999; Core and Guay, 2002; Coles et al., 2006).⁶ To alleviate concerns that arise from the skewness of vega, we measure CEO risk-taking incentives as $\ln(1 + \text{Vega})$ in our analysis.⁷ In addition to this traditional way of capturing managerial risk-taking incentives, as an extension, we construct a more comprehensive vega that considers the pay convexity in p-v grants that have become increasingly important in recent years, following the empirical methods of Bettis et al. (2018). We discuss this analysis in more detail in Section 3.2.1.

2.5. Control variables

Following the prior literature, we include several firm and CEO characteristics that are related to the design of CEO incentive compensation (Coles et al., 2006; Low, 2009; Hayes et al., 2012; Cohen et al., 2013). First, we control for firm characteristics, including firm size, measured as the natural logarithm of sales ($\ln(\text{Sales})$); profitability, measured as both the return on assets (ROA) and stock returns

⁵ Because the variation in customer concentration arises mainly in the cross-section, firm fixed effects may not be a good match for our empirical context (Zhou, 2001). Unsurprisingly, our results overall suggest that the relation between customer concentration and CEO vega is strong in the cross-section but not prominent in the time series.

⁶ A related measure is the fraction of option compensation. We do not use this measure because options have ambiguous implications for risk. On the one hand, options increase in value with firm risk. Their convex pay structure creates an incentive to take risk because managers share in the gains but not all of the losses. On the other hand, options increase the sensitivity of a risk-averse CEO's wealth to the underlying stock price, weakening the CEO's risk-taking incentives (Carpenter, 2000; Ross, 2004). Further, option compensation increases wealth, which may alter risk tolerance. Together, the net effect of option compensation on risk taking is not clear a priori and depends upon the level of CEO wealth, the degree of diversification in a CEO's personal portfolio, and the risk-aversion parameter, among others (Guay, 1999).

⁷ Our results are not materially affected if we replace $\ln(1 + \text{Vega})$ with *Vega*.

Table 1

Summary statistics.

Panel A reports a summary of the relative variation in the measures of customer concentration between and within firms. The first row reports the standard deviation for the full sample. The second and third rows report the standard deviation across different firms controlling for the time-series mean and within each firm. Panel B reports summary statistics for the variables used in our baseline analysis. For each variable, we report the number of observations, mean, standard deviation, 25th percentile, median, and 75th percentile. All variables are defined in Appendix.

Panel A. Panel variance statistics						
	Major customer sales			Customer HHI		
Overall std. dev.		0.181				0.076
Between firm std. dev.		0.173				0.075
Within firm std. dev.		0.095				0.046
Panel B. Descriptive statistics						
	Obs.	Mean	Std. dev.	25th	Median	75th
Main variables						
Vega (thousand \$)	38,366	115.398	199.723	7.823	39.271	124.973
Ln(1+Vega)	38,366	3.387	1.964	2.177	3.696	4.836
Ln(1+Augmented vega_S)	32,538	4.001	2.247	2.788	4.495	5.657
Ln(1+Augmented vega_SC)	32,538	4.006	2.252	2.806	4.498	5.660
Major customer sales	38,366	0.077	0.181	0.000	0.000	0.000
Customer HHI	38,366	0.022	0.076	0.000	0.000	0.000
Customer concentration measures for firms with a major customer						
Major customer sales	8738	0.340	0.233	0.144	0.263	0.470
Customer HHI	8738	0.096	0.136	0.020	0.045	0.107
Control variables						
Sales (million \$)	38,366	4755.908	9162.636	488.957	1352.919	4220.266
ROA	38,366	0.035	0.096	0.011	0.040	0.079
Tobin's Q	38,366	1.882	1.210	1.133	1.470	2.128
Leverage	38,366	0.237	0.190	0.072	0.219	0.355
Volatility	38,366	0.109	0.058	0.068	0.095	0.133
Stock return	38,366	0.144	0.452	-0.123	0.099	0.335
Age	38,366	55.910	7.009	51.000	56.000	60.000
Tenure	38,366	8.328	7.030	3.000	6.000	11.000
CEO ownership	38,366	0.092	0.289	0.000	0.000	0.000
CEO duality	38,366	0.519	0.500	0.000	1.000	1.000

(*Stock return*); investment opportunities, measured as Tobin's q (*Tobin's q*); information quality, measured as stock return volatility (*Volatility*); and firm leverage (*Leverage*). Moreover, the CEO characteristics that we control for include age (*Age*), tenure (*Tenure*), an indicator of whether the CEO also serves as the chairman of the board (*CEO duality*), and an indicator of whether the CEO holds more than 5% of the firm's outstanding shares (*CEO ownership*). Appendix provides detailed variable definitions.

2.6. Summary statistics

Panel B of [Table 1](#) reports summary statistics of the variables used in our baseline analysis. The dependent variable *Vega* has a mean value of \$115,398, which is comparable to the reported mean of \$149,453 in [Table 1](#) of [Hayes et al. \(2012\)](#). On average, sales to all major customers account for 7.7% of total revenue. For the subset of suppliers that disclose at least one major customer, the mean sales to all major customers account for 34.0% of these suppliers' total revenue.⁸ The mean *Customer HHI* is 2.2% for the whole sample and 9.6% for the subset

of suppliers with at least one major customer. These results are comparable to those of [Dhaliwal et al. \(2016\)](#) and [Campello and Gao \(2017\)](#).

An average firm in our sample has a sales revenue of \$4.76 billion, a return on assets of 3.5%, a Tobin's q of 1.88, a stock return of 14.4%, stock return volatility of 0.11, and a leverage of 23.7%. In addition, the average CEO is 56 years old and has a tenure of 8 years. 51.9% of our sample CEOs also serve as the chairman of their board and 9.2% hold more than 5% of total shares outstanding.

3. Customer concentration and supplier CEO risk-taking incentive provision

3.1. Baseline results

We start our analysis by examining whether a concentrated customer base affects the supplier CEO's risk-taking incentives in her compensation package. [Table 2](#) presents the results of this analysis, using both measures of customer concentration. The coefficient estimates of *Major customer sales* and *Customer HHI* are positive and significant at the 1% level, suggesting a positive relation between customer concentration and supplier CEO *vega*. To interpret the economic significance, we compare the differences

⁸ In 23% of our observations, a firm reports that at least one major customer accounts for 10% or more of revenues.

Table 2

Customer concentration and CEO vega.

This table examines the impact of customer concentration on risk-taking incentives in the CEO's compensation package. The dependent variable is the natural logarithm of one plus Vega, where Vega is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. All other variables are defined in Appendix. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: $\ln(1 + Vega)$	
	(1)	(2)
Major customer sales	0.346*** (3.00)	
Customer HHI		0.923*** (4.15)
Ln(Sales)	0.512*** (27.78)	0.513*** (27.98)
ROA	-0.385** (-2.46)	-0.367** (-2.35)
Tobin's Q	0.177*** (8.86)	0.176*** (8.79)
Leverage	-0.001 (-0.01)	-0.006 (-0.04)
Volatility	-2.594*** (-6.53)	-2.605*** (-6.54)
Stock return	0.012 (0.55)	0.012 (0.54)
Age	-0.014*** (-4.34)	-0.014*** (-4.39)
Tenure	0.010*** (2.72)	0.010*** (2.73)
CEO ownership	-0.693*** (-8.11)	-0.692*** (-8.10)
CEO duality	0.298*** (7.14)	0.298*** (7.14)
Industry-Year FE	Yes	Yes
N	38,366	38,366
Adjusted R ²	0.317	0.318

in customer concentration and CEO vega between suppliers that do not depend on any major customers and the average supplier with at least one major customer. The average supplier with at least one major customer has a total percentage of sales to all major customers of 34.0% and a customer concentration HHI of 0.096. Since both customer concentration measures take the value of 0 for suppliers that do not have any major customers, the coefficient estimates in regressions (1) and (2) suggest firms with at least one major customer offer risk-taking incentives in managerial compensation that are 11.8% ($=0.346 \times 0.340$) and 8.9% ($=0.923 \times 0.096$) higher, respectively.

The results for the control variables are relatively stable in terms of their magnitude and significance levels across the different specifications and are generally consistent with those in the prior literature. Similar to Chang et al. (2016), we find pay-risk sensitivity is higher for chairman-CEOs and decreases with CEO age. Consistent

with Bakke et al. (2020), we also find CEO vega is positively associated with firm size and investment opportunities.⁹

3.2. Robustness tests

This section reports an extensive set of robustness checks we undertake to strengthen our baseline findings.

3.2.1. Performance-vesting provisions

Despite the voluminous literature on stock options and risk taking (see, e.g., Hayes et al., 2012; Armstrong and Vashishtha, 2012; Gormley et al., 2013; Bakke et al., 2016), options themselves are not the only source of risk-taking incentives in managerial compensation. Over the past decade, p-v provisions that set certain performance hurdles for equity and/or cash awards have played an increasingly important role in conveying compensation convexity. According to Bettis et al. (2018), the usage of p-v equity awards to top executives in large U.S. companies grew from 20% in 1998 to almost 70% in 2012. In particular, a shift away from option grants toward p-v stock grants has occurred, and this trend was pronounced around FAS123R, which removed the preferential treatment in reporting and expensing option pay from 2006 onward (Bettis et al., 2010, 2018).

If the convexity in compensation contracts comes primarily from p-v stock grants, especially in the later years of our sample, the conventional vega becomes an incomplete measure of risk-taking incentives provided to CEOs. We conduct two tests to ensure this issue does not contaminate our inferences. As a first step, we restrict our sample to the period before the change of compensation disclosure rules in 2006, which is likely to be less contaminated by the measurement error in CEO vega. We report the results in Table IA2 of the Internet Appendix and confirm that this restriction has little impact on the results.

Second, to more formally address the measurement concern, we follow the empirical methods developed by Bettis et al. (2018) and construct more comprehensive measures of pay convexity: *Augmented vega_S*, which enhances the conventional vega by adding the pay convexity arising from p-v stock awards, and *Augmented vega_SC*, which enhances the conventional vega by incorporating the pay convexity arising from both p-v stock and p-v cash awards. Our data on p-v provisions are from the ISS Incentive Lab, which limits the sample period for this analysis to 1998–2018 because this database has broad coverage only from 1998 onward. Following Bettis et al. (2018), we focus on p-v awards with a single (accounting or stock) performance metric to keep the task manageable. We discuss

⁹ While not the main focus of the paper, as a complement, we broaden the inquiry and examine the effect of customer concentration on risk-taking incentives for other named executive officers (NEOs) beside the CEO. We define NEOs as non-CEO executives whose compensation is disclosed in ExecuComp and construct an analogous measure based on the average vega of NEOs' compensation contracts. We then estimate the relation between the customer concentration measures and *Average NEO vega*, using the same set of controls as in Table 2. The results shown in Table IA1 of the Internet Appendix provide parallel evidence that customer concentration is positively related to NEO vega as well, pointing to a broader scope for the effect of customer concentration.

Table 3

Incorporating pay convexity of performance-vesting provisions.

This table re-estimates the effect of customer concentration on managerial risk-taking incentives using more comprehensive pay convexity measures that incorporate single-metric performance-vesting (p-v) stock and cash awards. $\ln(1 + \text{Augmented vega}_S)$ is the natural logarithm of one plus *Augmented vega_S*, where *Augmented vega_S* is the augmented vega after incorporating the pay convexity arising from p-v stock awards. $\ln(1 + \text{Augmented vega}_{SC})$ is the natural logarithm of one plus *Augmented vega_{SC}*, where *Augmented vega_{SC}* is the augmented vega after incorporating the pay convexity arising from both p-v stock and p-v cash awards. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. The same set of control variables and industry-year fixed effects as in our baseline models are included. The estimated parameters of the other controls are not reported for brevity. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable			
	$\ln(1 + \text{Augmented vega}_S)$		$\ln(1 + \text{Augmented vega}_{SC})$	
	(1)	(2)	(3)	(4)
Major customer sales	0.385*** (2.85)		0.374*** (2.71)	
Customer HHI		1.018*** (3.74)		1.015*** (3.71)
All controls	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
N	32,538	32,538	32,538	32,538
Adjusted R ²	0.296	0.297	0.300	0.300

further details about the estimation procedure and variable construction in the Internet Appendix. Table 3 reports regression results in which the dependent variables are the two augmented CEO vega measures. The coefficient estimates on customer concentration variables are all positive and significant at the 1% level. The observation that our results remain unchanged using these two alternative managerial incentive measures that take p-v provisions into account is reassuring.

3.2.2. Additional robustness tests

We perform a series of other robustness tests. First, we explore different ways of defining the customer concentration variable. In the baseline results, we already use two measures of customer concentration. In Panel A of Table 4, we go a step further and consider three more measures: (i) *Major customer* is an indicator variable set to 1 if a firm discloses at least one corporate customer that accounts for 10% or more of its total revenue, and 0 otherwise; (ii) *Major customer max* is the highest percentage sales to major customers; and (iii) *Major customer count* is the total number of a firm's major customers. The results show that the positive relation between customer concentration and CEO risk-taking incentive provisions is robust to using the three alternative measures.

Second, in June 1997, the FASB issued FAS No. 131, revising SFAS No. 14, which affected disclosure requirements of some of the segment customer information. To ensure this rule change does not drive our findings, we restrict the beginning of our sample period to 1998 and re-estimate the baseline specifications. Panel B of Table 4 reports the results. The estimated effect is not much affected.

Third, one may argue that institutional investors and corporate governance could affect our baseline results because previous studies show these factors are important determinants of CEO compensation (Core et al., 1999; Hartzell and Starks, 2003). To address this concern, we retrieve institutional equity holding data from the Thomson Reuters Institutional (13f) Holdings database and construct a variable *Institutional ownership*, and use a *Takeover index* developed by Cain et al. (2017).¹⁰ We include these two variables in our baseline regressions and report the results in Panel C of Table 4. We continue to observe positive and significant coefficient estimates of customer concentration variables.

Fourth, in our baseline, we include industry-year fixed effects to account for potential heterogeneity in customer concentration across sectors in a given year. We now add state-year fixed effects to further account for potential heterogeneity within states and years. Panel D of Table 4 presents the results. Again, we find a positive relation between customer concentration and CEO vega.

Fifth, one may be concerned that our results could be driven by the financial crisis in 2008, because significant changes occurred in both customer relationships and CEO risk-taking incentive provisions. In Panel E of Table 4, we repeat our baseline analysis in a sample that excludes the

¹⁰ The takeover index is constructed based on the passage of 12 different types of state anti-takeover laws, one federal statute, and three state standards of review, where higher values indicate greater susceptibility to hostile takeovers. The state laws are matched to the firms based on their state of incorporation. The data are available at: <https://pages.uoregon.edu/smckeon/>.

Table 4

Robustness checks.

This table contains a number of checks testing the robustness of the relationship between customer concentration and risk-taking incentives in the CEO's compensation package to alternative model specifications, subsamples, and variable definitions. For each robustness check, we estimate OLS regressions separately for alternative measures of customer concentration. The same set of control variables and industry-year fixed effects as in our baseline regressions are included, unless otherwise specified. For brevity, we only report the coefficients on the customer concentration variables. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable: $\text{Ln}(1+\text{Vega})$	
Panel A. Alternative measures of customer concentration	
Major customer	0.085* (1.78)
Major customer max	0.523*** (3.31)
Major customer count	0.046* (1.88)
N	38,366
Panel B. Starting the sample period in 1998	
Major customer sales	0.351*** (2.84)
Customer HHI	0.953*** (3.89)
N	32,538
Panel C. Controlling for institutional ownership and the Cain et al. (2017) takeover index	
Major customer sales	0.365*** (3.58)
Customer HHI	1.051*** (4.02)
N	23,690
Panel D. Including state-year fixed effects	
Major customer sales	0.300** (2.54)
Customer HHI	0.844*** (3.70)
N	37,346
Panel E. Excluding the 2008–2009 crisis period	
Major customer sales	0.298** (2.56)
Customer HHI	0.822*** (3.63)
N	34,914
Panel F. Controlling for $\text{Ln}(1\pm\Delta)$ and $\text{Ln}(\text{Cash})$	
Major customer sales	0.153* (1.67)
Customer HHI	0.428** (2.47)
N	38,366

2008–2009 crisis period and show our results are robust to this exclusion.

Finally, customer concentration might affect the provision of performance incentives, or delta, to supplier firm managers. Such incentives expose the manager to more firm risk (Guay, 1999), which, in turn, could be an important consideration in the determination of vega. To address this concern and better isolate the effect of customer concentration on vega, we explicitly control for other aspects of compensation incentives in Panel F of Table 4, constructing and including the following variables. $\text{Ln}(1+\Delta)$ is the natural logarithm of one plus delta, where delta is defined as the change in the value of the CEO's wealth due to a 1% increase in the firm's stock price. We estimate

delta following Guay (1999) and Core and Guay (2002).¹¹ $\text{Ln}(\text{Cash})$ is the natural logarithm of CEO cash compensation, where cash compensation consists of salary and bonus. The coefficient estimate on the customer concentration variables remains positive and significant across all specifications, suggesting our results are robust to controlling for cash and performance incentives in compensation contracts.

Overall, the results in Table 4 reinforce our key finding of a positive relation between customer concentration

¹¹ Note this estimated delta does not incorporate the sensitivity of p-vg grants to stock performance.

and CEO risk-taking incentives. Our baseline findings remain relatively stable across all robustness checks. For instance, the coefficient estimate on *Major customer sales* ranges from 0.153 to 0.365. The stability of these coefficient estimates suggests that any potential bias arising from omitted variables or unobserved selection is likely to be low (Oster, 2019).

4. Addressing potential endogeneity

While the results so far are robust and consistent with the hypothesis, the observed relation between customer concentration and supplier CEO vega could tell us little about causality, given the endogeneity of the relation between risk-incentive compensation and risk. For example, some unobserved firm and CEO characteristics could be affecting both the concentration of the firm's customer base and managerial risk-taking incentives. Alternatively, managerial incentive compensation is arguably designed in anticipation of a particular risk environment. In this section, we adopt a multi-pronged approach to mitigate these concerns. Overall, the tests confirm our baseline results and show that the data are inconsistent with several particular concerns. Although these observations are reassuring, we are mindful that completely ruling out alternative explanations in general is impossible.

4.1. Propensity score matching estimates

As a first step to alleviate endogeneity problems, we employ a PSM approach whereby firm-year observations with a major customer are matched with those without a major customer. A perfect experiment for examining the effect of a concentrated customer base on the supplier CEO's risk-taking incentive provision would be one that compares CEO vega of firms that rely on at least one major customer in a year with CEO vega of the same firm in the same year, had it not relied on any major customers. However, since this counterfactual cannot be observed, we have to adopt a second-best experiment based on matching, whereby we compare CEO vega of a customer-dependent supplier with CEO vega of another non-dependent supplier that is sufficiently similar to the dependent supplier.

We proceed in two steps to identify a matched sample of firm-years without a major customer that exhibit no significant differences in other observable characteristics with those with a major customer. We first estimate the probability that a firm has at least one major customer by running a logit regression, reported in regression (1) of Panel A of Table 5, that includes the same controls as in the regressions in Table 2.¹² Consistent with Banerjee et al. (2008) and Campello and Gao (2017), the results show that, on average, customer-dependent supplier firms are smaller and have higher investment opportunities. Moreover, these firms appear to be less profitable during our sample period. In the second step, we construct matched samples using the nearest-neighbor

method based on the propensity scores calculated from the first-step logit model. Specifically, each firm-year observation with a major customer (the treatment group) is matched with the firm-year observation without a major customer (the control group) with the closest propensity score. To ensure observations in the treatment and control groups are sufficiently indistinguishable, we require that the maximum difference (i.e., the caliper) in the propensity score between each firm-year with a major customer and that of its matched peer does not exceed 0.001 in absolute value.¹³

To verify that firms in the treatment and control groups are truly comparable, we conduct two diagnostic tests. The first test consists of re-estimating the logit model for the post-match sample. The results are shown in regression (2) of Panel A of Table 5. None of the coefficient estimates are statistically significant, suggesting no distinguishable trends in CEO vega exist between the two groups. Further, the coefficient estimates in regression (2) are much smaller in magnitude than those in regression (1), suggesting the results in regression (2) are not simply an artifact of a decline in degrees of freedom in the restricted sample. The second test consists of examining the difference for each observable characteristic between the treatment firms and the matched control firms. The results are reported in Panel B of Table 5. Again, none of the differences in observable characteristics between the treatment and control firms is statistically significant. Overall, the diagnostic test results suggest PSM removes all observable differences other than the difference in the concentration of the firm's customer base, increasing the likelihood that any difference in CEO vega between the two groups is due to customer concentration.

Finally, Panel C of Table 5 reports the PSM estimates.¹⁴ The results suggest a significant difference (at the 5% confidence level) exists in CEO vega between firms with a major customer and those without. In detail, CEOs of firms with a major customer have a 6.9% higher vega than those in otherwise indistinguishable firms without a major customer.

4.2. Newly appointed CEOs

A major concern with our baseline results is that some unobservable CEO characteristics might affect both customer concentration and risk-incentive compensation in the same direction, resulting in the observed positive concentration-vega relation. For example, incumbent CEOs who have had more interactions with the board could have greater abilities to affect their own compensation packages and at the same time influence the concentration of the customer base. To help address this concern and isolate the effect of customer concentration on CEO vega, we examine a subset of newly appointed CEOs who should have little or no time to gain control over corporate decisions or their own pay (Chang et al., 2016).

¹² The results are robust to adding the following controls in the logit regressions: *R&D intensity*, *Investment intensity*, *SGA/Sales*, and *Adv/sales*, as well as using a probit model in the first step.

¹³ Our results remain robust when we increase the maximum permissible difference in propensity scores to 0.01 and 0.005 in absolute value.

¹⁴ The difference in means between the treatment group and matched control group is the PSM estimate of the average treatment effect on the treated (ATT).

Table 5

Propensity score matching estimate.

This table reports the propensity score matching estimation results. Panel A reports parameter estimates from the logit model used to estimate propensity scores. The dependent variable is an indicator variable equal to 1 for firms with at least one major customer, and 0 otherwise. All independent variables are defined in Appendix. Industry and year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. Panel B reports the univariate comparisons of firm characteristics between firms with and without a major customer. Panel C reports the average treatment effect estimates. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Panel A. Pre-match propensity score regression and post-match diagnostic regression				
	Dependent variable: Dummy equals 1 for firms with a major customer, and 0 otherwise			
	Pre-match		Post-match	
	(1)		(2)	
Ln(Sales)	-0.251***	(-21.66)	0.006	(0.42)
ROA	-0.049	(-0.33)	-0.238	(-1.40)
Tobin's Q	0.042***	(3.32)	0.014	(0.97)
Leverage	-0.102	(-1.18)	-0.017	(-0.17)
Volatility	3.938***	(12.75)	0.030	(0.08)
Stock return	-0.100***	(-3.07)	-0.040	(-1.07)
Age	-0.015***	(-6.61)	0.002	(0.81)
Tenure	-0.002	(-0.89)	-0.000	(-0.17)
CEO ownership	0.082	(1.58)	-0.014	(-0.23)
CEO duality	-0.043	(-1.36)	0.007	(0.19)
Industry and year FE	Yes		Yes	
N	36,800		14,853	
Pseudo R ²	0.228		0.002	

Panel B. Difference in firm characteristics				
	Firm-years with a major customer	Firm-years with no major customers	Difference	t-stat
Ln(Sales)	6.929	6.933	-0.004	-0.15
ROA	0.030	0.033	-0.003	-1.52
Tobin's Q	2.048	2.048	0.000	-0.00
Leverage	0.221	0.220	0.001	0.43
Volatility	0.124	0.123	0.001	0.60
Stock return	0.133	0.138	-0.005	-0.63
Age	55.329	55.243	0.086	0.74
Tenure	8.245	8.252	-0.007	-0.06
CEO ownership	0.097	0.099	-0.002	-0.58
CEO duality	0.479	0.480	-0.001	-0.11

Panel C. Propensity score matching estimate				
	Firm-years with a major customer	Firm-years with no major customers	Difference	t-stat
Vega	3.401	3.332	0.069	2.27**

Table 6

Customer concentration and CEO vega: Newly appointed CEOs.

This table examines the relation between customer concentration and CEO vega on the sample of newly appointed CEOs. The dependent variable is the natural logarithm of one plus *Vega*, where *Vega* is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. All other variables are defined in Appendix. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: $\ln(1+Vega)$	
	(1)	(2)
Major customer sales	1.429*** (4.71)	
Customer HHI		2.292** (2.50)
All controls	Yes	Yes
Industry-Year FE	Yes	Yes
N	2342	2342
Adjusted R ²	0.271	0.262

In Table 6, we examine how the vega of the supplier's newly appointed CEO is affected by its customer concentration. A newly appointed CEO's vega is measured over the first full fiscal year after the CEO assumes office, because the first year's compensation package could reflect less than a full year's pay for CEOs with tenure less than one year.¹⁵ The same set of controls as in the baseline models are included, except *Tenure*, which is omitted because new CEOs by definition have zero tenure. The variables of interest are the customer concentration measures. Using both measures, the coefficient estimates on the concentration variable are positive and significant at the 5 or 1% level. These observations suggest firms with more concentrated customer bases provide their newly appointed CEOs with greater risk-taking incentives, which once again supports our hypothesis.

4.3. Instrumental variable estimates

Our baseline estimates of the concentration-vega relation are likely to be tainted by several endogeneity concerns. First, customers might assess suppliers' managerial compensation packages prior to entering contracts. To the

¹⁵ If the tenure is less than one year, we use the vega for the second year after the CEO assumes office. For a similar approach, please refer to Berry et al. (2006). As a robustness check, we find that the results continue to hold if we define newly appointed CEOs' vega based on their first-year compensation.

extent that pay convexity is perceived to intensify the conflicts of interest between shareholders and other key stakeholders (Kuang and Qin, 2013; Akins et al., 2019), major customers may avoid suppliers with high CEO vega, which makes developing important trade relationships difficult for such suppliers. This potential selection driven by customers would spuriously reduce the estimated relation between customer concentration and CEO vega.

In terms of omitted variables, some unobserved firm characteristics could be affecting both the structure of the customer base and managerial risk-taking incentives. For example, firms with inclusive stakeholder strategies are likely to be more attractive to large customers, while they might be more cautious about providing convex payoffs (Leung et al., 2019). Alternatively, firms that operate in a more competitive business environment could provide stronger managerial incentives (Karuna, 2007), and such firms also face greater challenges in maintaining major customer relationships. In both cases, a spurious negative relation could exist between customer concentration and CEO vega, which is likely to attenuate the positive coefficient estimate on customer concentration toward zero, that is, bias against finding a significantly positive customer concentration effect.

To further address these endogeneity concerns, we use an instrumental variable approach to extract a plausibly exogenous component of customer concentration and use it to explain supplier CEO vega. Regarding the sources of plausibly exogenous variation, we use two instrumental variables that capture the concentration of the firm's customer base, but are uncorrelated with supplier CEO vega, except through variables we control for. For the purpose of this analysis, we focus on supplier firms that disclose at least one major corporate customer, because the instruments used offer meaningful variation with which to capture customer concentration only when major corporate customers exist.¹⁶

Our first instrument, *Customer Industry M&A*, initially proposed by Campello and Gao (2017), exploits the variation in the intensity of merger and acquisition activity in customers' industries (downstream M&A) that could drive changes in customer concentration. Existing research suggests mergers of customers with other firms in the same industry lead to stronger combined buyer positions and in turn a more concentrated customer base (Fee and Thomas, 2004; Bhattacharyya and Nain, 2011). In support of this view, Campello and Gao (2017) document that the sales of a supplier to acquirer customers increase rapidly following downstream mergers, with 30% growth in the same year of the merger and 80% growth in two years after the merger. Therefore, we expect the M&A intensity in customer industries to increase the concentration of the supplier's customer base, satisfying the relevance condition of the instrumental variable approach.

Meanwhile, as argued by Campello and Gao (2017), we can reasonably expect downstream M&A activities to only affect the supplier CEO's incentive pay through its

¹⁶ Nonetheless, our results are not much affected if we do not impose this sample restriction.

effects on customer concentration, because downstream M&A activities among customers are likely independent of the supplier's CEO compensation policy choices. However, one might be concerned that downstream M&A activities are potentially influenced by the supplier's industry dynamics that could ultimately affect both the supplier's customer base and its CEO's risk-taking incentives. This concern is mitigated by the inclusion of the supplier's industry-year fixed effects in our tests, which, as we discuss previously, allows us to eliminate any unobserved industry dynamics that may contaminate the validity of the instrument.

To construct *Customer Industry M&A*, we take the following steps. We first obtain the firm-level annual costs of M&A activities from Compustat (Item AQC). The industry-level five-year mean M&A intensity is then measured as the average M&A intensity of an industry (two-digit SIC) over the past five years, where industry M&A intensity is computed as the aggregate M&A costs divided by the aggregate sales across all firms within that industry in a given year. Finally, for a supplier i in year t , *Customer Industry M&A* is the weighted sum of the five-year M&A intensity across the industries to which the firm's major customers belong, weighted by the supplier's percentage sales to each customer. The variable is then defined as follows:

Customer industry M&A_{it}

$$= \sum_{j=1}^n \%Sales_{ijt} \times \text{Industry five year average} \left(\frac{M\&A \text{ costs}}{Sales} \right)_{jt}$$

Our second instrument, *Customer regulation index*, exploits plausibly exogenous variation in aggregate regulatory restrictions of customers' industries, which is also used by Gutiérrez and Philippon (2017) and Duan et al. (2019). The rationale behind this instrument is that rising regulatory stringency introduces barriers that limit entry by actual and potential rivals. Such barriers are advantageous to incumbent firms and may ultimately shift market power towards a small number of sizable firms, increasing the concentration of the customer base (Gutiérrez and Philippon, 2017). We therefore expect a positive relation between regulatory restrictions and customer concentration. Meanwhile, the differences in the level of regulation across customers' industries are unlikely to be directly linked to the supplier CEO's risk-taking incentives. Again, the inclusion of supplier industry-year fixed effects in our tests allows us to address the possibility that some government regulations affect both the supplier and customer industries concurrently.

To construct this instrument, we obtain the industry-specific regulation data from the RegData database compiled by McLaughlin and Oliver (2018).¹⁷ The RegData covers all US federal regulations issued by various regulatory agencies. A primary attraction of this dataset is that it quantifies two dimensions of regulatory quality, namely, *restrictiveness*, meaning the occurrence of words/phrases indicating binding constraints in the regulatory text, and

relevance, meaning the applicability of each regulation to a specific industry. Combining the two proxies, we compute *Industry regulation index* for each industry year as the weighted sum of the number of legally binding words (including "shall," "must," "may not," "prohibited," and "required") contained in regulatory text across all regulations, weighted by the relevance of each regulation to that industry.¹⁸ Finally, for each supplier year, *Customer regulation index* is the weighted sum of *Industry regulation index* across the industries to which the firm's major customers belong, weighted by the supplier's percentage sales to each customer:

Customer regulation index_{it}

$$= \sum_{j=1}^n \%Sales_{ijt} \times \text{Industry regulation index}_{jt}$$

Panel A of Table 7 presents the results of the first-stage regressions in which the dependent variables are the customer concentration variables. The explanatory variables include the above-mentioned instruments and the same set of controls as in the baseline models in Table 2. Regressions (1) and (2) use *Customer Industry M&A* as the instrument, regressions (3) and (4) use *Customer regulation index*, and regressions (5) to (6) use both instruments. Consistent with the rationale behind the instruments, the results show that a supplier's customer concentration is positively correlated to the customer industries' M&A intensity as well as to the customer industries' aggregate regulatory restrictions. In particular, the coefficient estimates on the instruments across all specifications are significant at the 1% level. The reported *F-statistics* are also large for all six regressions, suggesting none of our instruments are weak. Finally, the *p-values* for Hansen's (1982) *J* over-identification test are large, suggesting we cannot reject the null hypothesis that the instruments are valid.

Panel B of Table 7 reports the results for the second-stage regressions whose dependent variable is supplier CEO *vega*. The variable of interest is the variable with the predicted values of the customer concentration variables from the first-stage regressions. The coefficient estimates of the variable of interest in all six regressions are positive and significant, confirming the positive effect of customer concentration on supplier CEO *vega*. The results from the instrumental variable approach further support that our baseline findings are not due to endogeneity in the customer-base structure.

Comparing the results obtained from the OLS regressions (Table 2) with those obtained from the above two-stage least squares (2SLS) regressions, it is interesting to observe that the magnitudes of the 2SLS coefficient estimates are larger than those of the OLS estimates (although the coefficient estimates from both approaches are positive and statistically significant). This observation

¹⁷ The dataset spans 1970–2017 and is available at: <https://quantgov.org/regdata-us/>.

¹⁸ The industry regulation index is based on the four-digit North American Industry Classification System (NAICS) classification, the only industry classification available in the RegData database. See Al-Ubaydli and McLaughlin (2017) for a more detailed description of the industry regulation index. Hassan et al. (2019) use the same index to capture industry-level regulatory stringency.

Table 7

Instrumental variables approach.

This table presents estimates using the instrumental variables method based on two-stage least squares (2SLS) panel regressions.

Panel A presents the first-stage regression results in which dependent variables are different measures of customer concentration. The instrumental variables are as follows. *Customer industry M&A* is a measure of the intensity of merger and acquisition (M&A) activities in customers' industries. *Customer regulation index* is a measure of aggregate regulatory restrictions of customers' industries. Panel B reports the second-stage regression results. The dependent variable is the natural logarithm of one plus *Vega*, where *Vega* is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls. The Hausman test examines whether the OLS and 2SLS coefficients on the customer concentration variables are statistically different. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A. First-stage regressions						
	Dependent variable					
	Major cust. Sales		Customer HHI		Major cust. Sales	
	(1)	(2)	(3)	(4)	(5)	(6)
Customer industry M&A	12.902*** (7.28)	10.245*** (8.31)			9.780*** (4.57)	6.877*** (5.72)
Customer regulation index			0.009*** (4.87)	0.011*** (7.20)	0.006** (2.31)	0.007*** (5.37)
All controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	4157	4157	3653	3653	2917	2917
F-statistic	53.06	68.98	23.70	51.89	23.41	37.28
Hansen's J test p-value					0.753	0.160

Panel B. Second-stage regressions						
	Dependent variable: Ln(1 + Vega)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Major customer sales	2.277*** (2.87)		2.898** (2.51)		2.753*** (3.50)
Customer HHI		2.868*** (2.84)		2.582** (2.50)		2.784*** (3.21)
All controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	4157	4157	3653	3653	2917	2917
Adjusted R ²	0.342	0.343	0.351	0.336	0.372	0.352
Hausman test p-value	0.013	0.007	0.018	0.082	0.081	0.066

is consistent with our earlier discussion that the spurious negative concentration-vega relation caused by customer selection and/or omitted variables is the main driving force that biases the coefficient estimates of interest downward in OLS regressions. Once we use the instruments to clean up the spurious negative correlation, the endogeneity of the customer-base structure is mitigated and the coefficient estimates increase, that is, become more positive. Substantiating the attenuation bias in the OLS estimates, we perform the Hausman test and it rejects the null hypothesis that the 2SLS and OLS coefficient estimates on the customer concentration variables are the same.

An important concern about the instrumental variable approach is that the instruments may lose value with repeated uses because they can be rivalrous: each successful use of an instrument potentially compromises the validity of all other uses of that instrument (Heath et al., 2020). In our case, the previous uses of the two in-

struments, *Customer Industry M&A* and *Customer regulation index*, by Campello and Gao (2017), Gutierrez and Phillipon (2017) and Duan et al. (2019), show that loan features, investment intensity, and ownership structure can be affected by customer concentration and hence are correlated with the instruments. Because valid instruments should vary only in response to exogenous factors, accounting for potential endogenous factors shown to be correlated with our instruments seems important. To ensure the validity of the analysis given previous studies and help reconcile the exclusion condition with existing evidence, we include more controls for loan features, investment intensity, and ownership structure in our 2SLS regressions: *Borrowing cost* is the ratio of interest expenses to total debt. *Debt maturity* is the fraction of long-term debt maturing in one year. *Investment intensity* is defined as capital expenditures scaled by total assets. *Institutional ownership* is constructed as the total number of shares held by institutional investors divided by the total number of shares

outstanding, based on the data obtained from SEC 13f filings. We report the results in Table IA3 of the Internet Appendix. We find the results are qualitatively similar with these additional controls. In addition, none of the coefficient estimates on the additional controls for loan features, investment intensity, and ownership structure are statistically significant, which further ensures the satisfaction of the exclusion condition of our instrumental variables.

4.4. Addressing reverse causality

Whereas our identification attempts so far all point to a causal effect of customer concentration on CEO's risk-taking incentives, a plausible alternative interpretation of our main results is that supplier CEOs' risk-taking incentives affect the characteristics of customer firms in the product market, resulting in the positive relation between customer concentration and CEO vega. For example, the structure of managerial compensation could be chosen to induce certain investment outcomes (Bizjak et al., 1993), and some of these investments might create forces for consolidation or fragmentation in customer firms' product markets. This alternative interpretation suggests the direction of causality could be the other way around. To gain insights about whether our findings are driven by reverse causality, we undertake two tests.

First, we restrict our sample to a subset of firm-year observations for which the reverse causation problem is less severe. Large firms are more likely to have the market power and motive to actively influence customer firms' product markets and hence are more subject to the reverse causality concern. We re-examine the effects of customer concentration after excluding, respectively, the largest 10% and the largest 25% suppliers in terms of sales and report the results in Table 8. We find that the customer concentration variables continue to be economically and statistically significant in all specifications. To the extent that the concentration of the customer base can be viewed as predetermined for small firms, these findings provide further assurance that the positive concentration-vega relation does not appear to arise from reverse causation.

Second, we follow Cen et al. (2017) and investigate the effect of relationship establishment events on supplier CEO vega. A trend of increasing CEO vega before the event would suggest the presence of reverse causality, and vice versa. Relationship establishment occurs when a firm reports a major customer in year t for the first time in which the relationship lasts for at least three years (i.e., years t , $t + 1$, and $t + 2$). In untabulated analyses, two key takeaways arise. First, we find that, in a four-year period around the relationship establishment with major customers, the dependent supplier's CEO vega increases by 5.6% from year t to year $t + 2$, consistent with the prediction. Second, the increase in CEO vega becomes large and significant only after the relationship establishment but is absent before the relationship establishment, suggesting the positive concentration-vega relation is unlikely driven by reverse causation.¹⁹

¹⁹ One caveat of this test, however, as mentioned in Cen et al. (2017), is that the "new" relationship establishment defined here is not necessarily

5. Cross-sectional heterogeneity

In this section, we conduct cross-sectional tests that make use of variation in several characteristics of supplier CEOs, supplier firms, and customer-supplier relationships to shed light on the mechanisms underlying our main findings. Specifically, we examine whether the effect of customer concentration on CEO vega varies with supplier CEOs' attitudes toward (customer concentration) risk, supplier firms' investment opportunities, customer firms' cost of switching to different suppliers, and relationship-specific investments (RSI). Overall, these heterogeneity tests provide further support for our causal inferences of the positive effect of customer concentration on CEO vega, because coming up with an omitted variable that biases our results equally in all cross-sectional dimensions discussed in this section is difficult.

5.1. Supplier CEOs' risk attitudes

5.1.1. CEO age

We substantiate the argument that firms with higher customer concentration provide greater CEO pay convexity to reduce risk-related conflicts between shareholders and managers. If firms use convex pay structure to offset managerial risk aversion and encourage value-enhancing risk taking, the positive relation between customer concentration and supplier CEO vega should be more prominent when the CEO is less open to risk taking (i.e., risk-taking incentives in compensation are more needed).

We proxy for a CEO's openness to risk taking with her age: a younger CEO is more willing to take risk. Prendergast and Stole (1996) develop a theoretical model that predicts younger CEOs with long career horizons to reap benefits have stronger incentives to signal superior ability by taking greater risk in firm decisions. Consistent with this view, Serfling (2014) and Li et al. (2017) provide empirical evidence that younger (older) CEOs are associated with higher (lower) stock return volatility and more (less) risky investment and financial policies.²⁰ Hence, we expect the positive customer-concentration-vega relation to be weaker for firms led by young CEOs, where additional risk-taking incentives in the form of pay convexity are less needed.

To test this prediction, in Panel A of Table 9, we split the sample into quartiles based upon the age of the CEO

new. The supplier could start to disclose a particular customer, or a customer could become a major customer as the customer just crosses the 10% disclosure requirement threshold.

²⁰ We acknowledge another strand of the literature that considers the impact of CEO age on firm risk preferences. Models incorporating career concerns, such as those of Hirshleifer and Thakor (1992) and Holmstrom (1999), predict that younger CEOs are more risk-averse because they do not yet have reputations as high quality managers and thus can be punished more severely for poor performance through reduced human capital in the managerial labor market. Further, given that younger CEOs are further away from retirement, they are expected to be more affected by the loss of labor market value than older CEOs. Together, these arguments lead to the prediction that the positive concentration-vega relation should be more pronounced for firms led by young CEOs, which we do not find in our data.

Table 8

Customer concentration and CEO vega: Excluding largest suppliers.

This table estimates the baseline regressions after excluding, respectively, the largest 10 and 25% suppliers in terms of sales. The dependent variable is the natural logarithm of one plus Vega, where Vega is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: Ln(1+Vega)			
	Excluding largest 10%		Excluding largest 25%	
	(1)	(2)	(3)	(4)
Major customer sales	0.397*** (3.38)		0.377*** (3.26)	
Customer HHI		0.887*** (3.86)		0.917*** (4.12)
All controls	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
N	28,707	28,707	34,526	34,526
Adjusted R ²	0.256	0.256	0.285	0.286

descendingly. The Old CEO columns indicate the top quartile sample, and the Young CEO columns indicate the bottom quartile sample. We then repeat the analyzes in Table 2 in subsamples of old and young CEOs separately. For brevity, we report only the coefficient estimates on the customer concentration variables, although we include the same set of control variables and industry-year fixed effects as in our baseline models. For both measures of customer concentration, we find that the coefficient of interest is statistically significant only when the firm is run by an old CEO and that the estimated effect is more than four to six times larger for old CEO firms than for young CEO firms.

5.1.2. CEO general managerial ability

In a similar vein, in Panel B of Table 9, we test the idea that the positive relation between customer concentration and supplier CEO vega is more prominent when the CEO is more susceptible to firm risk associated with the customer-base structure, entailing stronger risk-taking incentives in compensation. Prior literature has argued that CEOs with general managerial abilities (generalist CEOs) can move across firms and industries more easily than specialist CEOs with focused business experience (Custódio et al., 2013; Mishra, 2014). As a result, the broader set of outside options available to generalist CEOs makes them less sensitive to customer concentration risk. Thus, we expect the positive customer-concentration-vega relation to be less (more) prominent for firms with generalist (specialist) CEOs.

We use the variable General Ability Index, or *GAI*, developed by Custódio et al. (2013), to measure CEO general managerial ability. The index incorporates five aspects of a

CEO's lifetime career experience, including the past number of (i) positions, (ii) firms, and (iii) industries in which the CEO worked; (iv) whether the CEO has held a CEO position at a different company; and (v) whether the CEO has worked for a conglomerate firm. Specifically, the value of the index for CEO *i* in year *t* is calculated based on the following model:

$$GAI_{i,t} = 0.268 \cdot X1_{i,t} + 0.312 \cdot X2_{i,t} + 0.309 \cdot X3_{i,t} + 0.218 \cdot X4_{i,t} + 0.312 \cdot X5_{i,t}$$

where *X1* is the number of positions the CEO held during his or her career; *X2* is the number of firms where a CEO worked; *X3* is the number of industries at the four-digit SIC level in which a CEO worked; *X4* is a dummy variable that equals 1 if the CEO held a CEO position at another firm, and 0 otherwise; and *X5* is a dummy variable that equals 1 if the CEO worked for a multi-division firm, and 0 otherwise. The index is the first factor of a principal component analysis of the five proxies. A higher value of the index indicates greater general managerial ability. As in Custódio et al. (2013), the index is standardized to have a zero mean and a unit standard deviation. A higher value of the index indicates greater general managerial ability. Due to the availability of the general ability index data, the sample period for this analysis spans from 1993 to 2007.²¹

We then split the sample into firms with generalist CEOs and those with specialist CEOs based on the sample median of *GAI* and separately estimate baseline specifications for these two subsamples. The generalist (specialist)

²¹ We thank the authors of Custódio et al. (2013) for kindly sharing their general ability index data.

Table 9

Effect of supplier CEOs' risk attitudes.

This table examines whether the positive relation between customer concentration and supplier CEO vega varies with supplier CEOs' attitudes toward firm (customer concentration) risk. We use two proxies: *Age* is the age of the CEO; and *General Ability Index (GAI)* is an index developed by Custódio et al. (2013) to measure a CEO's general managerial skills. In Panel A, we split the sample into quartiles based upon the age of the CEO. The Old CEO columns indicate the top quartile sample, and the Young CEO columns indicate the bottom quartile sample. In Panel B, we then split the sample into firms with generalist CEOs and those with specialist CEOs based on the sample median of *GAI* and separately estimate baseline specifications for these two subsamples. The generalist (specialist) CEO sample consists of firm-year observations with above (below) median *GAI*. The dependent variable is the natural logarithm of one plus *Vega*, where *Vega* is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls are not reported for brevity. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A. CEO age				
	Dependent variable: Ln(1+Vega)			
	Old CEO		Young CEO	
	(1)	(2)	(3)	(4)
Major customer sales	0.475** (1.97)		0.107 (0.65)	
Customer HHI		1.535*** (3.50)		0.227 (0.74)
All controls	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
N	9502	9502	10,128	10,128
Adjusted R ²	0.300	0.301	0.309	0.309
Panel B. CEO general managerial ability				
	Dependent variable: Ln(1+Vega)			
	Specialist CEO		Generalist CEO	
	(1)	(2)	(3)	(4)
Major customer sales	0.689*** (3.42)		0.058 (0.31)	
Customer HHI		1.664*** (3.15)		0.304 (0.62)
All controls	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
N	9493	9493	9187	9187
Adjusted R ²	0.339	0.339	0.401	0.401

CEO sample consists of firm-year observations with above (below) median *GAI*. The results in Table 9 Panel B suggest that, for both measures, the effect of customer concentration on CEO vega is positive and significant at the 1% level for the specialist CEO sample, whereas the effect becomes statistically insignificant for the generalist CEO sample. Overall, the results in Table 9 are consistent with the notion that the board factors in the likely impact of customer concentration risk on managerial risk taking when designing CEO compensation packages.

5.2. Supplier firms' investment opportunities

We also consider whether the effect of customer concentration varies with the supplier firm's investment opportunities, as measured by *Tobin's Q*. If convex compen-

sation schemes are used to prevent CEOs from forgoing valuing-creating risky projects in response to increased customer concentration risk, the positive effect of customer concentration on CEO vega should be more pronounced for firms with greater investment opportunities, where the potential loss due to excessive CEO conservatism is high.

In Table 10, we partition the sample into high and low investment opportunity firms based on the sample median of *Tobin's q* and repeat our baseline tests for these two subsamples. Consistent with the prediction, we find the coefficient estimates of customer concentration variables are positive and significant in the subsample of firms with high investment opportunities, and insignificant in the subsample of firms with low investment opportunities. In addition, the magnitudes of the coefficient estimates of

Table 10

Effect of supplier investment opportunities.

This table examines whether the positive relation between customer concentration and supplier CEO vega varies with suppliers' investment opportunities. The measure of investment opportunities is *Tobin's q*, computed as the sum of total assets plus market value of equity minus book value of equity divided by total assets. The sample partition is based on the sample median of *Tobin's q*. The dependent variable is the natural logarithm of one plus *Vega*, where *Vega* is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: $\ln(1 + Vega)$			
	High growth		Low growth	
	(1)	(2)	(3)	(4)
Major customer sales	0.379*** (2.72)		0.120 (0.81)	
Customer HHI		0.847*** (3.32)		0.389 (1.17)
All controls	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
N	19,183	19,183	19,183	19,183
Adjusted R ²	0.293	0.293	0.347	0.347

the customer concentration index for firms with high investment opportunities is almost three times as large as those in the firms with low investment opportunities. The results suggest the positive effect of customer concentration on CEO vega is more pronounced in firms with high investment opportunities.

5.3. Customers' costs of switching suppliers

One of the primary concerns with having a concentrated customer base is that a major customer may switch to other suppliers, resulting in significant losses to the dependent supplier. Relying on a major customer for a large fraction of sales is especially risky when the customer can switch suppliers at a relatively low cost. Therefore, if pay convexity helps offset the CEO's aversion to the risk of losing major customers, we would expect the positive effect of customer concentration on supplier CEO vega to be more pronounced when major customers face lower switching costs.

To test this conjecture, we follow [Dhaliwal et al. \(2016\)](#) and proxy for customers' switching costs using *Supplier market share*, defined as the fraction of the supplier's total three-digit SIC industry sales captured by the supplier.²² The lower the supplier's market share, the more alternative suppliers that customers can purchase from, and

the lower the switching costs. We repeat the baseline analysis using subsamples with high and low values of *Supplier market share* based on the sample median.

[Table 11](#) presents the results. We find that when the supplier firm's sales account for a small fraction of its total industry sales, the coefficient estimates on the concentration variables are positive and significant at the 1% level. By contrast, the coefficient estimates become much smaller in magnitude and statistically insignificant when the supplier firm's sales account for a large fraction of its total industry sales. These findings are consistent with our conjecture and suggest the positive effect of customer concentration on CEO vega is more pronounced when customers face lower barriers to switching suppliers.

5.4. Relationship-specific investments

We next examine whether relationship-specific investments made by suppliers influence the effect of customer concentration on CEO vega. Major customer-supplier relationships are typically characterized by suppliers producing unique or customized products that offer little value outside the relationships ([Titman and Wessels, 1988](#)). Suppliers that have made relationship-specific investments face a greater risk of being unable to redeploy assets after the loss of a major customer. Moreover, as suppliers invest more in relationship-specific assets, they are more likely to be "held up" and subject to ex-post opportunistic behav-

²² The results are similar if we use the two-digit SIC industry classification.

Table 11

Effect of customer switching costs.

This table examines whether the positive relation between customer concentration and supplier CEO vega varies with customers' costs of switching to other suppliers. Customer switching costs are measured using *Supplier market share*, defined as the supplier firm's sales scaled by total three-digit SIC industry sales. The sample partition is based on the sample median of *Supplier market share*. The dependent variable is the natural logarithm of one plus *Vega*, where *Vega* is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity-robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: $\ln(1 + Vega)$			
	Low supplier market share		High supplier market share	
	(1)	(2)	(3)	(4)
Major customer sales	0.290** (2.13)		-0.031 (-0.15)	
Customer HHI		0.755*** (3.22)		0.021 (0.05)
All controls	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
N	19,183	19,183	19,183	19,183
Adjusted R ²	0.348	0.349	0.307	0.307

ior by customers.²³ Thus, to the extent that relationship-specific investments intensify customer concentration risk, we postulate that the positive effect of customer concentration on supplier CEO vega should be more prominent when suppliers engage in more relationship-specific investments.

Following Kale and Shahrur (2007) and Raman and Shahrur (2008), our measure of relationship-specific investments is the intensity of the supplier's R&D activities, computed as R&D expenditures scaled by total assets. This measure exploits the fact that research intensive suppliers tend to use more specialized inputs and produce unique products that require more relationship-specific investments for their customers (Levy, 1985; Allen and Phillips, 2000).

In Table 12, we partition our sample firms into subsamples with high and low R&D intensity based on its sample median, and repeat the baseline tests for these two subsamples.²⁴ The results show that the effect of customer

Table 12

Effect of relationship-specific investments.

This table examines whether the positive relation between customer concentration and supplier CEO vega varies with relationship-specific investments made by suppliers. We measure relationship-specific investments with the supplier's *R&D intensity*, defined as R&D expenditures scaled by total assets. The sample partition is based on the sample median of *R&D intensity*. The dependent variable is the natural logarithm of one plus *Vega*, where *Vega* is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. The main variables of interest are the two customer concentration measures. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: $\ln(1 + Vega)$			
	High R&D intensity		Low R&D intensity	
	(1)	(2)	(3)	(4)
Major customer sales	0.360*** (2.79)		0.168 (0.80)	
Customer HHI		1.040*** (4.50)		0.414 (0.93)
All controls	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes
N	15,912	15,912	22,454	22,454
Adjusted R ²	0.323	0.324	0.312	0.312

²³ Another possibility is that when suppliers make relationship-specific investments, major customers would also be more willing to invest in the relationships. In turn, these investments made by customers can increase the costs of switching suppliers and reduce the risk of losing major customers. This reasoning, however, leads to the prediction that the positive relation between customer concentration and CEO vega should be stronger when the relationships involve less specialized investments, which we do not observe in our data.

²⁴ The sample median is zero because firm-years with missing R&D information are assigned a zero value. This approach allows us to be consistent with the literature on R&D and innovation as well as to preserve as many observations as possible. In a robustness check, we confirm the findings of the split-sample analysis (based on R&D intensity) persist when we exclude firm-years with missing R&D information.

concentration on CEO vega is positive and significant at the 1% level for high R&D intensity firms, whereas the effect becomes much smaller in magnitude and statistically insignificant for low R&D intensity firms. These results are consistent with the view that supplier CEOs receive less risk-taking incentives in their compensation packages as customer concentration increases when the relationships involve fewer relationship-specialized investments.²⁵

5.5. Government customers and supplier CEO risk-taking incentives

Our analysis so far has focused on the effects of relying on major corporate customers. However, many supplier firms also report the government as their major customers. Unlike corporate customers, government customers are much less likely to default or declare bankruptcy. They are also more concerned about public interest and may therefore help financially distressed suppliers stay afloat to save the suppliers' employees from losing jobs. Further, government customers generally purchase for consumption and their purchases are longer-term and not profit-driven (Banerjee et al., 2008; Goldman et al., 2013), which reduces the likelihood that the government will switch to other suppliers. All of these suggest suppliers with a concentrated base of government customers gain operational efficiencies from, but do not bear much of the risk of, relying on major corporate customers. As such, if convex incentive structures alleviate the CEO's aversion to the risk associated with major corporate customers, we expect the positive concentration-vega relation to disappear, or even reverse for safer government customers.

To test this conjecture, we use the Compustat segment files to identify suppliers that report a government customer as accounting for at least 10% of total annual revenues.²⁶ We then create two measures to capture government customer concentration that mirror our corporate customer concentration measures. *Government customer sales* is the fraction of a supplier's total sales to all government customers that account for at least 10% of total sales, and *Government customer HHI* is the sales-based Herfindahl-Hirschman Index of government customers. In our sample, 5.2% of the suppliers report at least one major government customer. For these suppliers, sales to all government customers, on average, account for 43.2% of annual revenues.

The results in Table 13 show a negative relation between both measures of government customer concentration and CEO vega. The coefficient estimate on *Government customer sales*, for example, implies that firms with at least one major government customer offer risk-taking incentives in managerial compensation that are 19.1% (=

²⁵ Note that our preferred interpretation of the split-sample analysis results could be muddied by the likelihood that CEO vega stimulates the firm's investments in R&D. Caution should be exercised in interpreting the results.

²⁶ Customers reported as "Domestic Government" or "U.S. Navy," and so on, are classified as "government." In very few cases, companies report foreign governments as their major customers. Following Banerjee et al. (2008), we classify both domestic and foreign government customers as government customers.

Table 13

Government customer concentration and CEO vega.

This table examines the impact of government customer concentration on risk-taking incentives in the CEO's compensation package. The dependent variable is the natural logarithm of one plus *Vega*, where *Vega* is the change (in thousands of dollars) in the value of the CEO's wealth due to a 0.01 increase in the annualized standard deviation of the firm's stock return. *Customer HHI* is the corporate customer sales-based Herfindahl-Hirschman Index. *Government customer HHI* is the government customer sales-based Herfindahl-Hirschman Index. *Major customer sales* is the fraction of a firm's total sales to all corporate customers that account for at least 10% of total sales. *Major government sales* is the fraction of a firm's total sales to all government customers that account for at least 10% of total sales. The same set of control variables and industry-year fixed effects as in our baseline models are included. For brevity, we do not report the estimated parameters of the other controls. Industry-year fixed effects are constructed based on the two-digit Standard Industrial Classification (SIC) codes. Statistical significance is based on the heteroskedasticity robust firm-clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: Ln(1 + Vega)	
	(1)	(2)
Major customer sales	0.343*** (2.98)	
Major government sales	-0.442** (-2.23)	
Customer HHI		0.927*** (4.18)
Government customer HHI		-0.996*** (-3.09)
All controls	Yes	Yes
Industry-Year FE	Yes	Yes
N	38,366	38,366
Adjusted R ²	0.318	0.319

-0.442 × 0.432) lower. These findings are consistent with the view that the government with high creditworthiness and concerns for public interest represents a more stable source of revenues than other types of customers, and hence they could help lower the risk associated with the customer-base structure.

6. Conclusion

In this paper, we have examined how a firm's customer-base concentration affects its CEO's risk-taking incentives in her compensation package, as measured by vega. The results suggest a positive relation between customer concentration and supplier CEO vega. When the customer base is more concentrated, the supplier firm's CEO receives more risk-taking incentives. This finding is robust to different approaches that account for potential endogeneity. Our findings shed light on how major customers, as an important source of revenues, shape the supplier firm's managerial incentive contracts.

Exploring the cross-sectional heterogeneity of our baseline results, we show the positive effect of customer concentration on CEO vega is stronger when the CEO is more reluctant to take firm risk, when suppliers have high investment opportunities, when switching to other suppliers is less costly for customers, and when suppliers make more relationship-specific investments. Finally, we provide evidence that suppliers with a concentrated base

of safer government customers offer less risk-taking incentives. Overall, our findings suggest that boards evaluate a firm's customer-base structure and provide additional pay convexity to offset the CEO's aversion to customer concentration risk, thereby preventing excessive managerial conservatism at the expense of value maximization. These findings are especially valuable when customer concentration risk is higher due to severe supply chain disruptions during, for example, the COVID-19 pandemic.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.jfineco.2021.07.015](https://doi.org/10.1016/j.jfineco.2021.07.015).

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