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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

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. Hertzel 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

(Itzkowitz, 2013), innovation (

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

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

[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***	0.513***
	(27.78)	(27.98)
ROA	−0.385**	−0.367**
	(−2.46)	(−2.35)
Tobin's Q	0.177***	0.176***
	(8.86)	(8.79)
Leverage	−0.001	−0.006
	(−0.01)	(−0.04)
Volatility	−2.594***	−2.605***
	(−6.53)	(−6.54)
Stock return	0.012	0.012
	(0.55)	(0.54)
Age	−0.014***	−0.014***
	(−4.34)	(−4.39)
Tenure	0.010***	0.010***
	(2.72)	(2.73)
CEO ownership	−0.693***	−0.692***
	(−8.11)	(−8.10)
CEO duality	0.298***	0.298***
	(7.14)	(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 × 0.340) and 8.9% (=0.923 × 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 + 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 + 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+Augmented vega_S)		*Ln(1+Augmented vega_SC)*	
	(1)	(2)	(3)	(4)
Major customer sales	0.385***		0.374***	
	(2.85)		(2.71)	
Customer HHI		1.018***		1.015***
		(3.74)		(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. In 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 constru761 266.02129 639.4859 Tm (376.06237 702.54 Tmef)-10(

and CEO risk-taking incentives. baseline findings remain relatively stable across

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***	0.006
	(−21.66)	(0.42)
ROA	−0.049	−0.238
	(−0.33)	(−1.40)
Tobin's Q	0.042***	0.014
	(3.32)	(0.97)
Leverage	−0.102	−0.017
	(−1.18)	(−0.17)
Volatility	3.938***	0.030
	(12.75)	(0.08)
Stock return	−0.100***	−0.040
	(−3.07)	(−1.07)
Age	−0.015***	0.002
	(−6.61)	(0.81)
Tenure	−0.002	−0.000
	(−0.89)	(−0.17)
CEO ownership	0.082	−0.014
	(1.58)	(−0.23)
CEO duality	−0.043	0.007
	(−1.36)	(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

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:

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

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:

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

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 re

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

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*	*Customer HHI*	*Major cust. Sales*	*Customer HHI*
	(1)	(2)	(3)	(4)	(5)	(6)
Customer industry M&A	12.902***	10.245***			9.780***	6.877***
	(7.28)	(8.31)			(4.57)	(5.72)
Customer regulation index			0.009***	0.011***	0.006**	0.007***
			(4.87)	(7.20)	(2.31)	(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***		2.898**		2.753***	
	(2.87)		(2.51)		(3.50)	
Customer HHI		2.868***		2.582**		2.784***
		(2.84)		(2.50)		(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 instruments, *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

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***		0.377***	
	(3.38)		(3.26)	
Customer HHI		0.887***		0.917***
		(3.86)		(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

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

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

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

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.

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