Corporate Environmental Risk and the Customer-Supplier Relationship[*]

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Abstract

We provide empirical evidence on the adverse effects of supplier firms' environmental risk exposure on their relationship with principal customers. We document that supplier firms with high environmental risk are less likely to have principal customers. From principal customers' perspective, a higher level of environmental risk lowers a supplier firm's probability of being chosen relative to its industry peers by its potential customer. Conditional on an ongoing relationship with principal customers, supplier firms with high environmental risk have lower sales to principal customers and shorter relationship durations. These results are more pronounced when customers' environmental risk is low. Collectively, our findings suggest an important channel through which firms can benefit from being environmentally responsible.

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I. Introduction

Environmental risk can be generally defined as the actual or potential threat of adverse effects on living organisms and the environment by effluents, emissions, wastes, resource depletion, etc., arising out of an organization's activities.[1] Following on the heels of urbanization and industrialization, companies' exposure to environmental risk have received increasing public and political attention. Recent studies have documented that corporate environmental performance and risk exposure affect firm valuation and various corporate policies.[2] However, there is scant empirical evidence regarding whether and how corporate environmental risk exposure influences product market relationships, especially supplier firms' relationship with their principal customers. Our study takes an initial step in addressing this gap.

The customer-supplier relationship is a key aspect of a firm's operations, and extends beyond the pure provision of the product or the service (Chen et al., 2014). For supplier firms, principal customers are among the most important stakeholders that enhance long term operating performance and shareholder value (e.g., Fee and Thomas, 2004; Johnson, Kang, and Yi, 2010; Patatoukas, 2012). As such, supplier firms strive to initiate and maintain long term relationship with their major customers. From customer firms' perspective, choosing suppliers is an important operating decision made on a regular basis because the quality of the supply chain contributes greatly to their success in the product market. In this paper, we focus on supplier

[1] The definition is from Enterprise Risk Management (ERM) Strategies: http://www.erm-strategies.com/enterprise-risk-management/environmental-risk/

[2] See among others, Hughes (2000), Clarkson, Li, and Richardson (2004), Sharfman and Fernando (2008), and Chava (2014). We review the literature in greater detail in Section II.

firms' environmental risk exposure and expect it to have an *adverse* effect on the existence and strength of the relationship with principal customers for three reasons.[3]

First, incomplete contract theory suggests that supplier-customer relationships are governed by both explicit and implicit contracts.[4] Compared with explicit contracts, implicit contracts are more informal, more relational, and more likely to be breached with no legal remedy. As such, the value of implicit contracts relies heavily on both parties' trustworthiness, financial stability, and incentive and ability to honor commitments to the relationship. Prior implicit contracting studies (e.g., Maksimovic and Titman, 1991; Hertzel, Officer, and Rodgers, 2008; Cen et al., 2014) have shown that customers are reluctant to conduct business with suppliers with high business risk because high risk exposure reduces suppliers' willingness to honor implicit contracts, make relationship-specific investment, and produce high-quality products. Corporate environmental risk is a key source of business risk. It contributes significantly to firms' future operational risk and poor financial performance (Clarkson et al., 2011; Flammer, 2013). Facing increasingly more stringent environmental regulations, supplier firms with high environmental risk exposure are inevitably subject to more uncertainties arising from market demand due to damaged reputation, operating costs associated with waste management and future compliance, future litigation and enforcement activities, and the cost of external financing (e.g., Chava, 2014),

[3] Anecdotal evidence suggests that firms have become increasingly aware of their suppliers' environmental practice and started to explicitly outline environmental requirements for suppliers. For example, Procter & Gamble (P&G) has issued an environmental sustainability scorecard to track and rate the environmental performances of its key suppliers since 2010. This scorecard is further incorporated as a part of P&G's annual supplier performance measurement process and thus impacts suppliers' opportunities for future business with P&G. The Economist (May 19th, 2012) reports that environmental responsibility is now at the heart of product design and the supply chain management of corporations.

[4] See Williamson (1979), Grossman and Hart (1986), Cornell and Shapiro (1987), and Hill and Jones (1992) among others. For supplier-customer relationships, explicit contracts, such as supplier contracts and product warranties, are enforceable by law. Implicit contracts, such as continued services to customers and product quality, concern obligations or deliverables that cannot be specified precisely or objectively in advance.

all of which would weaken suppliers' ability to fulfill contracts or commitments in relationships.[5] Moreover, a customer would also find it hard to trust and make long-term relationship-specific investment if its supplier acts as if there is no tomorrow in terms of environmental performance.[6]

Second, in many developed countries including the U.S., the environmental regulations and standards are often determined based on the Best Available Technology (BAT).[7] As a result, supplier firms with superior environmental performance (low environmental risk exposure) effectively set environmental standards and drive the evolution of future environmental regulations for the industry (Clarkson, Li, and Richardson, 2004). They are motivated to innovate or increase environmental capital expenditures to convince the regulators that more stringent environmental standards are economically achievable. By doing so, they can enjoy early-mover advantages and enhance competitiveness either through discouraging rival firms from entering into competition or diminishing their competitiveness in that market (Salop, 1979). Dechant and Altman (1994) also suggest that good environmental performance has become an important source of competitive advantage of firms in keeping their leadership positions. Moreover, good environmental performance also allows supplier firms to tap into the markets

[5] As a recent example suggesting that high environmental risk exposure can lead to significantly negative earnings shocks, in August 2012, the US Environmental Protection Agency and the U.S. Department of Justice fined Sinclair Oil Corporation $3.8 million for violations of air pollution limits at refineries in Wyoming. The company must also pay roughly $10.5 million for additional pollution control equipment to reduce emissions of nitrogen oxides by 24 tons per year, sulphur dioxide by 385 tons per year, and particulate matter by 59 tons per year (Li, Simunic, and Ye, 2014). Moreover, non-compliance can force temporary shutdown of operations or even trigger bankruptcy. Eighty-five firms have filed for bankruptcy due to asbestos liabilities in 2002. Recent examples include Solutia Inc. and Tronox Inc. that filed for bankruptcy in 2003 and 2009, respectively, due to significant environmental risk exposure.

[6] On the flip side, a supplier's investment towards reducing environmental risk exposure can be viewed as long-term "sunk" production capital and signals the supplier's positive attitude towards honoring implicit contracts, similar to the role of long-term non-salvageable capital elements suggested by Klein and Leffler (1981). Benabou and Tirole (2010) argue that firms' superior social responsible behavior encourages stakeholder (for example, principal customers) engagement, thereby reducing overall contracting costs.

[7] BAT is defined in Section 5 of Environmental Protection Agency Acts, 1992 and 2003, as the "most effective and advance stage in the development of an activity and its methods of operation, which indicate the practical suitability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent or eliminate or, where that is not practicable, generally to reduce an emission and its impact on the environment as a whole".

where customers value low-pollution and energy-efficient products (Porter and van der Linde, 1995). Arora and Gangopadhyay (1995) and Hillman and Keim (2001) show that firms with superior environmental performance can attract and retain environmentally conscious consumers who are willing to pay a premium for the products for the sake of "green goodwill". In contrast, suppliers with poor environmental performance are forced to increase spending on environmental capital expenditures for compliance with more stringent environmental standards, thereby facing higher costs and losing customers to their greener industry rivals (Salop and Scheffman, 1987). In sum, the environmental regulatory setting puts suppliers with poor environmental performance at a significant disadvantage in their competitions with industry rivals for major customers.

Finally, there is an extensive marketing literature showing a positive association between corporate social responsibility (CSR hereafter) and customer loyalty.[8] This literature generally maintains that corporate social and environmental responsibility is similar to advertising in terms of enhancing a firm's brand name awareness and product recognition. As a result, CSR activities can increase demand for products and services, increase customer loyalty, and lower consumers' price elasticity (e.g., Sen and Bhattacharya, 2001; Albuquerque, Durnev, and Koskinen, 2012). To the extent that supplier firms with low environmental risk exposure are viewed as more socially and environmentally responsible, their relationship with customers should be stronger and more durable. Taken together, the above three rationales based on contract theory, regulation-induced competitive advantage, and customer preferences all suggest that supplier

[8] For example, Bhattacharya and Sen (2004) suggest that CSR leads to customer-company identification. Berens et al. (2005) show CSR influences customers' attitude towards the product. Luo and Bhattacharya (2006, 2009) establish the link between CSR and customer satisfaction and point out that higher customer satisfaction creates firm value. Homburg, Stierl, and Bornemann (2013) show that business practice CSR fosters customers' trust and philanthropic CSR strengths customer-company identification, which in turn enhance customer loyalty.

firms' environmental risk exposures adversely influence the relationship with their principal customers.

We use the Business Information File of Compustat to manually identify principal customers (defined as those accounting for 10% or more of total sales) for supplier firms in manufacturing industries over the period 1988-2009. We successfully identify at least one principal customer for 41.6% of supplier firms in our sample. We rely on the Toxic Release Inventory (TRI hereafter) program data supplied by the US Environmental Protection Agency (EPA hereafter) to define environmental risk exposure based on the toxicities and quantities of chemicals directly released into the environment. Our main measure of environmental risk exposure is the firm-level toxicity-weighted releases scaled by total sales. We use percentile ranks of this measure in regression analysis to mitigate the effects of outliers and skewness in the data.

We document that supplier firms with high environmental risk are less likely to have principal customers, particularly principal customers that are publicly listed companies, suggesting that publicly traded customer firms are more concerned about the environmental performance of their suppliers. We then take principal customers' perspective and study whether their decisions in selecting suppliers are affected by suppliers' environmental risk. Our results reveal that a higher level of environmental risk lowers a supplier firm's probability of being chosen relative to its industry peers by its potential customer. Furthermore, conditional on having a principal customer, a supplier's sales to the principal customer decreases with supplier's environmental risk. Higher environmental risk of supplier firms is associated with less durable business relationships with principal customers. These results are both economically and statistically significant. We then perform a variety of checks to ensure that our main results are robust to alternative model specifications and variable definitions.

To alleviate the endogeneity concerns, we adopt an instrumental variable approach using three instruments for environmental risk exposure: the natural log of weighted-average geographical distance between the EPA regional office and the firm's facilities, the weighted average population density within 100 kilometres of the census tract in which a firm's facility operates, the natural log of the number of facilities who report non-zero toxicity-weighted waste to TRI database. We justify the uses of these instruments in the section of empirical methodology. The main results still hold, suggesting a causal effect of supplier firms' environmental risk on the customer-supplier relationship.

We then examine how customers' environmental performance affects the link between suppliers' environmental risk and the customer-supplier relationship. To that end, we partition the sample according to customers' environmental risk exposure and find that the effects of suppliers' environmental risk exposure on their relationships with customers are more pronounced when customers' production process displays a higher environmental responsibility. This result indicates that environmentally conscious customers are more concerned about the potential disruptions caused by supplier environmental risk, and thus are more likely to choose suppliers that match their environmental practice.

Our paper contributes to the extant literature in two ways. First, we identify corporate environmental risk as a key determinant of product market relationships. Prior studies have established that the bilateral relationship between customers and suppliers is influenced by various counterparty risk that may lead to supply chain disruptions, such as bankruptcy risk (Hertzel et al., 2008), managerial turnover risk (Intintoli, Serfling, and Shaikh, 2013), takeover risk (Cen, Dasgupta, and Sen, 2012), and litigation risk (Cen et al., 2014). To the best of our knowledge, we are among the first to empirically show that corporate environmental risk has an

adverse impact on the existence and strength of relationship with firms' major stakeholders, i.e., principal customers. Second, our analysis reveals that customers' purchase decisions are significantly related to the amount of toxic releases of suppliers, supporting the important role of nonfinancial measures in corporate performance evaluation and decision making (e.g., Barth and McNichols, 1994; Hughes, 2000; Clarkson, Li, and Richardson, 2004).[9] Finally, while a number of studies suggest that companies can do well (in terms of firm value and operating performance) by doing good for the environment and society (e.g., Orlitzky, Schmidt, and Rynes, 2003; Guenster et al., 2011), few studies have examined the specific channels through which being environmentally responsible brings economic benefits. Our findings imply that corporate environmental risk exposure can harm firm performance through weakening the trading relationship with principal customers, thereby answering the call of Bénabou and Tirole (2010) and Moser and Martin (2012) for more research on the role of non-shareholder parties in CSR strategies.

The rest of the paper proceeds as follows. Section II provides a brief review of the related literature. We describe the sources of data, variable constructions, and summary statistics in Section III. The main results are presented in Section IV, followed by additional analysis reported in Section V. Section VI concludes.

II. A Brief Literature Review

Our paper brings together two strands of the literature which have attracted strong research interest in recent years, the CSR literature and the product market relationship literature.

[9] Recent studies show that non-financial environmental information is impounded into earnings forecast and stock recommendations by equity research analysts (De Franco, Li, and Zhou, 2013) and into audit fees by auditors (Li, Simunic, and Ye, 2014).

First, there is an ongoing debate on whether social or environmental responsibility is positively related to firms' financial performance. A high standard of environmental responsibility benefits entire communities, but the shareholders may bear the cost of the positive externalities (Coase, 1960). For example, setting up and maintaining systems to reduce toxic waste from manufacturing plants of corporations may increase production costs significantly. Friedman (1962) points out that if corporate executives accept a social responsibility other than making as much money as possible for their shareholders, the very foundation of free society can be undermined. Numerous studies have examined how social and environmental responsibility is related to firm performance, but the results are mixed and difficult to interpret because of various methodological weakness (e.g., Margolis, Elfenbein, and Walsh, 2009; Molina-Azorin et al., 2009). Bénabou and Tirole (2010) point out that empirical designs should focus on identifying the specific channels through which CSR may bring benefits. Moser and Martin (2012) suggest that empirical research should go beyond the financial performance perspective and investigate the role of non-shareholder parties in determining CSR strategies.

Accordingly, a number of studies show that more socially responsible firms perform better because they attract and retain higher quality employees, make better investment decisions, have better access to finance and valuable resources, encourage more stakeholder engagements, and create more intangible assets.[10] On the other hand, environmentally irresponsible firms are found to have higher costs of capital (Chava, 2014), higher credit risk (Schneider, 2011), higher litigation risk (Boone and Uysal, 2012), lower investment opportunities (Gormley and Matsa, 2011), lower analyst forecast accuracy (De Franco, Li, and Zhou, 2013), and higher audit fees (Li, Simunic, and Ye, 2014). We add to this literature by showing that environmental

[10] See among others, Deng, Kang, and Low (2013), Cheng, Ioannou, and Serafeim (2014), Dhaliwal et al. (2011), Turban and Greening (1997), Choi and Wang (2009), and Gardberg and Fombrun (2006).

responsibility is positively related to the strength and durability of trading relationships with principal customers, consistent with the view that it makes economic sense for companies to be socially and environmentally responsible.

Second, a relatively nascent literature points out that durable trading relationships with principal customers are valuable assets. Supplier firms invest heavily to initiate and maintain long term relationship with their principal customers (e.g., Fee and Thomas, 2004; Banerjee, Dasgupta, and Kim, 2008). From customer firms' perspective, choosing suppliers is a highly important operating decision as their eventual success in the product market hinges critically upon the quality of their supply chain. Johnson et al. (2010) point out that valuation of firms during IPOs are higher if they have relationships with large customers and these firms have better long term performance. Fee and Thomas (2004) show that the performance of supplier firms is affected significantly when their large customers are involved in significant mergers or takeover activities. Cen et al. (2012) argue that a hostile takeover disrupts the implicit contracts that form the basis for long term stakeholder relationships. Their results suggest that firms with principal customers experience an increase in shareholder value when the stability of these relationships increases as a result of an exogenous increase in anti-takeover provisions. Cen et al. (2014) shows that the litigation risk of suppliers adversely affects the continuation and strength of customer-supplier relationships.

A number of papers point out how supplier firms adjust their corporate policies to remain attractive to their customers and suppliers. Titman (1984) presents a model in which large stakeholders need to make relationship specific investments and they would lose out if the other party enters into financial distress or liquidation. As a result, large corporate customers, particularly those considering a long term relationship, would have an interest in the stability and

financial health of their suppliers. Hui et al. (2012) find that firms with corporate customers maintain conservative accounting practices in an effort to address the information asymmetry and conservatism increases when their customers are relatively stronger. Itzkowitz (2013) shows that supplier firms hold additional cash to signal that they are unlikely to enter into financial distress. Raman and Sharur (2008) find that firms engage in earnings management and inflate reported earnings in order to favorably influence stakeholder perceptions within supply chains. Banerjee, Dasgupta, and Kim (2008) provide evidence that firms with a substantial customer-supplier relationship maintain lower leverage, particularly if they supply specialised and durable products. In this paper we aim to empirically establish that environmental risk of suppliers also affect their relationships with principal customers.

III. Data and Empirical Methodology

A. Data and Sample

Our sample consists of manufacturing firms (primary SIC code within 2000 and 3990) that are included in the Compustat database and have at least one facility that reports to the EPA's TRI program at any point between 1988 and 2009.[11] We identify principal customers using the Business Segment File of Compustat. To measure environmental risk, we mainly rely on toxic emissions data under the TRI program, a unique source of annually reported and legally mandated firm-specific facility-level environmental performance data. Financial data are from the Compustat Industrial Annual files. Data on stock prices are retrieved from the Center for

[11] We follow Banerjee, Dasgupta, and Kim (2008) by restricting our attention to the manufacturing sector because its production process is more relationship-specific than other sectors. Firms in other sections, such as mining or utilities, also have significant environmental risk, however, their customer-supplier relationships are less stable owing to homogenous products and lower switching costs for suppliers.

Research in Security Prices (CRSP) files. Dollar values are converted into 2005 constant dollars using the GDP deflator.

We start our sample period in 1988 as the EPA starts collecting TRI data in 1987 and we use one-year lagged value of environmental risk measures when predicting the customer-supplier relationship. We end our sample period in 2009, up to which we manually identify principal customers. We exclude firms with missing values for environmental risk and for variables employed in regressions. These restrictions yield an unbalanced panel that consists of 16,895 firm-year observations from 1,557 supplier firms.

B. Identifying Principal Customers

We extract the identities of firms' customers and sales to customers from the Business Segment File of Compustat. The Statement of Financial Accounting Standards No. 14 (SFAS No. 14 - "Financial Reporting for Segments of Business Enterprise") of the Financial Accounting Standards Board (FASB) requires firms to disclose the sales to their customers if the revenue generated from each such customer exceeds 10% of the firm's total revenue or if the firm considers the sale important to its business.[12] Following Banerjee, Dasgupta, and Kim (2008), we define principal customers as those accounting for 10% or more of a firm's reported sales.[13] We then classify principal customers as public customers, private customers, government customers, or unidentified customers. Specifically, we first match the customer names with the

[12] In 1997, SFAS 14 was superseded by SFAS 131 which mandates firms to report sales to each principal customer, but not the identity of the principal customer. However, under Securities and Exchange Commission (SEC) Regulation S-K, firms with publicly traded equity are still required to disclose the names of customers that comprise 10% or more of their sales if the loss of such customer would have a material adverse effect on the firm (Ellis, Fee, and Thomas, 2012).

[13] Some firms (roughly 41.6% of firms disclosing their customers) voluntarily disclose information about customers responsible for less than 10% of their annual sales. Robustness checks (untabulated) show that our results are qualitatively the same if we include voluntarily disclosed customers that account for less than 10% of net sales as principal customers. In addition, Ellis, Fee, and Thomas (2012) document that some suppliers, especially those in competitive industries, do not reveal the identity of their principal customers.

historical names file in the CRSP/Compustat merged data file to identify public customers. For the unmatched customers and the customers with multiple matches, the classification is done manually by searching names using Lexis-Nexis Academic Universe and checking 10-K filings of the possible parent companies and their subsidiaries in the relevant time period.[14]

To measure the presence of principal customers, we set the indicator variable *Customer* equal to one if the firm has at least one principal customer that year, and zero otherwise. To explore heterogeneity across customers, we construct four customer category indicator variables (i.e., *Public*, *Private*, *Government*, and *Unidentified*) for whether a firm has at least one principal customer from the following categories or not: (1) government customers; (2) public customers; (3) private customers; or (4) unidentified customers. Government customers are expected to be substantially different from publicly traded or private customers in many aspects. For instance, they generally purchase for consumption and their purchases may not be driven by profit motives (Banerjee, Dasgupta, and Kim, 2008).

After identifying the principal customers, we organize our data at the customer-supplier pair level to study how a supplier's environmental risk exposure affects its probability of being chosen by principal customers (Table IV) and the intensity and duration of the customer-supplier relationship (Table V). For these tests, the exact identities of principal customers need to be

[14] The classification requires some amount of discretion since the reported principal customer names do not follow a set pattern and are often abbreviated. We follow the method of Banerjee, Dasgupta, and Kim (2008) and use the historical names file of the CRSP/Compustat merged data file, LexisNexis Academic Universe search based on customer company names of both listed and unlisted firms. We also conduct news search around the time period to determine whether a customer was a wholly-owned subsidiary of a listed company. We eliminate the matches that have nothing to do with the product of the segment concerned. If we are left with one listed company or one private company that could be the only possible match, then we classify the customer accordingly. However, based on reported customers in abbreviation, if we are left with more than one public company matches or at least one public and one private company for which we cannot distinguish, we classify the principal customer as "unidentified". Some customer names are deliberately suppressed by assigning names such as "Not reported" or "2 Customers", we thus put them in the "unidentified" group. If more than one private and no public company meet the search criteria, we classify the customer as "private." Customers reported as "Domestic Government" or "U.S. Navy," etc., are classified as "government". Very few companies report foreign governments as their principal customers, so we include both domestic and foreign government customers into a single group.

known, we thus follow Cen et al. (2014) and exclude government and unidentified customers from the relationship analysis.[15] This process results in 6,022 customer-supplier-year pairs where customers are public or private firms that are clearly identified.

C. Measuring Environmental Risk Exposure

As the current securities regulations and accounting standards leave firms considerable discretion in their environmental reporting, the environmental disclosure made by firms are often incomplete and inaccurate (Barth, McNichols, and Wilson, 1997; Schneider, 2011). We thus follow prior studies and rely on nonfinancial pollution measures from the TRI program to assess firms' exposure to environmental risk.[16] The TRI program was established by the Section 313 Emergency Planning and Community Right-to-Know Act (EPCRA) of 1987 and has been expanded to contain information on over 650 toxic chemicals from more than 20,000 U.S. industrial facilities. Each year, facilities are required to report to TRI the quantities of chemicals disposed or released into the environment (air, water, and land) and those that are treated, recycled, and recovered.[17] Environmental management activities, which include treatment, recovering and recycling, reflect firms' on-going expenditures to achieve and maintain compliance with environmental laws and regulations, while the toxicities and quantities of

[15] In other words, for this analysis we only include customer-supplier relationships in which customers are publicly traded or privately held firms. We exclude unidentified principal customers because we cannot distinguish them from each other. Government customers are typically reported as "US Government" or "US domestic government", so it is unclear what levels of government or which government agencies or departments they represent.

[16] Barth and McNichols (1994) and Hughes (2000) show that nonfinancial pollution measures, i.e., the number of Superfund sites and sulfur dioxide emissions, respectively, capture the exposure of polluting firms to future environmental liabilities. Also see among others, Cormier, Magnan, and Morand (1993), Clarkson, Li, and Richardson (2004), and Carroll et al. (2004). De Franco, Li, and Zhou (2013) show that the TRI's toxic emission data constitutes an important source of non-financial information for analysts to assess firms' future environmental risk exposure and financial prospect.

[17] A facility is required by law to report to the TRI program if it meets the following three criteria: (1) it has 10 or more full-time employees, (2) its North American Industry Classification System (NAICS) code is covered by the TRI program, and (3) it processes, manufactures, or otherwise uses any listed toxic chemical in excess of the threshold amount.

chemicals directly released capture firms' exposure to environmental risk. Namely, a high level of toxic chemicals released is positively associated with expenditures for compliance with future stringent environmental laws and regulations, the probability of future litigations, enforcement actions, and remediation activities arising from past and on-going environmental contamination, as well as serious damages to human health, property, and economic activities.

Specifically, we first calculate the facility-level production-related toxic chemical releases by summing up all the chemicals released in a given year. To account for the inherent heterogeneity of chemicals, we multiply the mass of each chemical by its toxicity, which is taken from the EPA's Risk-Screening Environmental Indicator (RSEI) model. We then aggregate the toxicity-weighted amounts of releases across facilities owned by the firm to obtain the firm-level toxicity-weighted releases and scale it using total sales to control for production scale. The aggregation procedure results in many extreme values because of the enormous variation in the toxicity of TRI chemicals, which spans seven orders of magnitude on a pound-for-pound basis.[18] To mitigate the effects of outliers and skewness in the data, we transform the raw scaled amounts of toxicity-weighted releases to percentile ranks, which range from 0.032 (the lowest environmental risk) to 1 (the highest environmental risk).[19] We then use the percentage ranks (*EnvRisk*) as the key variable of our interest in the regression analysis. In Section IV.D, we show that our results are robust to alternative measures of environmental risk exposure.

[18] For instance, less-toxic chemicals, such as Formic acid and Ethylene, have toxicity less than 0.5, while the most toxic chemicals, such as, Asbestos and Thorium dioxide, have toxicity equal to 1,000,000. For chemicals that have no assigned toxicity by EPA, we set toxicity equal to zero. EPA provides two toxicity weights based on the exposure path: the inhalation toxicity weight and the oral toxicity weight. We follow EPA's methodology and use the inhalation toxicity weight for releases (transfers) to fugitive air, stack air, and off-site incinerations. The oral toxicity weight is used for releases (transfers) to direct water and publicly-owned treatment works (POTWs). If the path through which a chemical is released (transferred) is unknown, the higher of the two toxicity weights is used.

[19] Specifically, a percentile rank equals the cumulative frequency that corresponds to a given amount of toxicity-weighted releases scaled by total sales, for which we try to find the percentile rank, divided by the number of observations in our sample. The same rank in assigned to tied values (Cox, 2002). As 1,090 firm-year observations have zero toxicity-weighted releases, the lowest percentile rank is 545.5/16,895 = 0.032.

D. Control Variables

We control for a number of variables that have been shown by previous studies to influence the presence of principal customers. Specifically, we include the natural log of total assets (*Ln*(*Assets*)) to control for firm size. To account for the effect of a firm's life cycle on its relation with customers, we employ the natural log of firm age, *Ln*(*Firm Age*), which is the number of years elapsed since a firm enters the CRSP database. Patatoukas (2012) documents that customer-base concentration is positively associated with firm operating performance, and negatively related to selling, general, and administrative (SG&A) expenses. Thus, we include *EBITDA/Assets* and *SG&A/Assets* to capture operating performance and SG&A expenses. The market-to-book ratio (*M/B*) is included to proxy for firm-specific growth opportunities. Maksimovic and Titman (1991) and Titman (1984) argue that customers may be reluctant to conduct business with suppliers with high financial leverage or financing difficulties, which weaken suppliers' ability to honour implicit contracts. We thus follow Banerjee, Dasgupta, and Kim (2008) and use the book leverage ratio (*Leverage*), which is defined as the long-term debt divided by total assets, to measure financial leverage. To capture a company's access to bond markets, we employ a debt rating indicator variable (*Debt Rating*) that equals one if a firm has debt ratings assigned by Standard & Poor's, and zero otherwise. Also included is the net Property, Plant, and Equipment (*PPE*) scaled by the total assets (*PPE/Assets*) to account for tangibility. Additionally, as firms with high research and development (R&D) intensity are more likely to provide customers with services or products that are unique and indispensible (e.g., Bowen, DuCharme, and Shores, 1995), we include as control variables the R&D expenses scaled by total assets (*R&D/Assets*) and an indicator variable (*RNDD*) which equals one if R&D

expenses are missing, and zero otherwise. All control variables are measured at *t*-1 in the regressions.

E. Summary Statistics

Table I reports the descriptive statistics for all supplier firms in our sample. We winsorize the variables at the top and bottom 1% of their distributions.[20] This approach reduces the impact of extreme observations by assigning the cutoff values to those that are beyond the cutoff points. Our results (untabulated) are qualitatively the same when we truncate (rather than winsorize) the distributions.

[Insert Table I here]

The distributions of raw releases and toxicity-weighted releases are highly skewed. An average (a median) firm in our sample generates 1.94 (0.07) million pounds of releases. The mean (median) value of toxicity-weighted releases is 9.05 billion (9.06 million). Our main measure of environmental risk (*EnvRisk*) is the percentile rank of scaled toxicity-weighted releases. It has the mean and median values equal to 0.500and has the standard deviation equal to 0.289.

44.2% of our firms have at least one principal customer. 6.5% of them have at least one government customer. We are able to identify at least one public (private) customer for 20.3% (4.4%) of the firms, while 26.3% of firms have at least one unidentified principal customer. Table I also reports summary statistics for the control variables used in our main tests. Since our sampling approach and variable construction criteria follow the literature, the reported figures in Table I resemble those found in related studies (e.g., Banerjee, Dasgupta, and Kim 2008). In the interest of brevity, we omit discussion of the descriptive statistics for control variables.

[20] The only exception is *EnvRisk*, which is percentile ranks that do not take extreme values.

[Insert Table II here]

Table II tabulates the distribution of supplier firms having principal customers across industries classified using the two-digit SIC code. The fraction of suppliers having principal customers is the highest in Electrical Equipment industries, followed by Transportation Equipment, Chemicals and Allied Products, Machinery, and Measuring, Analyzing & Controlling Instruments. Government purchases cluster in Electrical Equipment, Transportation Equipment, and Measuring, Analyzing & Controlling Instruments sectors, of which Electrical Equipment and Transportation Equipment are identified as high-polluting industries (Delmas and Toffel, 2008). Overall, the presence of principal customers exhibits a large variation across supplier industries. As environmental risk measures tend to be industry-specific (Clarkson, Li, and Richardson, 2004), we include four-digit SIC industry fixed effects in our regression analysis to control for heterogeneity along the industry dimension.

IV. Main Results

In this section, we perform three main tests regarding the effects of environmental risk on the customer-supplier relationship. First, we examine whether a firm's environmental risk exposure affects the presence of principal customers. Second, we take principal customers' perspective and study whether their decisions in selecting suppliers are affected by suppliers' environmental risk. We then explore the effects of environmental risk on the intensity and duration of the existing trading relationships. Finally, we conduct various checks to ensure that our main results are robust to alternative model specifications, alternative variable definitions, and endogeneity concerns.

A. Effects of Environmental Risk Exposure on the Presence of Principal Customers

We use Probit regressions to examine how the probability of having principal customers is affected by corporate environmental risk. Specifically, we estimate the model

$$\text{Prob.}[Customer_{i,t} = 1] = \Phi(\alpha + \beta EnvRisk_{i,t-1} + \gamma X_{i,t-1} + \delta Industry_{i,t} + \theta Year_i), \quad (1)$$

where the dependent variable, *Customer*, is equal to one if firm *i* has at least one principal customer in year *t*, and zero otherwise. Φ denotes the normal cumulative distribution function. The key explanatory variable, *EnvRisk*, is measured one year before supplier firms' principal customers are observed. The coefficient (β) on *EnvRisk* is expected to be negative. $X_{i,t\text{-}1}$ represents a set of pre-determined control variables that are defined in Section III.D and measured at *t*-1. We include the four-digit SIC industry fixed effects (*Industry*) that control for heterogeneity across industries. Also included are year fixed effects (*Year*) that account for macro-economic factors that influence the demand or supply in the product market.[21] The standard errors of the estimated coefficients allow for clustering of observations by firm but our conclusions are not affected if we allow clustering by both firm and year. We report the coefficients reflecting the marginal effects that capture the impact of a one unit change in explanatory variables on the dependent variable.

[Insert Table III here]

We estimate equation (1) using the entire sample and present the results in column (1) of Table III. The estimated coefficient on *EnvRisk* is negative and statistically significant (*z*-statistics = -4.2), suggesting that high environmental risk reduces supplier firms' likelihood of having principal customers. Economically, increasing *EnvRisk* from the 25th percentile (0.25) to

[21] We do not include firm fixed effects in our main specifications because both *Customer* and *EnvRisk* are highly persistent variables. The first order autocorrelations for *Customer* and *EnvRisk* are 0.75 and 0.92, respectively. Zhou (2001) points out that the persistence of key variables can reduce the signal-to-noise ratio and lower the power of panel data estimators.

the 75th percentile (0.75) decreases the probability of having at least one principal customer by roughly 0.08, corresponding to a 17% reduction relative to the average probability (0.442) reported in Table I.[22]

The estimated coefficients of control variables indicate that small and rated supplier firms are more likely to have principal customers. Supplier firms that invest more in R&D and those with lower SG&A expenses are associated with a higher likelihood of having principal customers.

In columns (2)-(4), we group principal customers into government and firm categories and examine the effect of environmental risk on the presence of principal customers from each category. The results reveal that *EnvRisk* attracts a negative but insignificant coefficient (*z*-statistics = -1.0) in the regression explaining the likelihood of having government customers. In contrast, the negative effects of *EnvRisk* on the presence of public or private customers are both economically and statistically significant (*z*-statistics = -3.3 and -1.9 , respectively).

The insignificant relation between *EnvRisk* and *Government* suggests a low sensitivity of government purchases to suppliers' environmental risk. This result is consistent with the key differences between government and company customers. Publicly traded or private principal customers usually use the goods as inputs in their own production process or for reselling, while the government generally purchases goods for consumption (Banerjee, Dasgupta, and Kim, 2008). As a result, although environmental risk exposure may adversely affect suppliers' incentives to maintain product quality, reputational or monetary losses from poor quality products procured from the suppliers may be less important when the government is a principal customer. Furthermore, rigorous administrative controls over procurement contracts make the decision-making process of government purchases mainly dependent on price and the stated

[22] Specifically, -0.154 × (0.75 – 0.25) = -0.08.

quality features of the products instead of the environmental impact of suppliers' production process.[23]

Comparing columns (3) and (4), we find that the effect of *EnvRisk* on the likelihood of having public customers is more pronounced than that on the likelihood of having private customers, suggesting that publicly traded companies are more concerned about the environmental performance of their suppliers because they are more subject to public scrutiny (Michaely and Roberts, 2012) and pressures from consumer groups than their private counterparts.

B. Effects of Environmental Risk Exposure on Customers' Choices of Suppliers

The regression analysis in Table III investigates supplier firms' likelihood of having principal customers. We now take principal customers' perspective and study whether their decisions in selecting suppliers are affected by suppliers' environmental risk exposure. It is worth investigating because in a competitive product market, unless a customer is severely distressed financially, the power to select the counterparty likely resides with the customer side (Chen et al., 2014). The analysis is performed using all principal customer-potential supplier pairs that are constructed based on actual customer-supplier relationships. Specifically, for each actual customer-supplier relationship in a year, we follow Sundaram, John, and John (1996) and identify potential suppliers (also referred as to competing suppliers) as all firms that are in the same four-digit SIC industry as the actual supplier and covered by the TRI program.[24] We require at least one potential supplier (except the actual supplier) for each actual customer-

[23] Similarly, Banerjee, Dasgupta, and Kim (2008) find that government customers are less likely to be concerned about the suppliers' financial leverage.

[24] We exclude the customer itself from the potential suppliers if the customer and the actual supplier are in the same industry.

supplier relationship. Each principal customer's decision is modelled as choosing a supplier from all potential suppliers, whereby the choice is influenced by suppliers' environmental risk exposure and a number of supplier and relationship-specific characteristics. To operationalize this, we model the probability that a customer *j* chooses a supplier *i* in year *t* using the following Probit model.

$$\text{Prob.}[Supplier_{i,j,t} = 1] = \Phi(\alpha + \beta EnvRisk_{i,t-1} + \gamma X_{i,t-1} + \rho Y_{i,t} + \delta Industry_{i,t} + \theta Year_i), \quad (2)$$

where $Supplier_{i,j,t}$ is a dummy variable that equals one if a potential supplier *i* is chosen by customer *j* in year *t* as the actual supplier, and zero otherwise, $X_{i,t-1}$ is the set of supplier characteristics described in Section III.D, and *Industry* (*Year*) is supplier industry (year) fixed effects. $Y_{j,t}$ in equation (2) includes two relationship-specific variables. *Ln*(*NumSup*), the natural logarithm of the number of potential suppliers that a customer has, is supposed to be negatively related to the probability of a potential supplier being chosen. *Alliance* is a dummy variable that equals one if any strategic alliance or joint venture was established between a principal customer and its potential supplier, and zero otherwise.[25] We expect that the presence of explicit alliance agreements increases potential suppliers' chance of being chosen. As discussed in Section III.B, we consider publicly traded and privately held customers only, for which potential suppliers can be meaningfully identified. As a result, the analysis is performed using 42,210 customer-potential supplier-year pairs, among which 5,518 are actual customer-supplier relationships.

[Insert Table IV here]

The result reported in column (1) of Table IV shows a negative and significant coefficient on *EnvRisk*, implying that a higher level of environmental risk exposure lowers a supplier firm's probability of being chosen relative to its industry peers by its potential customer. The economic

[25] We retrieve information on alliances and joint ventures from the Securities Data Corporation (SDC) strategic alliance database.

magnitude is such that the likelihood of a supplier being chosen by a customer would decrease by 15% over and above the unconditional probability (5,518/42,210 = 0.131) if *EnvRisk* increases from the 25th percentile (0.25) to the 75th percentile (0.75). *Ln*(*NumSup*) and *Alliance* are found to be negatively and positively related to the probability of a supplier being chosen, respectively. The estimated coefficients of other control variables are generally consistent with those reported in Table III. In a robustness check (untabulated), we augment equation (2) by including customer fixed effects to account for the influence of time-invariant customer characteristics, and obtain qualitatively similar results.[26]

Columns (2) and (3) of Table IV investigate the choices of public and private customers, respectively. The results suggest that *EnvRisk* affects public customers' supplier choice more than that of private customers, paralleling the findings in Table III.

C. Effects of Environmental Risk Exposure on the Intensity and Durability of the Customer-Supplier Relationship

We now focus on actual principal customer-supplier relationships and examine the effect of supplier environmental risk exposure on the intensity and durability of the trading relationship. Each actual customer-supplier-year is treated as a single observation in the regression analysis. We define *Intensity* as the fraction of a supplier's sales that are made to the principal customer. By definition, this variable is censored from both below (by the value of 10%) and above (by the value of 100%), we thus estimate the following equation using Tobit regression with double censoring.[27]

[26] After including customer fixed effects, the estimated coefficient of *EnvRisk* becomes -0.042 with z-statistic = -3.44.

[27] If the fraction of sales made to a customer drops below 10% in year *t*, the customer is no longer classified as a principal customer according to our definition. However, the customer-supplier relationship may actually continue

$$Intensity_{i,j,t} = \alpha + \beta EnvRisk_{i,t-1} + \gamma X_{i,t-1} + \rho Y_{i,j,t} + \delta Industry_{i,t} + \theta Year_i + \varepsilon_{i,j,t}, \qquad (3)$$

where $X_{i,t-1}$ is the set of supplier characteristics described in Section III.D, and $Y_{i,j,t}$ represents the two relationship-specific control variables, *Ln*(*NumSup*) and *Alliance*.

[Insert Table V here]

The results reported in column (1) of Table V shows that the coefficient on *EnvRisk* is negative and significant at the 5% level (*z*-statistic = -2.0), suggesting that the percentage of sales to principal customers decreases with supplier's environmental risk. Other things being equal, if *EnvRisk* increases from the 25th percentile (0.25) to the 75th percentile (0.75), the fraction of sales made to a principal customer would decreases by 1.2%, which amounts to 7% of the average fraction of sales made to principal customers in our sample (18%).

Next, we employ a Cox proportional hazard model to examine the effect of environmental risk exposure on the duration of the customer-supplier relationship.[28]

$$h(t)_{i,j} = h_0(t)_{i,j} \exp(\alpha + \beta \overline{EnvRisk}_i + \gamma X_i + \rho Y_{i,j} + \delta Industry_i + \theta Year_i + \varepsilon_{i,j}), \qquad (4)$$

where $h(t)_{i,j}$ gives supplier firm *i*'s hazard (probability) at time *t* that the relationship with its principal customer *j* will be terminated within an interval of time, given that the relationship has survived up to the beginning of the interval. $h_0(t)_{i,j}$ is the baseline hazard function in the absence of explanatory variables. For explanatory variables, we follow prior studies (e.g., Fee, Hadlock, and Thomas, 2006; Raman and Shahrur, 2008) by using the average *EnvRisk* over the duration of the relationship and setting the values of supplier characteristics (*X*) and relationship-specific

in year *t* with the fraction of sales made to the customer being any number between 0 and 10%. Thus, to account for relationship deterioration potentially caused by high environmental risk, we assume that the fraction of sales to a principal customer decreases to 10% in year *t* if the customer has been a principal customer until *t*-1 but stops being a principal customer in year *t*. Assuming that the fraction reduces to 0 or 5% in year *t* generates similar results.

[28] In the model, the hazard, i.e., the probability of relationship termination, is assumed to depend on a set of explanatory variables (covariates). Proportional hazard refers to the assumption in the model that the hazard for any firm is constant across time and is a constant proportion of the baseline hazard. Following common practice, when estimating equation (1), we adjust for delayed entry for relationships existing in the first year of our sample. Durations not completed at the end of the sample period are treated as right censored.

variables (*Y*) to their values in the first year that we observe the relationship during the sample period. As suggested by Raman and Shahrur (2008), *Intensity* is included in *Y* as an additional explanatory variable. Since the estimation of equation (4) is based on the hazard function, a positive coefficient of an explanatory variable implies that an increase in the variable results in shorter relationship length. Each principal customer-supplier relationship is treated as a single observation in the regression. That is, equation (4) is estimated using data arranged at the relationship level rather than at the relationship-year level, so the number of observation is 1,820.

Column (2) of Table V reports the regression results for equation (4). We find that the coefficient on $\overline{EnvRisk}$ is positive and significant at the 5% level, indicating that higher environmental risk exposures of supplier firms are associated with less durable business relationships with their principal customers. Economically, increasing $\overline{EnvRisk}$ from the 25th percentile (0.21) to the 75th percentile (0.66) increases the hazard of relationship termination by 10.4%.[29] In addition, we find that the hazard of relationship termination is negatively related to *intensity* and supplier's size, but positively associated with supplier's age.[30]

To complement the duration analysis by the Cox proportional hazard model, we estimate the following Probit model investigating whether environmental risk adversely affects the likelihood of relationship continuation.[31]

$$\text{Prob.}[Continue_{i,j,t}=1]=\Phi(\alpha+\beta EnvRisk_{i,t}+\gamma X_{i,t-1}+\rho Y_{i,j,t}+\delta Industry_{i,t}+\theta Year_i), \quad (5)$$

[29] Specifically, the percentage change in the hazard is 100%×[exp(0.232× (0.66 − 0.21))] = 10.4%.

[30] Similar results (untabulated) are obtained if we exclude *Intensity* as an explanatory variable, follow Fee, Hadlock, and Thomas (2006) and include $intensity^2$ as an additional explanatory variable to account for the possible nonlinear relation between the hazard of relationship termination and *Intensity*, or if we conduct the duration analysis using the Weibull model where the length of the relationship for each supplier-customer pair is assumed to follow a Weibull distribution.

[31] Similar to the intensity analysis, to account for relationship deterioration potentially caused by high environmental risk, we assume that the fraction of sales to a principal customer decreases to 10% in year *t* if the customer has been a principal customer until *t*-1 but stops being a principal customer in year *t*.

where $Continue_{i,j,t}$ is a dummy variable that equals one if a principal customer-supplier relationship continues in year *t*, and zero otherwise. The results presented in column (3) of Table V reveal that higher environmental risk exposures significantly lower the probability of the customer-supplier relationship continuation. Specifically, the likelihood that a principal customer stays in year *t* declines by 2.1% if *EnvRisk* increases from the 25th percentile (0.25) to the 75th percentile (0.75).

Taken as a whole, the results in Table V indicate that suppliers' ongoing environmental risk exposure adversely influences the subsequent evolution of the trading relationship and significantly weakens their bond with principal customers. Furthermore, we repeat the analysis in Table VI for relationships with public and private customers separately, and not surprisingly, we find that the results are more pronounced for those with public customers. However, these results are not tabulated for the sake of brevity.

We perform a number of additional tests to ensure that our main results reported in Tables III-V are robust to alternative model specifications and different variable definitions. To save space, results are not tabulated but are available upon request. Specifically, our results hold when (*A*) Scaling *Weighted Releases* by the costs of goods sold or total assets when computing percentile ranks (*B*) defining environmental risk as *Ln*(*Weighted Releases*)*/Sales*; (*C*) defining environmental risk as (*Raw Releases*)*/Sales*; and (*D*) ranking (*Weighted Releases*)*/Sales* by year or industry.

D. Endogeneity Issues

We have documented a robust relation between suppliers' environmental risk exposure and the customer-supplier relationship, but its causal interpretation remains hypothetical. The

abovementioned results are potentially subject to two types of endogeneity. The first type is omitted variable bias. While we have controlled for a standard set of variables in the regressions, our main findings may be spurious if our models omit any variables that affect both suppliers' environmental risk exposure and their relationship with principal customers. The other possible endogeneity issue is reverse causality running from the trading relationship with principal customers to suppliers' environmental risk. For example, the presence of principal customers may encourage suppliers to make relationship-specific investment related to pollution control and prevention activities, thereby reducing suppliers' environmental risk exposure. In both cases, the coefficient estimates in Tables III-V can be biased and inconsistent.

We perform a battery of tests to alleviate these concerns. We tabulate the results in Table VI. While all control variables in equations (1)-(5) are still included in these new tests, we only report the coefficients of *EnvRisk* and the newly added variables for brevity.

[Insert Table VI here]

Panels A-C of Table VI show the results from additional tests that address the issues related to omitted variables that may affect both supplier's environmental risk exposure and the customer-supplier relationship. Hong, Kubik, and Scheinkman (2012) show that firms behave in a more socially responsible manner when they have more financial slack. To the extent that customer firms would prefer to conduct business with supplier firms that are financially healthy, the relation between suppliers' environmental risk exposure and the customer-supplier relationship may be driven by suppliers' financial strength or constraints. To mitigate this concern, we include as additional control variables Hadlock and Pierce's (2010) index of

financial constraints, and the cash-to-assets ratio.[32] The results, reported in Panel A of Table VI, suggest that our main results are unaffected.

Lev, Petrovits, and Radhakrishnan (2013) find that corporate charitable contributions stimulate sales growth via enhancing consumer satisfaction. To the extent that firms making more charitable contributions are more likely to engage in environmental management activities, our findings may just capture the effects of suppliers' giving decisions. To rule out this possibility, we augment our model by including *Charity*, a dummy variable that is equal to one if a supplier has at least one strength in the three charity-related categories evaluated by Kinder, Lydenberg, and Domini (KLD) Research & Analytics.[33] Panel B of Table VI reveals that our results remain.

In Panel C, we use $EnvRisk_{t-3}$, instead of $EnvRisk_{t-1}$, as the key explanatory variable, because more distantly lagged values of *EnvRisk* should be less correlated with *current* omitted firm characteristics. Similar results are obtained.

In Panel D, we explicitly control for environmental management activities (*EnvRisk_RRT*), and pollution prevention activities (*Prevention*) to mitigate the concern of reverse causality. To measure *EnvRisk_RRT*, we compute the toxicity-weighted and log-transformed amount of waste that is recycled, recovered, and treated and scale the measure by sales. As firms do not disclose the amount of chemicals reduced by pollution prevention activities, we follow Doshi, Dowell, and Toffel (2013) and extrapolate the amount using the production ratio reported by the TRI

[32] Hadlock and Pierce's (2010) index is defined as $-0.737 \times Ln(Assets) + 0.043 \times Ln(Assets)^2 + 0.04 \times Firm\ Age$. *Firm Age* is the number of years elapsed since a firm enters the CRSP database. We find qualitatively similar results using the alternative financial constraints classifications suggested by Kaplan and Zingales (1997), Cleary (1999), and Whited and Wu (2006).

[33] Our charitable giving data comes from the KLD database. KLD evaluates corporate philanthropy in three categories, which include whether or not the firm has given over 1.5% of trailing three-year net earnings before taxes to charity, supports nonprofit organizations, and makes charitable contribution abroad. In addition, to account for missing values of *Charity*, we include an indicator variable (*CharityDum*) as an additional control, which equals one if *Charity* is missing, and zero otherwise.

database.[34] *Prevention* is then defined as the toxicity-weighted and log-transformed amount of waste reduced by pollution prevention activities scaled by sales. The results indicate that *EnvRisk* remains economically and statistically significant in our regressions, alleviating the concern that our results are driven by principal customers encouraging suppliers to reduce environmental risk through environmental management and pollution control activities.

Finally, we employ a two-step bootstrapping approach to further mitigate endogeneity concerns. In particular, we predict the level of environmental risk exposure based on a set of possible determinants of environmental risk in the first step, and use the predicted *EnvRisk* in the second step for trading relationship regressions. We follow Chang, Dasgupta, and Hilary (2006) and bootstrap the two-step system 500 times to obtain consistent standard errors, based on which we construct and report the 95 percent confidence intervals.

In selecting the determinants of environmental risk, we start by introducing three instrumental variables in the first stage estimation. The first instrument, *Ln*(*1+DisPro*), is the log of the weighted average geographical distance between EPA regional offices and a firm's facilities. We first calculate the geographical distance for each facility-EPA regional office pair, and then weight the distance using toxicity-weighted waste generated by each facility.[35] To the extent that information asymmetries and monitoring costs increase with the physical distance from EPA regional offices, EPA regional offices would be less effective in making more remote firms reduce environmental risk exposure, implying a positive relation between *Ln*(*1+DisPro*) and *EnvRisk*. The second instrumental variable, *PopDensity*, is the average population density

[34]Specifically, the production ratio of a facility is the production level in the current year divided by the production level in the previous year (Berrone and Gomez-Mejia, 2009). We predict the waste level generated in a given year by multiplying the production ratio by the total waste generated in the previous year, and then subtract the actual waste from the predicted waste to obtain the amount of waste that is reduced by pollution prevention.

[35] We use Coval and Moskowitz's (1999) formula to calculate the physical distance for every facility-EPA regional office pair. The geographic coordinates of reported facilities are provided by the TRI database. The coordinates of EPA's regional offices are based on zip codes from EPA's website.

within 100 kilometres around the census tracts in which a firm's facilities operate, weighted by toxicity-weighted waste generated by each facility. Kassinis and Vafeas (2006) document that communities with a higher population density exert more pressure on firms to reduce their emissions. We therefore expect *PopDensity* to be negatively related to *EnvRisk*. As the third instrument, we take the natural log of the number of facilities reporting non-zero toxicity-weighted waste to the TRI program, *Ln*(*1+NumFac*). Firms with a larger number of facilities processing toxic chemicals are expected to have a higher level of environmental risk exposure. These three instrumental variables, however, are not expected to directly influence the trading relationship, rather than affecting it through suppliers' environmental risk exposure.[36]

Furthermore, we include a number of company characteristics proposed by previous studies (e.g., McWilliams and Siegel, 2000; Clarkson et al., 2011) as additional determinants of environmental risk. We include the production scale (*Ln*(*Sales*)), profitability (*EBITDA*/*Assets*), and growth opportunities (*M/B*) because large firms, firms with fewer growth opportunities, and firms with higher profitability are more willing to engage in pollution control and prevention activities to reduce environmental risk. *R&D/Assets* and *RNDD* are included as firms with higher R&D investment are more capable of making the production process less polluting. Also included is capital expenditure scaled by gross PPE (*CAPEX/PPE*) as firms may make more investment reduce pollution. In addition, we employ the percentage of revenues from foreign markets (*Foreign*) to account for the effect of foreign operations. We also add *Leverage* since Chang et al. (2014) document that firms' leverage ratios are negatively related to the amount of

[36] A possible concern is that *NumFac* is highly correlated with firm size, and therefore may have a direct effect on the presence of principal customers. However, ex ante, the correlation between *NumFac* and firm size is weak. A facility is covered by the TRI program as long as it has 10 or more employees. In addition, if *NumFac* captures the effect of firm size, it should work against us finding a negative relation between environmental risk and trading relationships, because larger firms typically have lower environmental risk exposure (Ioannou and Serafeim, 2012) and lower likelihood of having principal customers (Table III).

toxic chemicals released. Finally, we include four-digit SIC industry, headquarter state, and year fixed-effects.[37]

The results of the first-step regression are reported in Appendix A. As expected, *Ln*(*1+NumFac*) and *Ln*(*1+DisPro*) are significantly and positively related to *EnvRisk* (*t*-statistics are 23.2 and 6.0, respectively). *PopDensity* is significantly and negatively associated with *EnvRisk* (*t*-statistic = -3.8). The coefficients of other explanatory variables are generally consistent with those reported in previous studies. More importantly, we report the results of the second-step regressions in Panel E of Table VI. Columns (1)-(3) reveal that the bootstrapped 95% confidence intervals for the coefficients of the predicted *EnvRisk* do not span zero, suggesting that the effects of *EnvRisk* are significantly different from zero at less than the 5% level. In column (4), we perform the duration analysis using $\overline{EnvRisk}$ computed based on the predicted *EnvRisk*. The 95% confidence interval does not span zero, suggesting that the coefficient estimate on $\overline{EnvRisk}$ is significant at the 5% level. [38]

V. Further Analysis

In this section, we first partition our sample to examine whether our results vary across supplier firms depending on their customers' environmental risk exposure. We then experiment with an alternative environmental risk measure constructed using Kinder, Lydenberg, and Domini (KLD) Research & Analytics data.

[37] Firms' headquarter states are obtained from the Compact Disclosure Database and Compustat.

[38] Instead of bootstrapping the two-step system, we use the standard two-stage instrumental variable approach for columns (1)-(3) with *Ln*(*1+DisPro*), *PopDensity*, and *Ln*(*1+NumFac*) being the instrumental variables. The instruments pass the relevance test as the *F*-statistics from the joint test of excluded instruments are significant at the 1% level. The *p*-values of the over-identification tests are insignificantly different from zero, thereby confirming the validity of the instrumental variables. The second-stage regression results are consistent with those obtained using the bootstrapping approach. The standard instrumental variable approach, however, cannot be applied to the duration analysis in column (4) since its second stage involves estimating the Cox proportional hazard model.

A. Customers' Environmental Risk

To examine how customers' environmental risk exposure affects our findings, we partition our sample into two groups according to the median values of customers' environmental risk exposure every year, and re-estimate equations (2) and (3) for the two groups, respectively. For the duration analysis, we divide our sample based on the average customer environmental risk over the duration of the relationship and re-estimate equation (4) for both subsamples. While all control variables in equations (2)-(4) are included in these tests, we only report the coefficients of *EnvRisk* for brevity. The results, reported in Table VII, indicate that our results are more pronounced in the subsample where customers have lower environmental risk exposures. These findings indicate that suppliers' environmental risk exposure is more damaging for trading relationships with greener principal customers.

[Insert Table VII here]

B. An Alternative Measure of Environmental Risk Exposure

A potential concern with our analysis is that our main measure of environmental risk only captures exposures associated with a specific set of toxic chemicals, and thus may not be able to provide a comprehensive picture of a firm's environmental risk. To address the issue, we rely on an alternative data source, namely, KLD Research & Analytics.

The KLD database has been widely used in prior studies of corporate social responsibility. It provides binary ratings to approximately 80 factors in seven CSR areas based on data from various sources, including company disclosures, media reports, data from government and non-

government agencies, and dialogs with companies.[39] We focus on the area of environment that contains ratings for seven environmental concern items and seven environmental strength items. For each item, KLD sets the rating equal to one if a firm has the strength or concern, and zero otherwise. The seven strength items include *Pollution Prevention*, *Recycling*, *Clean Energy*, *Property Plant and Equipment*, *Beneficial Products and Service*, *Communications*, and *Other Strength*. The seven concern items are *Hazardous Waste*, *Regulation Problems*, *Ozone Depleting Chemicals*, *Substantial Emissions*, *Agricultural Chemicals*, *Climate Change*, and *Other Concern*. Each concern adds one point to firms' environmental risk exposure, while each strength reduces environmental risk by one point. Our alternative measure of environmental risk, *EnvRisk_KLD*, is a net measure of environmental concerns, which is defined as the number of environmental concerns minus the number of environmental strengths. By construction, a higher value of *EnvRisk_KLD* indicates a higher level of environmental risk exposure. After merging the KLD database with Compustat, we end up with a sample that consists of 10,010 firm-years from 1992 to 2009.

[Insert Table VIII here]

Table VIII reports the results obtained by estimating equations (1)-(4) using KLD data. Consistent with the main results using the TRI data, we find that *EnvRisk_KLD* is negatively and significant associated with the presence of principal customers and the intensity and duration of the trading relationship. In unreported tests, we further include jointly all environmental concerns and strengths of suppliers in regressions, and find that suppliers' hazardous waste, regulation problems, substantial emissions, and other concern all have negative and significant impacts on the trading relationship.

[39] See among others, El Ghoul et al. (2011), Kim, Park, and Wier (2012), Deng, Kang, and Low (2013), and Di Giuli and Kostovetsky (2014). The seven areas include environment, corporate governance, community, diversity, employ ee relations, human rights, and product. Each area has a set of strength factors and concern factors.

VI. Conclusion

In this paper, we explore the implications of corporate environmental risk for customer-supplier relationships. Using a large sample of firms covered by the Compustat and the TRI program between 1988 and 2009, we document a negative and significant relation between suppliers' environmental risk exposure and the probability of having principal customers. Consistent with this finding, we also provide evidence that customers are more likely to favour firms with low environmental risk relative to their competitors with high environmental risk. Moreover, we examine how suppliers' environmental risk adversely affects its ongoing relationships with principal customers. We find that higher environmental risk leads to a significant decline in the proportion of sales to customers and shorter relationship duration. These results are robust to using environmental data from KLD database to define the measure of environmental risk and controlling for endogeneity issues. Further analyses show that the effects of environmental risk on customer-supplier relationships are more pronounced when the customer's production process displays a higher environmental responsibility, consistent with the notion that environmentally conscious customers are more likely to be concerned about the potential disruptions caused by suppliers' environmental risk.

Taken together, our results indicate that environmental risk weakens supplier firms' ability to initiate and maintain valuable trading relationships with principal customers, thereby revealing an important channel through which being environmentally responsible increases firm value. Our study falls within the line of research that examines the causal link from social and environmental responsibility to firm value.

Appendix A Determinates of corporate environmental risk

This table reports the results of the determinants of environmental risk. The dependent variable is *EnvRisk* at *t*-1, the percentile ranks of *Weighted Releases/Sales*. *DisPro* is the weighted average physical distance between the EPA regional office and the firm's facility. *PopDensity* is defined as the weighted average population density (thousands) within 100 kilometers of the census tract in which a firm's facility operates. *NumFac* is the number of facilities who report non-zero toxicity-weighted waste to TRI. *Sales* is net sales. *M/B* is (*Assets* + Market value of equity - Book value of equity)/*Assets*. *EBITDA*/*Assets* is earnings before interest, taxes, depreciation and amortization scaled by *Assets*. *R&D/Assets* is R&D expenses scaled by *Assets*. *RNDD* is a dummy variable equal to one if R&D expenses are missing and zero otherwise. *CAPEX/PPE* is capital expenditure scaled by gross Property, Plant, and Equipment (*PPE*). *Foreign* is the percentage of revenues from foreign markets. *Leverage* is long-term debt/*Assets*. Dollar values are converted into 2005 constant dollars using the GDP deflator. All explanatory variables are lagged one year relative to the dependent variable. Constant terms, year fixed effects, four-digit SIC industry fixed effects, and headquarter state fixed effects are included in all regressions but their coefficients are not reported. The *t*-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors, which are also corrected for correlation across observations for a given firm. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Dependent Var.	$EnvRisk_{t-1}$
Ln(*1+DisPro*)	0.017***
	(6.0)
PopDensity	-0.069***
	(-3.8)
Ln(*1+NumFac*)	0.165***
	(23.2)
Ln(*Sales*)	-0.034***
	(-8.1)
M/B	0.006
	(1.1)
EBITDA/Assets	-0.075
	(-1.5)
R&D/Assets	-0.173
	(-1.2)
RNDD	0.007
	(0.5)
CAPEX/PPE	-0.000***
	(-2.8)
Foreign	0.030
	(1.3)
Leverage	0.015
	(0.6)
Industry and year fixed effects	Y
State fixed effects	Y
N/R^2	14,286/0.58

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Table I Summary statistics

The sample consists of manufacturing firms jointly covered in Compustat and the TRI program between 1988 and 2009. *Raw Releases* is in million pounds and measured as the amount of chemicals released in a given year. *Weighted Releases* is in millions and obtained by multiplying the mass of each chemical by its toxicity. *EnvRisk* is percentile ranks of *Weighted Releases/Sales*. *Sales* is net sales. *Customer* is a dummy variable that equals one if the firm has at least one principal customer, and zero otherwise. *Government* is a dummy variable that equals one if the firm has at least one principal government customer, and zero otherwise. *Public* (*Private*) is a dummy variable that equals one if the firm has at least one principal public (private) customer, and zero otherwise. *Unidentified* is a dummy variable that equals one if the firm has at least one customer not identified, and zero otherwise. *Assets* is the book value of total assets. *Firm Age* is the number of years elapsed since a firm enters the CRSP database. *EBITDA*/*Assets* is earnings before interest, taxes, depreciation and amortization scaled by *Assets*. *SG&A/Assets* is SG&A expenses scaled by *Assets*. *M/B* is the market-to-book ratio defined as (*Assets* + Market value of equity - Book value of equity)/*Assets*. *Leverage* is long-term debt/*Assets*. *Debt Rating* is a dummy variable equal to one if the firm has a debt rating assigned by Standard & Poor's and zero otherwise. *Tangibility* is the net PPE over *Assets*. *R&D/Assets* is R&D expenses scaled by *Assets*. *RNDD* is a dummy variable that equals one if R&D expenses are missing, and zero otherwise. Dollar values are converted into 2005 constant dollars using the GDP deflator. Q1 and Q3 stand for the 25th and 75th percentiles of the distribution, respectively. All variables are winsorized at the top and bottom 1% of their distributions.

Variables	Mean	Standard Deviation	Minimum	Q1	Median	Q3	Maximum
Raw Releases (*million pounds*)	1.941	14.19	0.000	0.008	0.070	0.515	1080.3
Weighted Releases (*millions*)	9052.3	78389.9	0.000	0.207	9.058	442.2	3558079.0
Weighted Release/Sales	4.914	56.79	0.000	0.001	0.015	0.308	4011.5
EnvRisk	0.500	0.289	0.032	0.250	0.500	0.750	1.000
Customer	0.442	0.497	0.000	0.000	0.000	1.000	1.000
Government	0.065	0.246	0.000	0.000	0.000	0.000	1.000
Public	0.203	0.402	0.000	0.000	0.000	0.000	1.000
Private	0.044	0.205	0.000	0.000	0.000	0.000	1.000
Unidentified	0.263	0.440	0.000	0.000	0.000	1.000	1.000
Assets(*$millions*)	3988.1	10146.2	9.194	201.1	714.8	2754.8	77195.2
Ln(*Assets*)	6.636	1.882	2.219	5.304	6.572	7.921	11.25
Firm Age (*years*)	25.65	15.63	1.000	11.00	25.00	39.00	54.00
EBITDA/*Assets*.	0.094	0.083	-0.236	0.054	0.095	0.140	0.315
SG&A/Assets	0.223	0.148	0.000	0.114	0.197	0.297	0.797
M/B	1.639	0.871	0.678	1.096	1.374	1.865	5.692
Leverage	0.205	0.162	0.000	0.075	0.185	0.300	0.761
Debt Rating	0.455	0.498	0.000	0.000	0.000	1.000	1.000
Tangibility	0.315	0.160	0.040	0.195	0.289	0.408	0.804
R&D/Assets	0.027	0.037	0.000	0.000	0.013	0.036	0.179
RNDD	0.309	0.462	0.000	0.000	0.000	1.000	1.000

Table II The distribution across industries of supplier firms having principal customers

The sample consists of manufacturing firms jointly covered in Compustat and the TRI program between 1988 and 2009. In column (1), *N* is the number of supplier firms having principal customers in a two-digit SIC industry. *%* represents the number of supplier firms having principal customers in a two-digit SIC industry divided by the total number of supplier firms having principal customers. Columns (2) to (5) report the numbers and percentages of supplier firms having government, public, private, and unidentified principal customers, respectively.

		(1)		(2)		(3)		(4)		(5)	
Two-digit	Industry	*Customer*		*Government*		*Public*		*Private*		*Unidentified*	
SIC	Name	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
20	Food & Kindred Products	264	3.53	0	0.00	138	4.02	13	1.76	197	4.44
21	Tobacco Products	27	0.36	0	0.00	25	0.73	0	0.00	4	0.09
22	Textile Mill Products	173	2.32	2	0.18	70	2.04	20	2.70	105	2.37
23	Apparel & other finished products	40	0.54	2	0.18	37	1.08	2	0.27	19	0.43
24	Lumber & Wood Products, Except Furniture	74	0.99	2	0.18	23	0.67	9	1.22	59	1.33
25	Furniture & Fixtures	146	1.95	9	0.82	81	2.36	3	0.41	91	2.05
26	Paper & Allied Products	200	2.68	0	0.00	89	2.59	10	1.35	148	3.33
27	Printing Publishing & Allied Products	88	1.18	0	0.00	42	1.22	15	2.03	63	1.42
28	Chemicals & Allied Products	974	13.0	59	5.41	398	11.60	112	15.1	603	13.6
29	Petroleum Refining & Related Industries	107	1.43	10	0.92	40	1.17	19	2.57	63	1.42
30	Rubber & Miscellaneous Plastics Products	270	3.61	1	0.09	142	4.14	23	3.11	181	4.08
31	Leather & Leather Products	26	0.35	9	0.82	5	0.15	5	0.68	12	0.27
32	Stone, Clay, Glass, & Concrete Products	129	1.73	12	1.10	63	1.84	11	1.49	86	1.94
33	Primary Metal Industries	500	6.69	34	3.12	171	4.98	61	8.24	379	8.54
34	Fabricated Metal Products, Except Machinery & Transportation Equipment	429	5.74	67	6.14	181	5.28	51	6.89	267	6.02
35	Industrial & Commercial Machinery & Computer Equipment	657	8.79	47	4.31	269	7.84	71	9.59	415	9.35
36	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,589	21.3	244	22.4	802	23.4	139	18.8	998	22.5
37	Transportation Equipment	1,000	13.4	386	35.4	579	16.9	115	15.5	326	7.35
38	Measuring, Analyzing, & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	620	8.30	206	18.9	180	5.25	44	5.95	344	7.75
39	Miscellaneous Manufacturing Industries	160	2.14	1	0.09	96	2.80	17	2.30	78	1.76
Sum		7,473	100	1,091	100	3,431	100	740	100	4,438	100

Table III Effects of environmental risk on the presence of principal customers

The sample consists of manufacturing firms jointly covered in Compustat and the TRI program between 1988 and 2009. Probit models are estimated to capture the effects of environmental risk on the presence of principal customers. *Customer* is a dummy variable that equals one if the firm has at least one principal customer, and zero otherwise. *Government* is a dummy variable that equals one if the firm has at least one principal government customer, and zero otherwise. *Public* (*Private*) is a dummy variable that equals one if the firm has at least one principal public (private) customer, and zero otherwise. *EnvRisk* is percentile ranks of *Weighted Releases/Sales*. *Weighted Releases* is obtained by multiplying the mass of each chemical by its toxicity. *Assets* is the book value of total assets. *Firm Age* is the number of years elapsed since a firm enters the CRSP database. *EBITDA*/*Assets* is earnings before interest, taxes, depreciation and amortization scaled by *Assets*. *SG&A/Assets* is SG&A expenses scaled by *Assets*. *M/B* is the market-to-book ratio defined as (*Assets* + Market value of equity - Book value of equity)/*Assets*. *Leverage* is long-term debt/*Assets*. *Debt Rating* is a dummy variable equal to one if the firm has a debt rating assigned by Standard & Poor's and zero otherwise. *Tangibility* is the net PPE over *Assets*. *R&D/Assets* is R&D expenses scaled by *Assets*. *RNDD* is a dummy variable that equals one if R&D expenses are missing, and zero otherwise. All explanatory variables are measured one year before supplier firms' principal customers are observed. Constant terms, year fixed effects, and four-digit SIC industry fixed effects are included in all regressions but their coefficients are not reported. Reported coefficients reflect the marginal effects that capture the impact of a one unit change in explanatory variables on the dependent variable. The *z*-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors, which are also corrected for correlation across observations for a given firm. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Dependent Var.	*Customer*	*Government*	*Public*	*Private*
	(1)	(2)	(3)	(4)
EnvRisk	-0.154***	-0.003	-0.082***	-0.004*
	(-4.2)	(-1.0)	(-3.3)	(-1.9)
Ln(*Assets*)	-0.090***	-0.004***	-0.043***	-0.005***
	(-10.7)	(-5.6)	(-7.7)	(-8.8)
Ln(*Firm Age*)	-0.014	0.004***	-0.019***	-0.000
	(-1.4)	(4.0)	(-2.9)	(-0.5)
EBITDA/*Assets*	0.126	-0.001	0.139**	0.003
	(1.3)	(-0.2)	(2.2)	(0.6)
SG&A/Assets	-0.756***	-0.046***	-0.307***	-0.045***
	(-8.5)	(-6.1)	(-5.1)	(-6.6)
M/B	0.021*	-0.001	-0.002	0.000
	(1.9)	(-1.0)	(-0.3)	(0.1)
Leverage	0.017	-0.001	0.043	-0.000
	(0.3)	(-0.2)	(1.3)	(-0.0)
Debt Rating	0.075***	0.003	0.035**	0.002
	(2.8)	(1.4)	(2.0)	(0.9)
Tangibility	-0.000	-0.020***	0.044	0.010**
	(-0.0)	(-3.1)	(0.9)	(2.1)
R&D/Assets	0.938**	0.032	0.683***	0.058***
	(2.5)	(1.1)	(3.0)	(2.8)
RNDD	-0.049*	-0.005**	-0.037**	-0.001
	(-1.7)	(-2.3)	(-2.0)	(-0.5)
Industry and year fixed effects	Y	Y	Y	Y
N/Pseudo R^2	16,895/0.23	16,895/0.47	16,895/0.23	16,895/0.29

Table IV Effects of environmental risk on customers' choices of suppliers

The analysis is performed using all customer-potential supplier pairs that are constructed based on actual customer-supplier relationships. For each actual customer-supplier relationship in a year, potential suppliers are identified as all firms that are in the same four-digit SIC industry as the actual supplier and covered by the TRI program. Probit models are estimated to capture the effects of environmental risk on customers' decision to choose a supplier among all potential suppliers. The dependent variable, *Supplier*, is a dummy variable that equals one if a potential supplier is chosen by a customer as the actual supplier, and zero otherwise. *EnvRisk* is percentile ranks of *Weighted Releases/Sales*. *Weighted Releases* is obtained by multiplying the mass of each chemical by its toxicity. *Ln*(*NumSup*) is the log of the number of potential suppliers that a customer has. *Alliance* is a dummy variable that equals one if any strategic alliance or joint venture was established between the customer and its potential supplier, and zero otherwise. Other variable definitions are in the legend of Table III. All explanatory variables are measured one year before supplier firms' principal customers are observed. Constant terms, year fixed effects, and four-digit SIC industry fixed effects are included in all regressions but their coefficients are not reported. Column (1) studies the decisions of both public and private customers. Columns (2) and (3) investigate the choices of public and private customers, respectively. Reported coefficients reflect the marginal effects that capture the impact of a one unit change in explanatory variables on the dependent variable. The *z*-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors, which are also corrected for correlation across observations for a given relationship. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Dependent Var. = *Supplier*	Public and Private Customers (1)	Public Customers (2)	Private Customers (3)
EnvRisk	-0.040***	-0.043***	-0.029*
	(-3.0)	(-2.7)	(-1.9)
Ln(*Assets*)	-0.030***	-0.026***	-0.038***
	(-10.4)	(-7.4)	(-9.9)
Ln(*Firm Age*)	-0.014***	-0.018***	-0.000
	(-4.0)	(-4.3)	(-0.1)
EBITDA/Assets	0.088***	0.129***	0.023
	(2.8)	(3.3)	(0.6)
SG&A/Assets	-0.293***	-0.259***	-0.369***
	(-8.9)	(-6.7)	(-6.8)
M/B	-0.003	-0.006	-0.001
	(-0.8)	(-1.5)	(-0.2)
Leverage	0.031	0.037	0.026
	(1.6)	(1.6)	(1.0)
Debt Rating	0.013	0.012	0.006
	(1.5)	(1.1)	(0.5)
Tangibility	0.027	0.004	0.090***
	(1.0)	(0.1)	(2.6)
R&D/Assets	0.356***	0.342***	0.461***
	(3.5)	(2.8)	(3.3)
RNDD	-0.026***	-0.028**	-0.013
	(-2.7)	(-2.4)	(-1.3)
Ln(*NumSup*)	-0.103***	-0.109***	-0.072***
	(-10.1)	(-8.9)	(-5.0)
Alliance	0.284***	0.272***	0.235***
	(7.1)	(6.4)	(2.6)
Industry and year fixed effects	Y	Y	Y
N/Pseudo R^2	42,210/0.13	32,802/0.12	9,408/0.22

Table V Effects of environmental risk on the customer-supplier relationship

The analysis is performed based on actual customer-supplier relationships in which customers are public or private firms. *EnvRisk* is percentile ranks of *Weighted Releases/Sales*. *Weighted Releases* is obtained by multiplying the mass of each chemical by its toxicity. Other variable definitions are in the legends of Table III and Table IV. In column (1), we estimate Tobit regression with double censoring with the dependent variable, *Intensity*, being the fraction of a supplier's sales that are made to the principal customer. Column (2) presents results obtained using the Cox proportional hazard model to examine the effect of environmental risk on the duration of customer-supplier relationships. $\overline{EnvRisk}$ is the average *EnvRisk* over the duration of the relationship. Column (3) reports results from the Probit model investigating whether environmental risk adversely affects the likelihood of relationship continuation. *Continue* is a dummy variable that equals one if a principal customer-supplier relationship continues in year *t*, and zero otherwise. Constant terms, year fixed effects, and four-digit SIC industry fixed effects are included in all regressions but their coefficients are not reported. The *z*-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors, which are also corrected for correlation across observations for a given relationship. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) Tobit	(2) Cox	(3) Probit
Dependent Var.	*Intensity*		*Continue*
EnvRisk	-0.024**		-0.041**
	(-2.0)		(-2.0)
$\overline{EnvRisk}$		0.232**	
		(2.1)	
Ln(*Assets*)	-0.015***	-0.099***	0.011**
	(-5.4)	(-4.1)	(2.4)
Ln(*Firm Age*)	-0.010***	0.111***	-0.000
	(-2.7)	(4.2)	(-0.1)
EBITDA/*Assets*	0.030	-1.011***	0.125**
	(1.0)	(-4.5)	(2.3)
SG&A/Assets	-0.103***	-0.450*	0.117**
	(-3.1)	(-1.8)	(2.1)
M/B	0.006	0.010	0.002
	(1.4)	(0.4)	(0.3)
Leverage	-0.022	-0.241	0.040
	(-1.3)	(-1.5)	(1.3)
Debt Rating	0.011	-0.075	0.012
	(1.3)	(-1.0)	(0.8)
Tangibility	0.067**	-0.078	0.055
	(2.1)	(-0.4)	(1.4)
R&D/Assets	0.220*	1.230**	-0.115
	(1.9)	(2.0)	(-0.7)
RNDD	0.005	0.130**	0.008
	(0.7)	(2.0)	(0.6)
Ln(*NumSup*)	-0.007	0.125	0.007
	(-0.9)	(1.5)	(0.5)
Alliance	0.056***	0.004	-0.043
	(3.8)	(0.0)	(-1.4)
Intensity		-1.815***	-0.058*
		(-8.2)	(-1.8)
Industry and year fixed effects	Y	Y	Y
N/Log likelihood	7,318/5659.5	1,820/ -9897.4	6,826/-2924.0

Table VI Tests for endogeneity

All regressions include the same control variables as those used in Tables III-VI, but their coefficients are not tabulated. *Customer* is a dummy variable that equals one if the firm has at least one principal customer, and zero otherwise. *Supplier* is a dummy variable that equals one if a potential supplier is chosen by a customer as the actual supplier, and zero otherwise. *Intensity* is the fraction of a supplier's sales that are made to the principal customer. Column (4) presents results obtained using the Cox proportional hazard model to examine the effect of environmental risk on the duration of customer-supplier relationships. $\overline{EnvRisk}$ is the average *EnvRisk* over the duration of the relationship. *Cash/Assets* is the cash-to-assets ratio. *HP* index is $-0.737\times Ln(Assets)+0.043\times Ln(Assets)^2-0.04\times Firm\ Age$. *Charity* is a dummy variable that equals one if firm has at least one strength in the KLD charity-related categories. *CharityDum* is a dummy variable that equals to one if is *Charity* is missing, and zero otherwise. $EnvRisk_{t-3}$ is percentile ranks of *Weighted Releases/Sales* at *t*-3. *EnvRisk_RRT* is the toxicity-weighted and log-transformed amount of waste that is recycled, recovered, and treated scaled by *Sales*. *Prevention* is the toxicity-weighted and log-transformed amount of waste reduced by pollution prevention activities scaled by *Sales*. In Panel E, *EnvRisk* is predicted by the model presented in Appendix A and $\overline{EnvRisk}$ is calculated based on the predicted *EnvRisk*. The *z*-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors, which are also corrected for correlation across observations for a given firm (column (1)) and for a given relationship (columns (2)-(4)). The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. In Panel E, 95% confidence intervals in square brackets are calculated from 500 bootstrap replications of the two-step estimation based on resampling from the data set with replacement of clusters.

	Column (1) of Table III	Column (1) of Table IV	Column (1) of Table V	Column (2) of Table V
	(1) Probit	(2) Probit	(3) Tobit	(4) Cox
Dependent Var.	*Customer*	*Supplier*	*Intensity*	
	Panel A: Controlling for financial constraints and cash holdings			
EnvRisk	-0.160***	-0.040***	-0.023*	
	(-4.3)	(-3.1)	(-1.9)	
$\overline{EnvRisk}$				0.227**
				(2.1)
Cash/Assets	-0.199**	-0.009	0.009	0.311*
	(-2.3)	(-0.4)	(0.4)	(1.7)
HP index	0.107**	0.001	0.036*	0.023
	(2.2)	(0.1)	(1.9)	(0.1)
N	16,893	42,206	7,318	1,820
	Panel B: Controlling for charitable contribution			
EnvRisk	-0.178***	-0.048***	-0.022*	
	(-4.5)	(-3.6)	(-1.8)	
$\overline{EnvRisk}$				0.206*
				(1.7)
Charity	-0.013	0.014	0.005	0.088
	(-0.3)	(0.8)	(0.5)	(0.4)
CharityDum	-0.000	-0.011	-0.000	0.152*
	(-0.0)	(-1.3)	(-0.1)	(1.7)
N	13,686	37,375	6,440	1,587
	Panel C: Replacing $EnvRisk_{t-1}$ by $EnvRisk_{t-3}$			
$EnvRisk_{t-3}$	-0.141***	-0.032**	-0.039***	
	(-3.5)	(-2.3)	(-3.0)	
$\overline{EnvRisk_{t-3}}$				0.210*
				(1.7)
N	14,195	36,878	6,171	1,539
	Panel D: Controlling for environmental management and pollution prevention activities			
EnvRisk	-0.154***	-0.037***	-0.023*	
	(-4.1)	(-2.8)	(-1.9)	
$\overline{EnvRisk}$				0.240**
				(2.0)
EnvRisk_RRT	0.018	-0.013	0.020	0.088
	(0.3)	(-0.7)	(0.8)	(1.3)
Prevention	-0.041	-0.020	-0.020	-0.089
	(-0.6)	(-0.9)	(-0.8)	(-1.2)
N	16,895	42,210	7,318	1,656
	Panel E: Employing a two-step bootstrapping approach			
EnvRisk	-0.239	-0.161	-0.030	
	[-.417,-.061]	[-.303,-.019]	[-.055,-.004]	
				0.742
$\overline{EnvRisk}$				[.168,1.31]

Table VII Cross-sectional differences in the effects of environmental risk on customer-supplier relationships

This table partitions firms into subsamples and re-estimates equations (2)-(4). All regressions include the same control variables as those used in Tables III-VI, but their coefficients are not tabulated. *Supplier* is a dummy variable that equals one if a potential supplier is chosen by a customer as the actual supplier, and zero otherwise. *Intensity* is the fraction of a supplier's sales that are made to the principal customer. Columns (5)-(6) present results obtained using the Cox proportional hazard model to examine the effect of environmental risk on the duration of customer-supplier relationships. $\overline{EnvRisk}$ is the average *EnvRisk* over the duration of the relationship. In columns (1)-(4), a firm is classified as having customers with high (low) environmental risk if their customers' environmental risk is above (below) the sample median. In columns (5)-(6), a firm is classified as having customers with high (low) environmental risk if their customers' environmental risk over the duration of the relationship is above (below) the sample median. The *z*-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors, which are also corrected for correlation across observations for a given relationship. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Column (1) of Table IV		Column (1) of Table V		Column (2) of Table V	
	(1) Probit	(2) Probit	(3) Tobit	(4) Tobit	(5) Cox	(6) Cox
Dependent Var.	*Supplier*	*Supplier*	*Intensity*	*Intensity*		
	Low	*High*	*Low*	*High*	*Low*	*High*
EnvRisk	-0.047**	0.017	-0.067***	0.028		
	(-2.0)	(0.5)	(-2.8)	(1.1)		
					0.446*	0.176
$\overline{EnvRisk}$					(1.7)	(0.6)
N	8,455	9,175	1,445	1,642	425	425

Table VIII Alternative measure of environmental risk

The sample consists of manufacturing firms jointly covered in Compustat and the KLD database between 1992 and 2009. The net score of KLD environmental rating (*EnvRisk_KLD*) is used as an alternative measure of environmental risk. *EnvRisk_KLD* is defined as the total environmental concerns minus the total environmental strengths. *Customer* is a dummy variable that equals one if the firm has at least one principal customer, and zero otherwise. *Supplier* is a dummy variable that equals one if a potential supplier is chosen by a customer as the actual supplier, and zero otherwise. *Intensity* is the fraction of a supplier's sales that are made to the principal customer. Column (4) presents results obtained using the Cox proportional hazard model to examine the effect of environmental risk on the duration of customer-supplier relationships. $\overline{EnvRisk\_KLD}\_Dum$ is a dummy variable that equals one if the average *EnvRisk_KLD* over the duration is greater than or equal to zero, and zero otherwise. Other variable definitions are in the legends of Table III and Table IV. All regressions include year and industry fixed effects, defined based on two-digit SIC code. The *z*-statistics in parentheses are calculated from the Huber/White/Sandwich heteroskedastic consistent errors, which are also corrected for correlation across observations for a given firm (column (1)) and for a given relationship (columns (2)-(4)). The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Dependent Var.	(1) Probit *Customer*	(2) Probit *Supplier*	(3) Tobit *Intensity*	(4) Cox
EnvRisk_KLD	-0.031**	-0.007***	-0.007*	
	(-2.1)	(-3.0)	(-1.8)	
$\overline{EnvRisk\_KLD}\_Dum$				0.238*
				(1.8)
Ln(*Assets*)	-0.039***	-0.003**	-0.006**	-0.045
	(-3.5)	(-2.3)	(-2.2)	(-1.4)
Ln(Firm Age)	-0.025**	-0.005***	-0.009**	0.029
	(-2.0)	(-3.4)	(-2.6)	(0.9)
EBITDA/*Assets*	0.479***	0.048***	-0.044*	-0.591***
	(5.5)	(4.9)	(-1.8)	(-3.2)
SG&A/Assets	-0.247***	-0.005	-0.107***	-0.706***
	(-3.7)	(-0.7)	(-5.1)	(-4.3)
M/B	-0.018**	-0.002***	-0.000	-0.004
	(-2.5)	(-2.7)	(-0.1)	(-0.2)
Leverage	0.016	0.018**	-0.016	-0.158
	(0.2)	(2.4)	(-0.9)	(-0.9)
Debt Rating	0.024	-0.005	-0.002	-0.107
	(0.8)	(-1.3)	(-0.2)	(-1.4)
Tangibility	-0.240***	-0.015	0.017	-0.103
	(-2.8)	(-1.2)	(0.5)	(-0.5)
R&D/Assets	0.205	0.032*	0.203***	0.264
	(1.2)	(1.9)	(4.0)	(0.7)
RNDD	-0.057*	-0.005	0.001	-0.193**
	(-1.7)	(-0.8)	(0.1)	(-2.0)
Ln(*NumSup*)		-0.044***	-0.001	0.074**
		(-8.6)	(-0.4)	(2.5)
Alliance		0.107***	0.068***	0.109
		(7.0)	(5.0)	(1.0)
Intensity				-1.309***
				(-5.5)
Industry and year fixed effects	Y	Y	Y	Y
N/Log likelihood	10,010/-5919.9	68,388/-13179.0	5,877/1481.9	1,836/ -7993.4