Do Major Customers Help or Hurt Innovation? The Effects of Customer-Base Concentration on Radical and Incremental Innovation

Clara Xiaoling Chen
University of Illinois at Urbana-Champaign
cxchen@illinois.edu

Wei Jiang
Jinan University
tweijiang@jnu.edu.cn

Wentao Yao
University of Hong Kong
yaowt029@hku.hk

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ABSTRACT

We examine the effect of a firm's customer-base concentration on two types of firm innovation: radical (i.e., a revolutionizing breakthrough from existing technology) versus incremental innovation (i.e., minor improvements to existing practices). Drawing on theories of resource dependence and resource allocation, we predict that dependence on major customers can discourage a firm from making risky investments in radical innovation and encourage a firm to invest in incremental innovation. We test our hypotheses with a sample of 11,940 firm-year observations between 1984 and 2010. Consistent with our predictions, we find that customer-base concentration is positively associated with incremental innovation, and such association is more pronounced for firms with high investment irreversibility (i.e., low asset redeployability). Although we do not find a main effect of customer-base concentration on radical innovation, we find an interaction effect between customer-base concentration and investment irreversibility such that radical innovation is significantly lower in firms with high customer concentration and high investment irreversibility than in other firms. Our results suggest that firms with high customer concentration may allow their innovation resource allocation decisions to be shaped by major customers, leading to incremental innovations at the expense of radical innovations.

Keywords: *Customer-base Concentration, Radical Innovation, Incremental Innovation, Asset Redeployability*

1. INTRODUCTION

Innovation has long been considered to be the single most important source of long-term economic growth (e.g., Schumpeter 1912; Solow 1957; Levinson 2016). For firms, innovation represents vital drivers of competitive advantages (e.g., Porter 1992; Hall 1993). Prior literature has examined the determinants of firm-level innovation with a focus on the resources that are controlled *within* a firm (e.g., Holthausen, Larcker, and Sloan 1995; Manso 2011; Del Canto and Gonzalez 1999). Yet, innovation not only depends on intrafirm inputs such as R&D and effort, but also on external factors such as a firm's supply chain characteristics. In particular, with increasing market competition, many firms put their customers first and do their best to meet customer needs and preferences (Peters 1984). Prior research suggests that customers, especially major customers, can provide the supplying firm with information about consumer needs and encourage the supplier to innovate (Fang 2008; Coviello and Joseph 2012). However, existing evidence on the influence of major customers on firm-level innovation is mixed. On the one hand, prior literature suggests that customer involvement can help the supplier generate new ideas about product development (Lin, Chen, and Chiu 2010; Tsai 2009; von Hippel 1988). On the other hand, increased requirements imposed by major customers (Kraljic 1983; Liebeskind 1996; Lau 2009) can constrain the supplier firm's innovativeness (Christensen and Bower 1996). Furthermore, prior studies on the impact of customers on the supplier firm's innovation do not distinguish between radical vs. incremental innovation. In this study, we examine the effect of customer-base concentration on two different types of innovation: radical innovation and incremental innovation.

The extant literature on the effects of organizational design, governance mechanisms, and incentives on innovation (e.g., Holthausen, Larcker, and Sloan 1995;

Lerner and Wulf 2007; Manso 2011; Ederer and Manso 2013) has not distinguished between different types of innovation. Recent literature has started to make a distinction between radical and incremental innovation and provides some initial evidence that these two types of innovation are driven by different factors (e.g., Balsmeier, Fleming, and Manso 2017). Radical innovation is defined as an organizational change that represents a major departure from existing products, services, or procedures. Radical innovation tends to cost a large amount of time and money and have a more uncertain development process, and hence, it is associated with greater risk for the firm (Ettlie, Bridges, and O'Keefe 1984; Cardinal 2001; Slater, Mohr, and Sengupta 2014). Incremental innovation is defined as minor changes to existing products, services, or procedures. These changes typically cost a small amount and money and are associated with a lower level of risk for the firm (Dewar and Dutton 1986). Even though incremental innovation plays an important role in maintaining a firm's position in more stable and predictable environments, radical innovation can be critical to the long-term survival of firms in uncertain environments (Davila, Foster, and Li 2009b; Bedford 2015).

Drawing on prior literatures in accounting, finance, and operations management, we predict that a firm's customer-base concentration is positively associated with its incremental innovation and negatively associated with its radical innovation for two reasons. First, prior literature suggests that a supplier can decrease product substitution risk by making customization, specification, or product-fit improvements for its customers (Clark and Fujimoto 1991; Nishiguchi 1994). Hence, to the extent that major customers account for a large share of the supplier firm's revenue, the supplier firm is motivated to focus on customization, specification or product-fit improvements on existing products in order to make it more difficult for the major customers to fulfill similar needs elsewhere. Such improvements generally lead to incremental innovation, which by definition, improves or modifies existing practices. Second, theories of resource dependence and resource allocation suggest that a firm's resource allocation decisions in technology innovations can be heavily influenced by the demands of its customers. Christensen and Bower (1996)'s study of the world disk drive industry provide evidence from the real world that industry leaders failed to develop radical innovations because they target resource allocation to incremental innovations demanded by powerful customers. Because radical innovations often do not have an existing customer base, firms often fail to allocate resources to projects targeted at radical innovations. In addition, as non-financial stakeholders of the suppliers, major customers monitor their suppliers (Cremers, Nair, and Peyer 2008; Kale, Kedia, and Williams 2015) and often require their suppliers to make relationship-specific investments in assets that have limited resale opportunities should the relationship fail (e.g., Allen and Phillips 2000; Grinblatt and Titman 2002; Banerjee, Dasgupta, and Kim 2008; Itzkowitz 2013). As a firm's customer-base concentration increases, major customers tend to have greater bargaining power and hence are more likely to put pressure on the supplier firm to allocate resources to incremental innovations that improves or modifies existing practices.

We then consider how investment irreversibility moderates the effect of customer-base concentration on innovation. Drawing on prior literature in finance and economics on investment irreversibility, we expect investment irreversibility to amplify the positive association between customer-base concentration and incremental innovation as well as the negative association between customer-base concentration and radical innovation. This is because firms with greater investment irreversibility are more cautious about investment decisions than those with less investment irreversibility (Kim and Kung 2017). As discussed above, theories of resource dependence and resource allocation suggest that a firm's resource allocation decisions in technology innovations can be heavily influenced by the demands of its customers. Because radical innovations tend to have higher uncertainty and incremental innovations tend to have less uncertainty, we expect high-customer-concentration firms with high investment irreversibility to allocate even fewer resources to radical innovations and even more resources to incremental innovation than those with low investment irreversibility. Furthermore, investment irreversibility will exacerbate the hold-up problem when the supplier firm has to switch customers. The higher switching cost leads to the supplier firm's greater dependence on customers and hence lower bargaining power in the supplier-customer relationship (Kim and Zhu 2018). A supplier firm's lower bargaining power in the supplier-customer relationship can further motivate the supplier firm to allocate innovation resources to incremental innovations catering to the needs of major customers, leaving less resources for radical innovation.

We test our hypotheses with a sample of 11,940 firm-year observations between 1984 and 2010. Following prior literature (e.g., Patatoukas 2012; Irvine, Park, and Yıldızhan 2016), we measure customer-base concentration with a concentration measure ("CC") that captures both the number of major customers with which a focal firm interacts with and each customer's relative importance to the firm. Following Azoulay, Zivin, and Manso (2011) and Balsmeier, Fleming, and Manso (2017), we distinguish between radical and incremental innovation with patent-based data, including the patent's relative citation performance to other patents within firm in a given year, whether the patent is filed in a class that the firm has never or at least filled one patent before, self-cited patents, back-cited patents, and claims. To measure investment irreversibility, we follow Kim and Kung (2017)'s asset-level redeployability score (AR), which is calculated as the proportion of firms or industries that use a given asset. Consistent with our predictions, we find that customer-base concentration is positively associated with incremental innovation, and such association is more pronounced for firms with high investment irreversibility (i.e., low asset redeployability). We do not find a main effect of customer-base concentration radical innovation. However, we find some evidence for an interaction effect between customer-base concentration and investment irreversibility such that radical innovation is significantly lower in firms with high customer concentration and high investment irreversibility than in other firms. Our results are robust to alternative measures of customer-base concentration and alternative model specifications.

Our study contributes to two streams of literature. First, we extend the growing accounting literature on innovation (e.g., Davila 2000; Bisbe and Otley 2004; Ditillo 2004; Bisbe and Malagueño 2009; Davila, Foster, and Li 2009b; Chenhall, Kallunki, and Silvola2011; Grabner 2014). Our study answers the call for more research on the antecedents of radical versus incremental innovation (e.g., Davila, Foster, and Li 2009b). We complement prior studies that focus on the effect of internal firm characteristics (e.g., corporate governance, incentive system design) and CEO characteristics on innovation by shedding light on the impact of two external factors on innovation: customer concentration and investment irreversibility. Our empirical evidence suggests that supply chain characteristics play an important role in firms' innovation resource allocations.

Second, this study contributes to a growing accounting literature on customer concentration (e.g., Patatoukas 2012; Irvine, Park, and Yıldızhan 2016; Cen, Dasgupta, and Sen 2015; Gosman, Kelly, Olsson, and Warfield 2004; Matsumura and Schloetzer 2018). While the extant literature provides evidence on the influence of customer concentration on a focal firm's financial policies and performance, we complement this literature by providing evidence on the impact of customer concentration on innovation. Notably, while prior studies often document potential benefits of customer concentration for the focal firm, results of our study suggest a potential downside of customer concentration. That is, our results suggest that firms with high customer concentration may allow their innovation resource allocation decisions to be shaped by major customers, leading to incremental innovations at the expense of radical innovations. Even though this strategy may work in the short term, it may hamper the supplier firm's performance in the long term (Christensen and Bower 1996).

2. HYPOTHESIS DEVELOPMENT

2.1 The effect of customer-base concentration on firm performance and risk

The Statement of Financial Accounting Standards No.131 (SFAS 131) requires firms to disclose external customers that individually account for 10% or more of the firm's annual revenue. Existing literature largely shows that working with such major customers brings net positive benefits to the supplier's performance and profitability (Cen, Dasgupta, and Sen 2015; Patatoukas 2011; Irvine, Park, and Yıldızhan 2016). Notably, Patatoukas (2011) concludes in his large sample investigation that suppliers with concentrated customer bases improve their operating efficiencies by reducing SG&A

expenses per dollar of sales. Kalwani and Narayandas (1995) document that manufacturing firms that work closely with their major customers are better able to reduce control costs and inventory costs. Nevertheless, a reliance on a small group of major buyers can enhance a supplier's cash-flow volatility, structural risk, and/or financial distress cost (Ravenscraft 1983; Piercy and Lane 2006; Gosman and Kohlbeck 2009; Albuquerque, Papadakis, and Wysocki 2014; Dhaliwal, Michas, Naiker, and Sharma 2013).[1] In particular, Albuquerque, Papadakis, and Wysocki (2014) find that suppliers with higher customer concentration face higher idiosyncratic risk. Existing evidence on the influence of major customers on firm-level innovation is mixed. On the one hand, some studies suggest that involvement of major customers can help the supplier firm generate new ideas about product development (Lin, Chen, and Chiu 2010; Tsai 2009; von Hippel 1988; Arlbjørn and Paulraj 2013).[2] On the other hand, other studies suggest that major customers may impose requirements on the supplier firm (Kraljic 1983; Liebeskind 1996; Lau 2009) and can constrain the supplier firm's innovativeness (Christensen and Bower 1996). In this study, we complement prior literature on the consequences of customer concentration by examining the effect of customer-base concentration on innovation. In particular, we seek to understand the impact of customer-based concentration on two different types of innovation: radical innovation and incremental innovation.

[1] High CC firms also have lower financial leverage ratios (Banerjee, Dasgupta, and Kim 2008; Kale and Shahrur 2007), hold more cash (Itzkowitz 2013), and engage is more tax avoidance Huang, Lobo, Wang, and Xie 2016) – all due to the uncertainties or demands of major customers. These findings should also have implications on a firm's innovation strategy.

[2] For example, at little cost, Siemens Wind Power A/S incorporated a major customer's idea to improve the wind turbine blades' lightning protection system, and LEGO interacted with its supply chain partners to develop new packaging solutions that will provide benefits in the retail outlets (Arlbjørn and Paulraj 2013).

2.2 The effect of customer-base concentration on radical vs. incremental innovation

Innovation is an exploration of unknown approaches and untested methods (Holmstrom 1989). Within economics, management, and marketing literature, the radical versus incremental innovation dichotomy is widely used to contrast different levels of innovativeness (e.g., Arnold, Fang, and Palmatier 2011; Alexander and Knippenberg 2014; Doran and Ryan 2014; Maes and Sels 2014). Radical innovations are revolutionary changes that represent distinct departures from existing practice (Ettlie 1983).[3] That is, radical innovation produces fundamentally new changes in the firm's technology, products, processes, and organizational structure (Dewar and Dutton 1986). By contrast, incremental innovations are minor improvements or simple adjustments in the firm's currently existing practices (e.g., Munson and Pelz 1979; Dewar and Dutton 1986). For incremental innovation, the magnitude of novel technological content is low as it does not significantly disrupt or deviate from preexisting methods or knowledge (e.g., Balsmeier, Fleming, and Manso 2017). Recent literature increasingly makes a distinction between these two types of innovation and provides some initial evidence that these two types of innovation have different determinants (e.g., Balsmeier, Fleming, and Manso 2017; Byun, Chok, Dai, and Ding 2019). For example, Balsmeier, Fleming, and Manso (2017) find that when firms have more independent boards of directors, they tend to focus more efforts on more familiar areas of technology but do not allocate more efforts to more risky innovation activities. Similarly, Byun, Chok, Dai, and Ding (2019) find that although technology spillovers

[3] The Oslo Manual (2005) of the Organization for Economic Co-operation and Development (OECD) defines organizational innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations."

increase firms' overall innovation, such increase in overall innovation outputs are mainly driven by exploitation of existing knowledge and the resulting incremental innovation.

We predict that a focus on major customers can have a differential impact on radical versus incremental innovation. Specifically, drawing on prior literatures in accounting, finance, and operations management, we predict that customer-base concentration is positively associated with radical innovation and negatively associated with incremental innovation for the following reasons. First, a supplier faces the risk of losing substantial future revenue if a major customer decides to develop products internally or switches to a different supplier. Losing one major customer can lead to a sizable drop in the supplier's cash flows (Ravenscraft 1983; Balakrishnan, Linsmeier, and Venkatachalam 1996; Piercy and Lane 2006; Hertzel, Li, Officer, and Rodgers 2008), and this risk will be greater for firms with high customer-base concentration since customer-base concentration, by definition, captures both the number of major customers with which a focal firm interacts with and each customer's relative importance to the firm's total annual revenue. To mitigate the risk of losing major customers, suppliers can make it more difficult for their major customers to fulfill similar needs elsewhere by focusing on product modifications or improvements oriented toward major customers because the risk of product substitution can decrease in customization, specification, or improvements in product-fit (Clark and Fujimoto 1991; Nishiguchi 1994; Fischer and Reuben 2004). Such improvements generally lead to incremental innovation rather than radical innovation.

Second, theories of resource dependence and resource allocation suggest that a firm's resource allocation decisions in technology innovations can be heavily influenced by the demands of its customers. Christensen and Bower (1996)'s study of the world disk drive industry provide evidence from the real world that industry leaders failed to develop radical innovations because they target resource allocation to incremental innovations demanded by powerful customers. Because radical innovations often do not have an existing customer base, firms often fail to allocate resources to projects targeted at radical innovations. In addition, as non-financial stakeholders of the suppliers, major customers monitor their suppliers (Cremers, Nair, and Peyer 2008; Kale, Kedia, and Williams 2015) and often require their suppliers to make relationship-specific investments in assets that have limited resale opportunities should the relationship fail (e.g., Allen and Phillips 2000; Grinblatt and Titman 2002; Banerjee, Dasgupta, and Kim 2008; Itzkowitz 2013). As a firm's customer-base concentration increases, major customers tend to have greater bargaining power and hence are more likely to put pressure on the supplier firm to allocate resources to incremental innovations targeted at improving current products of the major customers (Fischer and Reuben 2004).

Third, prior literatures suggests that major customers can provide the supplier firm with operational efficiency improvement such as faster inventory turnover and better working capital management (Patatoukas 2011; Kalwani and Narayandas 1995; Yli-Renko and Jvanakiraman 2008).[4] That is, working with major customers allows streamlined processing, elimination of non-value adding activates along the supply chain, and less rework (Dean and Snell 1996). Such improvements will lead to incremental innovation, which, by definition, involves fine-tuning existing knowledge and improving existing practices. On the other hand, the close relationship between a firm and its major customers

[4] Studies show that close bilateral relationships entail high level coordination between a supplier and its major customers but enhances investment effectiveness, operational effectiveness, and cost efficiency (Cannon and Homburg 2001; Sobrero and Roberts 2001; Vickery, Jayaram, Droge, and Calantone 2003).

is likely to reduce the communication between the firm and its other customers and potential customers (Zhou, Zhang, Sheng, Xie, and Bao 2014), limiting potential opportunities for exploration activities and innovation.

Based on the above discussion, we predict that firms with high customer-base concentration are more likely to allocate their innovation resources to major-customer-oriented improvements or modifications of existing practices, and are less likely to focus on fundamental shifts from existing practices. We expect this resource allocation strategy to lead to more incremental innovation and less radical innovation. This discussion leads to our first set of hypotheses:

Hypothesis 1a: *There is a positive association between a firm's customer-base concentration and its incremental innovation.*

Hypothesis 1b: *There is a negative association between a firm's customer-base concentration and its radical innovation.*

We note that Hypothesis 1b is not without tension. Because radical innovation usually requires a longer development cycle and a greater amount of resources, firms engaging in radical innovation face larger financial pressure and risk. To the extent that customer concentration is positively associated with a firm's accounting performance (Patatoukas 2012), firms with higher customer concentration may be better able to withstand the financial pressure and risk in the process of radical innovation, hence facilitating radical innovation.

2.3 The moderating role of investment irreversibility

We then consider how investment irreversibility moderates the effect of customer-base concentration on innovation. A large theoretical literature on investment irreversibility (Bernanke 1983; McDonald and Siegel 1986; Abel and Eberly 1996) suggests that firms whose investments are more irreversible are more sensitive to negative outcomes because disposing of assets is more costly than acquiring assets. When investment irreversibility is high, assets have low liquidation values, making firms more vulnerable in bad states of the world (Caballero 1991; Bloom 2009).

Drawing on prior literature in finance and economics on investment irreversibility, we expect investment irreversibility to amplify the positive association between customer-base concentration and incremental innovation as well as the negative association between customer-base concentration and radical innovation. This is because firms with greater investment irreversibility are more cautious about investment decisions than those with less investment irreversibility (Kim and Kung 2017). For example, using a dichotomous measure of the existence of used asset markets for Italian firms, Guiso and Parigi (1999) find that the negative association between uncertainty and the demand-investment sensitivity is more pronounced for firms with greater investment irreversibility. Using asset redeployability as a reverse measure of investment irreversibility, Kim and Kung (2017) find that facing higher uncertainty, firms with greater investment irreversibility reduce investment more than those with lower investment irreversibility. As discussed above, theories of resource dependence and resource allocation suggest that a firm's resource allocation decisions in technology innovations can be heavily influenced by the demands of its customers. Because radical innovations are featured with higher uncertainty, we expect high-customer-concentration firms with high investment irreversibility to allocate even fewer resources to radical innovations than those with low investment irreversibility. Conversely, since incremental innovations tend to be less costly and involve less uncertainty compared to radical innovations, we expect high-customer-concentration firms with high investment irreversibility to allocate even more resources to incremental innovations than those with low investment irreversibility.

Furthermore, investment irreversibility will exacerbate the hold-up problem when the supplier firm switches customers, leading to greater supplier dependence on customers and hence lower bargaining power for the supplier firm in the supplier-customer relationship (Kim and Zhu 2018). Such an imbalance in bargaining power can further motivate the supplier firm to cater even more to the needs of major customers and engage in incremental innovations targeted at major customers rather than allocate resources to radical innovations.

Following Kim and Kung (2017), we use asset redeployability (the extent to which assets have alternative uses) as a reverse measure of investment irreversibility. The above discussion leads to our second set of hypotheses:

Hypothesis 2a: *The positive association between customer concentration and incremental innovation is more pronounced for firms with high investment irreversibility.*

Hypothesis 2b: *The negative association between customer concentration and radical innovation is more pronounced for firms with high investment irreversibility.*

3. DATA AND RESEARCH DESIGN

3.1 Sample

Our sample is determined by the joint availability and reliability of several databases. We obtain customer information from Compustat segment database, firm-level financial characteristic from Compustat fundamental annual Database, innovation data from National Bureau of Economic Research (NBER) patent citation database as well Harvard Business School Patent Network Dataverse, and investment irreversibility data from Kim and Kung (2017). The final sample starts at 1984 due to the availability of investment irreversibility data, and the sample ends at 2010 because this is the last year patent data is public available.[5] Table 1 discusses our sample selection procedure in detail. Following Balsmeier, Fleming, and Manso (2017) and Chu, Tian, and Wang (2019), we only include those firms that are identified by NBER patent citation database. This procedure avoids the measurement error concern that otherwise would exist if firms that have not been identified by NBER Patent database were assigned zero patents. We also exclude utility firms (SIC codes from 4900 to 4999) and financial firms (SIC codes from 6000 to 6999) from our sample. Further, we also exclude firms that have zero granted patents (non-innovative firms) throughout our sample period. The final sample consists of 11,940 firm-year observations from 1984 to 2010.

[Table 1 Here]

[5] The NBER patent citation database provides detailed patent information from United States Patent and Trademark Office (USPTO) from 1976 to 2006. We then augment the NBER database with the Harvard Business School (HBS) Patent Network Dataverse to extend the coverage to 2010.

3.2 Variables

Customer-base concentration

Our primary independent variable is customer-base concentration. Following Patatoukas (2011) and Irvine, Park, and Yıldızhan (2016), we sum the squares of the ratios of a focal firm's sales to its major customers to create a firm-level Herfindahl-Hirschman Index as follows:

$$CC_{i,t} = \sum_{j=1}^{n} \left(\frac{Sales\ to\ Customers_{i,j,t}}{Total\ Revenue_{i,t}} \right)^2$$

If firm ***i*** has n major customers in year *t*, then the measure of customer concentration ($CC_{i,t}$) of the firm is defined as the sum of the squares of the sales shares to each major customer. The sales share to each customer *j* in year *t* is calculated as the ratio of firm *i*'s sales to customer *j* in year *t* scaled by firm *i*'s total sales in year *t*. Customer Concentration (CC, thereafter) measures firms' reliance on their major customers and captures both the number of major customers with which a focal firm interacts with and each customer's relative importance to the firm's total annual revenue, making it an appropriate summary measure for a firm's customer base composition. The higher the CC, the more concentrated is the firms' customer.

Total Innovation, incremental innovation, and radical innovation

Our dependent variables, innovation measures, fall into three categories: Total innovation, radical innovation, and incremental innovation. We use patent-based and citation-based measures to capture innovation outputs. To measure total innovation, we follow prior literature and use *Ln(Patent),* the natural logarithm of one plus firms' total number of patents that are eventually granted in a given year, and *Ln(Citation),* the natural logarithm of one plus firms' total number of citations (Scherer 1965; Griliches 1981; He and Tian 2013).

For the incremental and radical innovation measures, we follow Balsmeier, Fleming, and Manso (2017) and use two sets of variables to differentiate incremental versus radical innovations. Specifically, we use the following measures to capture incremental innovation:

1) *Ln(BackCite)*, calculated as the natural logarithm of one plus the number of citations that each patent makes to prior patents. Higher backward citations indicate that firms' innovative activities focus on relatively more mature and crowded technological classes (Lanjouw and Schankerman 2004).

2) *Ln(SelfCite)*, calculated as the natural logarithm of one plus the number of times a given patent cites other patents owned by the same company. A larger number of self-citations indicates that firms' innovative activities tend to build on technological areas of their own expertise (Sorensen and Stuart 2000; Faleye, Hoitash, and Hoitash, 2011).

3) *Ln(KnownClass)*, calculated as the natural logarithm of one plus the number of patents that are filed in technology classes previously known to the firm. Known patent classes are defined as the technological classes that a firm have applied for any patent before in our data. Following Balsmeier, Fleming, and Manso (2017), we consistently use the original patent class at the time the patent is granted.

4) *TechProx*, calculated as the proximity between a firm's patent in year *t* and its patent portfolio up to year *t-1*, calculated as follows.

$$TechProx_{i,t} = \sum_{k=1}^{K} f_{i,k,t}\, f_{i,k,t-1} / \left(\sum_{k=1}^{K} {f_{i,k,t}}^2 \sum_{k=1}^{K} {f_{i,k,t-1}}^2 \right)^{\frac{1}{2}}$$

where $f_{i,k,t}$ is the fraction of firm i's patents that belong to patent class k at year t, and $f_{i,k,t-1}$ is the fraction of firm i's patent portfolio up to t-1 that belongs to patent class k. $P_{i,t}$ ranges between zero and one. This measure captures whether a firm stay in or deviate from known research areas.

5) *Ln(Uncited)*, natural logarithm of one plus the number of patents that were not cited.

6) *Ln(Claims)*, calculated as natural logarithm of one plus the total number of claims made by a firm's patent portfolio each year (Lanjouw and Schankerman 2004). Balsmeier, Fleming, and Manso (2017) argue that it is difficult to estimate *ex ante* the innovative value of any particular claim. However, as claims can be added as scope conditions that typically act as limitations on the basic invention, an increase in the total number of claims should capture the effort a firm puts into the patenting process. The number of claims is more likely to be related to short-term and low-risk innovation, so we use the number of claims to measure incremental innovation.

We use two variables to capture firms' radical innovations:

1) *Ln(NewClass)*, which is calculated as natural logarithm of one plus the number of patents that are filed in technology classes previously unknown to the firm. Unknown patent classes are defined as the technological classes that a firm have never applied for any patent before in our data.

2) *Ln(Top1Citation)*, calculated as the natural logarithm of one plus the number of patents that fall into the highest 1% of the citation distribution relative to other granted patents in the same technological class and year.

To sum up, we use variables *Ln(Uncited)*, *Ln(BackCite), Ln(SelfCite), Ln(Knownclass), TechProx,* and *Ln(Claims)* to capture firms' incremental innovations, and variables *Ln(NewClass)* and *Ln(Top1Citation)* to capture firms' radical innovations. Note that we do not use measures of originality and generality in our analysis. As pointed out by Balsmeier, Fleming, and Manso (2017), the correspondence of originality and generality innovation measures is unclear to incremental and radical innovation measures. For example, originality and generality measures calculate the spread of technological classes of patents and cited patents. A patent citing a wide range of technological class is identified as a patent of originality. However, although the class range of citation is widespread, the patent may also self-cites and back-cites, making itself a patent of generality. Therefore, compared with the measures of originality and generality, our measures have considered the characteristics of patent and its citation and better differentiate firm's incremental and radical innovation strategies.

Following the literature on innovation using NBER Patent Citation data, (e.g., Acharya, Baghai, and Subramanian 2013; Hsu, Lien, and Chen 2014; Bloom, Draca, and Van Reenen 2016; Chu, Tian, and Wang 2019), we also address the two well-documented truncation issues through our analysis. First, there is often a two-year or three-year lag between patent application and patent grant. Therefore, we can only observe the granted patents through 2010 in our sample, but we cannot observe the patent grant if a patent is applied in 2009, as it may be still under the review process. Following Hall, Jaffe, and Trajtenberg (2001, 2005), we correct for this truncation bias in patent counts using the "weight factors" computed from the application–grant empirical distribution. Second, as it takes time for a patent to generate citations, early granted patents receive more citations than later patents do. Following Hall, Jaffe, and Trajtenberg (2001), we use their "fixed-effects" rescaling to allow comparability of citation counts over time by removing variance components in the data.

Investment Irreversibility

For our second independent variable, investment irreversibility (*InvestIrrevese*), we use Kim and Kung's (2017) asset redeployability score (*AR*) and reverse code the score by multiply it with (-1) to facilitate interpretation. Using Bureau of Economic Analysis (BEA) 1997 capital flow table, which records the expenditures for 180 assets for 123 industries, Kim and Kung (2017) derive a firm-year asset redeployability measure in three steps.

In the first step, Kim and Kung (2017) calculate a redeployability score for each asset as the sum of weights of industries that use the asset. Industry weight is measured by the total industrial market capitalization of Compustat firms. Secondly, they take the value-weighted average of the asset-level redeployability scores to generate an industry-level asset redeployability score. The weight is calculated as the industrial expenditure on a particular asset divided by industrial total expenditures. Finally, they construct a firm-year redeployability score as the value-weighted average of the industry-level redeployability index across the business segments, which are from Compustat segment files, that the firm operates in. The weight is the proportion of each business segment sales divided by firms' total sales. If Compustat segment files are missing for certain firm-years, they impute the value using the industry-level redeployability score of firms' industries. The higher the asset redeployability score a firm has, the more flexibly a firm can reallocate assets structure, and hence, the lower the investment irreversibility.

In this study, we predict that suppliers with higher investment irreversibility (i.e., lower asset redeployability) would encounter stronger hold-up problem when they have concentrated customer base. With more irreversible assets, suppliers are less likely to engage in radical innovations and more likely to cater to major customers, leading to more incremental innovations. Thus, to facilitate interpretation of our results, we multiply asset redeployability score by -1 and define it as investment irreversibility (*InvestIrrevese)*.

Control variables

Following prior literature, we control for a vector of firm characteristics that could affect firm's innovation strategies (Balsmeier, Fleming, and Manso 2017; Gao, Hsu, and Li 2018; Chu, Tian, and Wang 2019): First, we use *R&D*, defined as research and development expenditures scaled by sales, to control for firms' innovation inputs. Second, we use *Size*, defined as the natural logarithm of total assets, to control for the effect of firm size on innovation strategy. Third, we control for *FirmAge*, defined as the natural logarithm of one plus firm's age, to account for the effect of firm life cycles on innovation strategy. Fourth, we use *Leverage*, defined as long-term debt plus debt in current liabilities to the total book assets, to control for the effect of financial leverage on innovation strategy. Fifth, we use *CapEx*, defined as capital expenditures scaled by sales, to control for the effect of firm's physical investment on innovation strategy. Sixth, we use *Tobin's Q,* defined as the annual closing price times outstanding shares divided by book equity, to control for the effect of growth opportunities on innovation strategy. Seventh, we control for a firm's cashholdings (*Cashholding*)*,* defined as the sum of cash and cash equivalents scaled by total assets. Finally, we use *ROA*, defined as operating income before depreciation divided by book assets at the beginning of a given year, to control for the effect of performance on innovation strategy.

3.3 Model specification

We estimate the following baseline regression to test Hypothesis 1a and Hypothesis 1b (main effects of customer-base concentration on innovation):

$$Innovation_{i,t} = \alpha + \beta_1 CC_{i,t} + \gamma' X_{i,t} + Year\ Fixed\ Effects + Firm\ Fixed\ Effects + \epsilon_{i,t} \quad (1)$$

where *i* indexes firms, and *t* indexes year. The dependent variable is a series of innovation measures that capture different innovation strategies (i.e., total, incremental, and radical), as described in Section 3.2. The independent variable of interest is $CC_{i,t}$. β_1 captures the effects of customer concentration on firms' different innovation strategies. $X_{i,t}$ is a set of firm-level control variables of firm *i* in year *t*, including *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, Cashholding,* and *ROA*. In addition, to deal with concerns of firm-level omitted variables and unobserved year-specific heterogeneity, we include firm- and year-fixed effects in all of our regressions. $\epsilon_{i,t}$ represents random errors. The standard errors for all regressions are heteroskedasticity-robust.

Then, to test Hypothesis 2a and Hypothesis 2b (interaction effects of customer-base concentration and investment irreversibility on innovation), we augment model (1) with investment irreversibility and an interaction term between *CC* and *InvestIrreverse* as following:

$$Innovation_{it} = \beta_0 + \beta_1 CC_{it} + \beta_2 InvestIrrevese_{it} + \beta_3 CC_{it} * InvestIrreverse_{it}$$

$$+ \gamma^{'} X_{i,t} + Year\,Fixed\,Effect + Firm\,Fixed\,Effect_{+}\,\epsilon_{it} \quad (2)$$

β_3 is the key coefficient of interest. Recall that we expect a firm with high investment irreversibility (low AR) to be more likely to focus on incremental innovation and less likely to focus on radical innovation when customer-base concentration is high. Hence, we expect the coefficient on the interaction term $CC_{it} * InvestIrreverse_{it}$ to be significantly positive for tests of incremental innovations and conversely, to be significantly negative for tests of radical innovations.

4. RESULTS

4.1 Descriptive statistics and correlation analysis

Table 2 reports descriptive statistics on measures of customer concentration, innovation, investment irreversibility, and control variables. The mean (median) CC is 0.18 (0.10). Given that large sample studies such as Irvine, Park, and Yıldızhan (2016) and Patatoukas (2011) respectively report mean (median) CC of 0.10 (0.05) and 0.10 (0.04), firms in our sample, which we find at the intersection of firms that have innovation outputs, appear to depend more heavily on purchases from major customers. The mean (median) of *Patent* for our sample firms is 19.55(2.00). Prior studies by Balsmeier, Fleming, and Manso (2017) show an average (median) *Patent* of 53.78 (3.00) while Chu, Tian, and Wang (2019) and Byun, Chok, Dai, and Ding (2019) show an average (median) Patent of 17.92 (1.00) and of 18.83. Our sample is comparable to those used in prior studies. Note that 20% of firm-years in our sample have zero value in *Patent*, and extremely scarce patents are in the top 1 percentage of citation distribution (i.e., less than 5% firms own such patents). These patterns are also comparable to that of prior studies using similar sample window. Finally, the mean (median) *InvestIrrevese* is -0.39 (-0.40). This is in line with Kim and Kung (2017), which report a mean (median) AR of 0.39 (0.41).

[Table 2 Here]

Table 3 present the Pearson and Spearman correlation matrix of the main variables used in our analysis. The correlations of *CC* with total innovation measures suggest that firms with more concentrated customer-base tend to generate fewer patents and receive fewer citations overall. In general, the correlations also show that firms with more concentrated customer-base tend to generate more incremental innovations and less radical innovations. Untabulated correlations of *CC* with firm characteristics suggest that smaller and younger firms tend to have a more concentrated customer-base, and that firms with more concentrated customer-base tend to have more R&D expenditures, more growth opportunity, and more cash holdings, in line with Patatoukas (2012).

[Table 3 Here]

4.2 Test of H1a and H1b

Table 4 presents the results of effect of customer concentration on total and incremental innovations, testing H1a. Overall, the results support our predictions and are strongly consistent through a series of incremental innovation measures. First, Column (1) and column (2) show significantly positive associations between customer concentration and total innovation output. Specifically, firms with 1% more concentrated customer base will generate 18.7% more patents and receive 23.3% more citations from their patents. From column (3) to column (8), coefficients of *CC* consistently show that customer concentration is positively associated with incremental innovations. Compared with sample mean, firms with 1% higher *CC* will generate more uncited patents (Coefficient = 0.134, p<0.01), more backward citations (Coefficient = 0.232, p<0.05) and self-citations (Coefficient = 0.120, p<0.10), more patents from known class (Coefficient = 0.208, p<0.01), more claims (Coefficient = 0.334, p<0.01), and have higher technology proximity with prior patents (Coefficient = 0.069, p<0.01). These results provide strong support for H1a.

H1b predicts a negative association between customer-base concentration and radical innovation. Table 5 presents the results of our test of H1b. As shown in Column (1) of Table 5, we do not find a significant coefficient on *CC* for our two measures of radical innovation, *Ln(NewClass)* and *Ln(Top1Citation)*. One limitation of the model specification in Column (1) is that radical innovation is measured at time t, which is contemporaneous with the customer concentration measure. In practice, however, compared with making incremental innovations, it may take more time for a firm to generate radical innovations. To address this concern, we also use the *t+1* to *t+3* of *Ln(NewClass)* and *Ln(Top1Citation)* as dependent variables in column (2) to (4) and column (6) to (8) of Table 5 respectively, to see if there are lagged effects of customer-base concentration. We find no significant effects of customer concentration even after taking into account the potential lead-lag relationship between customer concentration and radical innovation. Therefore, we do not find support for H1b.

[Table 4-5 Here]

Balsmeier, Fleming, and Manso (2017) show that firms' incremental innovation increases with more independent boards because such board oversight increases managerial efforts and risk aversion. To control for the effects of corporate governance including board independence on innovation, we add board size (*BoardSize)*, independent director ratio (*IndepRatio)*, and CEO's risk-taking proxies (*Vega* and *Delta*) in our regression models. As shown in Table 6 and Table 7, we replicate our baseline results after including these additional control variables. Consistent with the baseline results, we find statistically and economically significant coefficients on customer concentration for all incremental innovations variables in Table 6. Also, consistent with the baseline results, we find insignificant coefficients on customer concentration for radical innovation in Table 7, with the exception of Column (3), where we find a significantly negative association between *CC* and radical *Ln(NewClass)* in t+2. This result is economically significant. Specifically, a 1% increase in customer-base concentration will lead to a 52% decrease in the number of patents in new technology area in two years. This result is consistent with H1b. Taken together, we find strong evidence supporting H1a, but we only find very weak support for H1b.

[Table 6-7 Here]

Collectively, our evidence suggests that firms with higher customer-base concentration are associated with more innovations overall and that this effect is mostly driven by an increase in incremental innovations. Customer-base concentration has no effect or negative effect on radical innovations. This is in line with the Christensen and Bower (1996)'s theory that firm's resource allocation decisions in technology innovations can be heavily influenced by the demands of its customers and firms target resource allocation to incremental innovations demanded by powerful customers.

4.3 Addressing endogeneity concern

One potential concern with our results for H1a and H1b is endogeneity. We take several approaches to address this potential endogeneity concern. First, we include firm-fixed effects in the regression model to control for time-invariant variables, alleviating firm-level omitted variables concerns.

Second, we use a two-stage approach following Patatoukas (2012) and include determinants of customer concentration in the first-stage model. Specifically, we include the natural logarithm of market capitalization, the natural logarithm of firm age, annual percentage sales growth, an indicator variable equal to one if the firm reports at least two business segments, and the annual change in the Herfindahl-Hirschman index of competition in the firm's two-digit SIC industry. In the second stage, we regress the innovation measures on residuals (*CC_Residual*) estimated in the first stage. The second stage results are reported in Table 8. The results are consistent with our baseline results in Table 4.

[Table 8 Here]

4.4 Test of H2a and H2b

Next, we examine the moderating role of investment irreversibility on the association between customer-base concentration and innovation. Table 9 presents the results for our test for total and incremental innovations. As discussed in Section 3, our measure of investment irreversibility, *InvestIrreverse*, is calculated as asset redeployability score multiply -1, to facilitate interpretation. Thus, the higher the value of *InvestIrreverse,* the more irreversible a firm's investment and the higher switching costs a firm will face when it has to switch customers. We interact *InvestIrreverse* with *CC* to capture the moderating effect and mean-center the two continuous variables in the model to make coefficients interpretable (Aiken and West 1990). Results in Table 9 support H2a, indicating that investment irreversibility significantly amplifies the positive association between firms' customer concentration and incremental innovations. Specifically, in column (1), the interaction term, *CC#InvestIrreverse*, is significantly positive (Coefficient = 1.732, $p<0.05$), suggesting a significant moderating role of investment irreversibility on the association between firms' customer concentration and incremental innovations. In column (3), column (5), and column (6), we find strong and consistent results in interaction terms for uncited patents (Coefficient = 3.176, $p<0.01$), self-citations (Coefficient = 3.226, $p<0.01$), and patents in known technological class (Coefficient = 2.560, $p<0.01$). Overall, these results are consistent with H2a, suggesting that higher investment irreversibility will make suppliers even more likely to allocate innovation resources to incremental innovations to cater to the preferences of major customers.

[Table 9 Here]

Table 10 reports the results of our test of H2b, which predicts that investment irreversibility has a moderating effect on the relation between customer concentration and the supplier firms' radical innovation. As shown in Column (1) through Column (4) of Table 10, when we use patents in new technological class (i.e., *Ln(NewClass)*) as the dependent measure of radical innovation, we find significantly negative coefficients on the interaction term between customer concentration and investment irreversibility. These results are consistent with H2b, suggesting that higher investment irreversibility will make suppliers even less likely to allocate innovation resources to radical innovations. However, we do not find such moderating effects when we use the number of patents with citations in the top 1% of citation distribution (i.e., *Ln(Top1Citations)*) as the dependent measure of radical innovation. Given that only less than 5% firms in our sample have patents in the top 1 percentage of citation distribution, we conjecture that the insignificant result could be due to a lack of power. Collectively, we find strong support for H2a and some support for H2b, suggesting that a firm's resource allocation decisions in technology innovations are jointly influenced by how concentrated the customer base is and how irreversible the firm's investment is.

[Table 10 Here]

4.5 Ruling out an alternative explanation

One alternative explanation for a positive association between a firm's customer-base concentration and incremental innovation is innovation spillover from major customers. To rule out this alternative explanation, we follow Irvine, Park, and Yıldızhan (2016) and control for major customers' innovation in two ways.

First, for each measure of innovation, we add to model (1) a control variable that captures the number of corresponding innovations from a firm's major customers. For example, we add natural logarithm of one plus identified major customer's sales-weighted total patent number in *t-1* (i.e., lagged major customer's *LnPatent*) as a control variable in column (1) regression, in which the dependent variable is natural logarithm of one plus supplier's total patent number (*LnPatent*). These results are presented in Table 11. We find the results are quantitatively and qualitatively similar to our baseline results in Table 4. The coefficients of *CC* are significantly positive in all regressions through column (1) to column (8).

[Table 11 Here]

Second, for each measure of innovation, we subtract the number of corresponding patents of the focal firm that cite at least one patent belonging to one of the firm's major customers. For example, *NonCus_Ln(Patent)* is defined as the natural logarithm of one plus the number of patents that are not citing from one of identified major customers. We apply the similar fashion from column (2) to column (8) for the rest of innovation variables. These results are presented in Table 12. Again, we find results similar to our baseline results in Table 4.

[Table 12 Here]

Collectively, the above results suggest that the positive association between a firm's customer-base concentration and incremental innovation documented in our study is not driven by innovation spillover from major customers.

4.6 Robustness checks

We conduct additional analyses to check whether our results are robust to alternative measures of customer-base concentration. Following Patatoukas (2012) and Irvine, Park, and Yıldızhan (2016), we use the annual decile-rank of customer concentration measure, *RankCC*, scaled to 0(lowest rank) and 1(highest rank). As shown in Table 13, our results are robust to this alternative measure of customer-base concentration.

[Table 13 Here]

5. CONCLUSION

We examine the effect of a firm's customer-base concentration on two types of firm innovation: radical innovation versus incremental innovation. Drawing on theories of resource dependence and resource allocation, we predict that a dependence on major customers can discourage a firm from making risky investments in radical innovation and encourage a firm to invest in incremental innovation. We test our hypotheses with a sample of 11,940 firm-year observations between 1984 and 2010. Consistent with our predictions, we find that customer-base concentration is positively associated with incremental innovation, and such association is more pronounced for firms with high investment irreversibility (i.e., low asset redeployability). Although we do not find a main effect of customer-base concentration on radical innovation, we find an interaction effect between customer-base concentration and investment irreversibility such that radical innovation is significantly lower in firms with high customer concentration and high investment irreversibility than in other firms. Our results suggest that firms with high customer concentration may allow their innovation resource allocation decisions to be shaped by major customers, leading to incremental innovations at the expense of radical innovations.

Our study contributes to two streams of literature. First, we add to a growing accounting literature on innovation by answering the call for more research on the determinants of radical versus incremental innovation (e.g., Davila, Foster, and Li 2009b; Chen 2017). We examine the impact of two external factors, customer concentration and investment irreversibility, on innovation, and distinguish between the impact on incremental and the impact on radical innovation. Second, results of our study suggest that supply chain characteristics play an important role in firms' innovation resource allocations.

In doing so, we extend a growing accounting literature on customer concentration. While prior studies provide evidence on potential benefits of customer concentration for the focal firm, evidence provided in our study point to both potential benefits and potential downside of customer concentration. While firms with high customer concentration may have greater innovation outputs, these innovation outputs are mostly incremental in nature. Although our results do not suggest an overall negative impact of customer concentration on radical innovation, we do find a negative impact of customer concentration on radical innovation for firms with high investment irreversibility.

Results of our study have important practical implications. Do major customers help or hurt innovation? Our results suggest that it depends. Major customers do help incremental innovation of a firm, but when investment irreversibility is high, major customers can hurt radical innovation, which, in turn, may hamper a firm's long-term development. Our results are consistent with the evidence from case studies in Christensen and Bower 1996 that firms' innovation resource allocation decisions can be heavily influenced by their major customers, resulting in more incremental innovations and fewer radical innovations. While this strategy may work for the survival and stability of a firm in the short term, it may hurt the firm's performance in the long term.

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Appendix A. Variable Definitions

Variables	Definitions
Independent Variables	
CC	The Herfindahl-Hirschman index of sales to major customers.
RankCC	Annual decile ranks of *CC,* scaled to 0(lowest rank) and 1(highest rank).
InvestIrrevese	Investment Irreversibility. Equals firm's asset redeployability score multiplying -1. Asset redeployability score is calculated as the value-weighted average of the industry-level redeployability index across the business segments. Industry-level redeployability is calculated as the value-weighted average of the asset-level redeployability scores from Bureau of Economic Analysis (BEA) 1997 capital flow table (Kim and Kung 2017).
Innovation Measures	
Ln(Patent)	Total patent count. The natural logarithm of one plus the total number of patents a firm applies for (and eventually granted) in a given year. For firm-year without applied patent, we set to 0.
Ln(Citations)	Citation count. The natural logarithm of one plus the total number of citations on the patents a firm applies for in a given year.
Ln(BackCite)	Backward Citation. The natural logarithm of one plus the number of citations that each patent in a given year makes to prior patents (Lanjouw and Schankerman 2004).
Ln(SelfCite)	Self-Citation. The natural logarithm of one plus the number of citations that each patent in a given year makes to prior patents owned by the same company (Sorensen and Stuart, 2000; Faleye, Hoitash, and Hoitash 2011).
Ln(KnownClass)	Known Class patents. The natural logarithm of one plus the number of patents filed in a given year that

	is in the patent technological classification in which the company already has previously received patents in.
Ln(NewClass)	New Class Patents. The natural logarithm of one plus the number of patents filed in a given year that is in the patent technological classification in which the company already has not previously received patents in.
TechProx	Technology Proximity. The similarity distance between firm's patent portfolio in the current year and the previous years, defined in Section 3.2.
Ln(Top1Citation)	Top 1 Percentage Citation Patents. The natural logarithm of one plus the number of patents with top 1 percentile of citations received among patents in the same technology class and year (Azoulay, Graff, Zivin, and Manso 2011).
Ln(Uncited)	Uncited Patents. The natural logarithm of one plus the number of patents that were not cited.
Ln(Claims)	Total Claims. The natural logarithm of one plus the number of total claims made by patents applied for in a given year.
NonCustomer_XXX	Exclude the patents that are citing from one of identified major customers in suppliers current patent portfolio for variables XXX (refers to *Ln(Patent), Ln(Citations), Ln(BackCite), Ln(SelfCite), Ln(KnownClass), Ln(NewClass), TechProx, Ln(Top1Citation), Ln(Uncited), Ln(Claims)*
Control Variables	
R&D	Research and development expenditures, scaled by sales.
Size	The natural logarithm of total assets in a given year.
FirmAge	The natural logarithm of one plus firm's age, calculated as the given year minus the first year ever appeared in CRSP/Compustat Database.
Leverage	Long-term debt plus debt in current liabilities to the total book assets.

CapEx	Capital expenditures, scaled by sales.
Tobin's Q	Market-to-book equity value, calculated as the annual closing price times outstanding shares divided by book equity.
Cashholding	Cash and cash equivalents, scaled by total assets.
ROA	Operating income before depreciation divided by book assets at the beginning of a given year.
BoardSize	The natural logarithm of one plus the number of directors.
IndepRatio	Number of independent directors to number of total directors.
Vega	The sensitivity of CEO wealth to stock return volatility. It is measured by change (in thousands of dollars) in the dollar value of the executive's wealth when the annualized standard deviation of the firm's stock price changes by one percent (Core and Guay 2002).
Delta	The sensitivity of CEO wealth to stock price. It is measured by the change (in thousands of dollars) in the dollar value of the executive's wealth when the firm's stock price changes by one percent (Core and Guay 2002)

Table 1 Sample Selection

Selection Process	No. of Observations
1. Construct the customer concentration sample	89,071
Data source: *Compustat Customer Segment (1976-2010)*	
2. Merge with control variables from Compustat	70,756
*Exclude firms with missing CC and firms missing control variables	
*Exclude firms in utility industry (SIC code from 4900 to 4999) and financial industry (SIC code from 6000 to 6999)	
Data source: *Compustat Fundamentals Annual*	
3. Merge with patent data	13,562
*Exclude firms unidentified by the NBER database.	
*Exclude non-innovative firms during our sample period.	
Data source: *NBER Patent and Citation Database, and Harvard Patent Dataverse (1976-2010)*	
4. Merge with asset redeployability data (1984-2010)	11,940
Data source: *Kim and Kung (2017, RFS)*	
Full sample for baseline (1984-2010)	**11,940**
6. Merge with board data and CEO risk-taking data (i.e., Vega and Delta)	2,021
Data source: *Institutional Shareholder Services (ISS) (since 1996) Execucomp (since 1992)*	

This table presents how we construct the sample and the data sources. We mainly use the full sample (11,940 firm-year observations from 1984 to 2010) through our analysis.

Table 2 Descriptive Statistics

Variables	Mean	SD	P25	Median	P75	Obs.
Customer Concentration						
CC	0.18	0.21	0.04	0.10	0.24	11,940
RankCC	0.55	0.29	0.30	0.60	0.80	11,940
Innovation						
Patent	19.55	109.70	1.00	2.00	7.00	11,940
Citations	173.40	1027.00	0.00	12.00	66.00	11,940
BackCite	333.40	1909.00	7.00	31.00	124.00	11,940
SelfCite	42.91	370.20	0.00	1.00	7.00	11,940
KnownClass	18.32	109.00	0.00	1.00	6.00	11,940
NewClass	1.23	2.20	0.00	1.00	2.00	11,940
TechProx	0.43	0.39	0.00	0.43	0.82	11,940
Top1Citation	0.13	0.94	0.00	0.00	0.00	11,940
Uncited	6.16	53.44	0.00	0.00	1.00	11,940
Claims	378.40	2140.00	13.00	45.00	151.00	11,940
Investment Irreversibility						
InvestIrrevese	-0.39	0.07	-0.43	-0.40	-0.35	11,940
Control Variables						
R&D	0.13	0.19	0.03	0.08	0.16	10,684
Size	5.21	2.21	3.70	4.99	6.63	11,940
FirmAge	2.30	0.99	1.61	2.40	3.05	11,940
Leverage	0.44	0.43	0.21	0.38	0.57	11,940
CapEx	0.05	0.05	0.02	0.04	0.07	11,940
Tobin's Q	2.75	4.42	1.21	1.75	2.94	11,940
Cashholding	0.16	0.17	0.03	0.10	0.23	11,940
ROA	-0.09	0.53	-0.11	0.03	0.08	11,940
BoardSize	2.14	0.27	1.95	2.20	2.30	2,251
IndepRatio	0.70	0.17	0.60	0.71	0.83	2,251
Vega	0.10	0.17	0.02	0.05	0.11	3,447
Delta	0.73	2.27	0.06	0.19	0.57	3,355

This table reports the descriptive statistics of the main variables used in the analysis. All continuous variables are winsorized at 1% and 99%. The statistics include the value of first quartile (P25), median (Median), third quartile (P75), standard deviation (SD), mean (Mean), and number of observation (Obs.) All variables definitions are provided detailedly in Appendix A. The sample period is from 1984 to 2010.

Table 3 Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) CC		0.97	-0.04	-0.21	-0.04	-0.02	-0.03	-0.08	0.03	-0.05	0.10	-0.05	-0.01
(2) RankCC	0.87		-0.02	-0.09	-0.03	-0.02	-0.02	-0.03	0.04	-0.03	0.04	-0.02	0.00
(3) Ln(Patent)	-0.05	-0.03		0.41	0.93	0.87	0.98	0.47	0.65	0.49	0.77	0.98	0.16
(4) Ln(Citations)	-0.17	-0.08	0.78	1.00	0.68	0.61	0.72	0.52	0.48	0.50	0.26	0.77	0.16
(5) Ln(BackCite)	-0.03	-0.03	0.91	0.28		0.90	0.91	0.44	0.62	0.47	0.75	0.92	0.14
(6) Ln(SelfCite)	-0.02	-0.02	0.89	0.19	0.87		0.88	0.30	0.64	0.47	0.73	0.86	0.10
(7) Ln(KnownClass)	-0.05	-0.02	0.98	0.26	0.88	0.89		0.34	0.70	0.49	0.77	0.95	0.14
(8) Ln(NewClass)	-0.08	-0.03	0.51	0.36	0.46	0.33	0.40		0.11	0.28	0.25	0.49	0.16
(9) TechProx	0.03	0.04	0.65	0.23	0.67	0.64	0.71	0.13		0.32	0.52	0.63	0.00
(10) Ln(Top1Citation)	-0.06	-0.03	0.58	0.27	0.46	0.52	0.57	0.34	0.29		0.37	0.49	0.13
(11) Ln(Uncited)	0.06	0.04	0.82	-0.22	0.75	0.77	0.82	0.28	0.52	0.44		0.74	0.07
(12) Ln(Claims)	-0.04	-0.02	0.94	0.36	0.94	0.82	0.91	0.51	0.69	0.49	0.74		0.17
(13) InvestIrre	-0.01	0.01	0.20	0.13	0.18	0.13	0.19	0.18	0.06	0.14	0.10	0.20	

This table reports the Pearson (upper right) and Spearman (bottom left) correlations for the main variables used in the analysis. All continuous variables are winsorized at 1% and 99%. All variable definitions are provided detailedly in Appendix A.

Table 4 Regression Results Testing the Main Effect of Customer Concentration on Total and Incremental Innovations

Y=	*Ln(Patent)* (1)	*Ln(Citations)* (2)	*Ln(Uncited)* (3)	*Ln(BackCite)* (4)	*Ln(SelfCite)* (5)	*Ln(KnownClass)* (6)	*TechProx* (7)	*Ln(Claims)* (8)
CC	0.187***	0.233**	0.134***	0.232**	0.120*	0.208***	0.069***	0.334***
	(0.05)	(0.10)	(0.04)	(0.11)	(0.07)	(0.05)	(0.02)	(0.10)
R&D	0.473***	0.548***	0.263***	0.843***	0.434***	0.448***	0.098***	0.797***
	(0.07)	(0.14)	(0.05)	(0.15)	(0.08)	(0.08)	(0.04)	(0.15)
Size	0.294***	0.310***	0.196***	0.476***	0.321***	0.314***	0.076***	0.448***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.02)	(0.01)	(0.03)
FirmAge	0.013	-0.222***	-0.089***	-0.100**	0.238***	0.135***	0.028***	-0.174***
	(0.02)	(0.04)	(0.02)	(0.04)	(0.03)	(0.02)	(0.01)	(0.04)
Leverage	-0.076***	-0.103**	-0.038**	-0.097*	-0.024	-0.084***	-0.019	-0.098*
	(0.03)	(0.05)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.05)
CapEx	-0.233	-0.033	-0.477***	-0.445	-0.139	-0.295*	-0.054	-0.433
	(0.15)	(0.35)	(0.12)	(0.34)	(0.20)	(0.16)	(0.08)	(0.36)
Tobin's Q	0.006***	0.011***	-0.001	0.012***	0.008***	0.004*	0.001	0.009**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CashHolding	-0.041	0.215*	-0.155***	0.166	0.013	-0.056	0.001	-0.003
	(0.05)	(0.12)	(0.04)	(0.12)	(0.08)	(0.06)	(0.03)	(0.12)
ROA	-0.051**	-0.016	-0.054***	-0.070	-0.032	-0.065***	-0.015	-0.071
	(0.03)	(0.04)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.06)
Constant	0.011	2.670***	-0.624***	1.322***	-1.361***	-1.013***	-0.211**	1.859***
	(0.14)	(0.34)	(0.08)	(0.38)	(0.22)	(0.17)	(0.11)	(0.34)
Observations	11,940	11,940	11,940	11,940	11,940	11,940	11,940	11,940
Adj. R-squared	0.771	0.660	0.768	0.626	0.748	0.789	0.485	0.606
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the OLS estimation of the effect of customer concentration on firms' total and incremental innovations. The dependent variable is a series of total innovation measures, including *Ln(Patent)* and *Ln(Citations)*, and incremental innovation measures, including *Ln(Uncited)*, *Ln(BackCite)*, *Ln(Selfcite)*, *Ln(KnownClass)*, *TechProx*, and *Ln(Claims)*, corresponding to the results from column (1) to column (8), separately. The independent variable of interest is customer concentration (*CC*), defined as the Herfindahl-Hirschman Index of major customer's sales to firm. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 5 Regression Results Testing the Main Effect of Customer Concentration on Radical Innovations

Y=	*Ln(NewClass)*				*Ln(Top1Citations)*			
	t	*t+1*	*t+2*	*t+3*	*t*	*t+1*	*t+2*	*t+3*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CC	0.056	0.033	0.038	-0.032	0.020	0.007	-0.000	0.011
	(0.04)	(0.06)	(0.07)	(0.08)	(0.01)	(0.02)	(0.02)	(0.03)
R&D	0.128**	-0.018	-0.055	-0.079	0.013	-0.016	-0.014	-0.018
	(0.06)	(0.08)	(0.09)	(0.10)	(0.01)	(0.02)	(0.02)	(0.02)
Size	0.078***	0.045***	-0.013	-0.033	0.010**	0.004	0.010*	0.010
	(0.01)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)	(0.01)	(0.01)
FirmAge	-0.069***	0.054**	0.038	0.038	0.008	0.008	0.007	0.005
	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Leverage	-0.025	-0.023	0.003	-0.009	-0.006	-0.002	0.001	0.020**
	(0.02)	(0.02)	(0.03)	(0.04)	(0.00)	(0.01)	(0.01)	(0.01)
CapEx	0.205	0.419**	0.416**	0.575***	-0.012	0.050	0.047	-0.023
	(0.13)	(0.16)	(0.20)	(0.21)	(0.04)	(0.06)	(0.06)	(0.06)
Tobin's Q	0.003**	0.001	0.002	0.008***	-0.000	0.000	0.002**	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CashHolding	-0.011	0.063	-0.034	0.073	-0.001	-0.010	-0.005	0.036
	(0.05)	(0.06)	(0.07)	(0.08)	(0.01)	(0.02)	(0.02)	(0.02)
ROA	-0.008	0.015	0.005	0.036	-0.002	-0.003	0.001	0.009*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.01)
Constant	0.755***	0.199	0.672***	0.614***	-0.001	0.032	0.005	0.005
	(0.13)	(0.15)	(0.18)	(0.18)	(0.02)	(0.02)	(0.03)	(0.03)
Observations	11,940	8,908	7,154	5,788	11,940	8,908	7,154	5,788
Adj. R-squared	0.239	0.229	0.217	0.220	0.454	0.440	0.444	0.426
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the OLS estimation of the effect of customer concentration on firms' radical innovations. The dependent variable is a series of radical innovation measures, including *Ln(NewClass)* and *Ln(Top1Citations)*. Column (1) to column (4) reports the dynamic effects of customer concentration on *Ln(NewClass),* from t to t+4 correspondingly. Column (5) to column (8) reports the dynamic effects of customer concentration on *Ln(Top1Citations)*, from t to t+4 correspondingly. The independent variable of interest is customer concentration (*CC)*, defined as the Herfindahl-Hirschman Index of major customer's sales to firm. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 6 Regression Results Testing the Main Effect of Customer Concentration on Total and Incremental Innovations: Controlling for Board Characteristics and CEO Risk-taking Incentives

Y=	*Ln(Patent)*	*Ln(Citations)*	*Ln(Uncited)*	*Ln(BackCite)*	*Ln(SelfCite)*	*Ln(KnownClass)*	*TechProx*	*Ln(Claims)*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CC	0.459***	0.129	0.363**	0.702**	0.840***	0.545***	0.152***	0.582**
	(0.15)	(0.27)	(0.15)	(0.28)	(0.20)	(0.16)	(0.06)	(0.26)
R&D	0.765**	0.484	0.431	1.584**	1.250**	0.663	0.096	1.034
	(0.39)	(0.83)	(0.40)	(0.77)	(0.61)	(0.48)	(0.18)	(0.63)
Size	0.107*	0.074	0.127**	0.151	0.167**	0.148**	0.044*	0.122
	(0.06)	(0.10)	(0.06)	(0.11)	(0.08)	(0.06)	(0.02)	(0.10)
FirmAge	0.122	-0.037	0.120	-0.153	0.361*	0.197	-0.031	0.061
	(0.15)	(0.24)	(0.14)	(0.26)	(0.20)	(0.16)	(0.05)	(0.24)
Leverage	-0.011	-0.025	-0.130	-0.093	-0.113	0.015	0.106**	0.071
	(0.13)	(0.23)	(0.16)	(0.25)	(0.19)	(0.13)	(0.05)	(0.23)
CapEx	0.278	0.791	0.256	0.044	-0.087	-0.223	-0.391	0.211
	(0.56)	(1.07)	(0.62)	(1.22)	(0.73)	(0.57)	(0.25)	(1.21)
Tobin's Q	0.032**	0.058**	0.033**	0.026	0.027	0.035**	0.004	0.032
	(0.01)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.00)	(0.03)
CashHolding	-0.663***	-0.898**	-0.366*	-0.983**	-0.259	-0.835***	-0.192**	-0.910*
	(0.24)	(0.43)	(0.22)	(0.49)	(0.33)	(0.24)	(0.10)	(0.47)
ROA	0.000	0.039	-0.068	-0.061	0.027	-0.030	-0.088*	0.045
	(0.08)	(0.19)	(0.09)	(0.15)	(0.14)	(0.10)	(0.05)	(0.16)
BoardSize	0.461***	0.344	0.298**	0.730***	0.437**	0.603***	0.164***	0.726***
	(0.13)	(0.24)	(0.14)	(0.26)	(0.18)	(0.14)	(0.05)	(0.24)
IndepRatio	-0.088	0.061	-0.335*	-0.194	0.011	-0.003	0.029	-0.141
	(0.18)	(0.32)	(0.18)	(0.33)	(0.23)	(0.18)	(0.07)	(0.33)
Vega	0.822***	0.517	0.614***	1.316***	0.741**	0.869***	0.092	1.283***
	(0.22)	(0.41)	(0.22)	(0.46)	(0.36)	(0.23)	(0.12)	(0.42)
Delta	-0.077***	-0.077*	-0.065***	-0.081	-0.092**	-0.089***	-0.015	-0.096*
	(0.02)	(0.04)	(0.02)	(0.05)	(0.04)	(0.03)	(0.01)	(0.05)
Constant	0.397	3.476***	-1.240**	2.422**	-0.921	-0.664	0.029	2.502**
	(0.60)	(1.03)	(0.57)	(1.08)	(0.80)	(0.65)	(0.23)	(1.04)
Observations	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021
Adj. R-squared	0.861	0.832	0.827	0.738	0.848	0.872	0.601	0.745
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the OLS estimation of the effect of customer concentration on firms' total and incremental innovations controlling for board characteristics and CEO risk-taking incentives. The dependent variable is a series of total innovation measures, including *Ln(Patent)* and *Ln(Citations)*, and incremental innovation measures, including *Ln(Uncited)*, *Ln(BackCite)*, *Ln(Selfcite)*, *Ln(KnownClass)*, *TechProx*, and *Ln(Claims)*, corresponding to the results from column (1) to column (8), separately. The independent variable of interest is customer concentration (*CC)*, defined as the Herfindahl-Hirschman Index of major customer's sales to firm. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* We include *BoardSize* and *IndepRatio* to control for board characteristics and include *Vega* and *Delta* to control for managerial incentives. Balsmeier, Fleming, and Manso (2017) show that firm's exploitive innovation may increase with more independent boards, and such board oversight may increase managerial efforts and risk aversion. Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 7 Regression Results Testing the Main Effect of Customer Concentration on Radical Innovation: Controlling for Board Characteristics and CEO Risk-taking Incentives

Y=	*Ln(NewClass)*				*Ln(Top1Citations)*			
	t	*t+1*	*t+2*	*t+3*	*t*	*t+1*	*t+2*	*t+3*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CC	-0.035	-0.313	-0.517**	-0.375	-0.048	-0.040	-0.162	-0.022
	(0.14)	(0.21)	(0.23)	(0.25)	(0.08)	(0.11)	(0.11)	(0.12)
R&D	0.201	0.638	-0.445	-0.111	-0.128	0.180	-0.293	-0.133
	(0.36)	(0.41)	(0.38)	(0.53)	(0.18)	(0.23)	(0.25)	(0.35)
Size	0.051	0.062	-0.022	-0.069	0.014	0.022	-0.019	0.025
	(0.05)	(0.07)	(0.08)	(0.11)	(0.03)	(0.04)	(0.04)	(0.05)
FirmAge	-0.167	-0.048	0.245	0.305	0.140**	0.158*	0.131	-0.114
	(0.13)	(0.18)	(0.24)	(0.30)	(0.07)	(0.08)	(0.11)	(0.15)
Leverage	0.163	0.103	0.092	0.161	0.040	0.119	0.123	0.057
	(0.14)	(0.17)	(0.18)	(0.24)	(0.07)	(0.08)	(0.09)	(0.13)
CapEx	1.146**	1.002	-0.344	0.264	0.323	0.014	-0.311	0.279
	(0.55)	(0.75)	(0.84)	(1.16)	(0.23)	(0.29)	(0.31)	(0.38)
Tobin's Q	0.013	0.002	0.020	0.002	0.007	0.002	0.011	0.001
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
CashHolding	-0.162	0.105	-0.486	-0.269	-0.155	-0.092	0.035	0.046
	(0.24)	(0.27)	(0.30)	(0.35)	(0.10)	(0.11)	(0.13)	(0.20)
ROA	0.059	0.129	0.036	-0.023	0.013	0.051	-0.014	0.045
	(0.09)	(0.10)	(0.12)	(0.15)	(0.04)	(0.04)	(0.05)	(0.06)
BoardSize	0.126	0.252	0.022	0.106	0.022	0.131	0.072	0.105
	(0.14)	(0.18)	(0.21)	(0.25)	(0.07)	(0.08)	(0.09)	(0.11)
IndepRatio	-0.070	-0.025	0.054	0.368	0.011	0.041	0.143	0.130
	(0.16)	(0.20)	(0.24)	(0.26)	(0.09)	(0.10)	(0.11)	(0.12)
Vega	0.364*	0.283	0.500	0.271	0.033	0.092	-0.152	0.383**
	(0.22)	(0.30)	(0.41)	(0.35)	(0.09)	(0.14)	(0.13)	(0.15)
Delta	-0.039*	-0.030	-0.032	0.060	-0.003	-0.022	-0.013	-0.030
	(0.02)	(0.04)	(0.04)	(0.06)	(0.01)	(0.02)	(0.02)	(0.03)
Constant	0.641	-0.047	0.283	-0.150	-0.363	-0.661**	-0.193	-0.081
	(0.55)	(0.77)	(0.91)	(1.11)	(0.26)	(0.33)	(0.43)	(0.52)
Observations	2,021	1,428	1,106	854	2,021	1,428	1,106	854
Adj. R-squared	0.317	0.307	0.288	0.306	0.484	0.456	0.425	0.382
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the OLS estimation of the effect of customer concentration on firms' radical innovations controlling for board characteristics and CEO risk-taking incentives. The dependent variable is a series of radical innovation measures, including *Ln(NewClass)* and *Ln(Top1Citations)*. Column (1) to column (4) reports the dynamic effects of customer concentration on *Ln(NewClass),* from t to t+4 correspondingly. Column (5) to column (8) reports the dynamic effects of customer concentration on *Ln(Top1Citations)*, from t to t+4 correspondingly. The independent variable of interest is customer concentration (*CC*), defined as the Herfindahl-Hirschman Index of major customer's sales to firm. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* We include *BoardSize* and *IndepRatio* to control for board characteristics and include *Vega* and *Delta* to control for managerial incentives. Balsmeier, Fleming, and Manso (2017) show that firm's exploitive innovation may increase with more independent boards, and such board oversight may increase managerial efforts and risk aversion. Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 8 Two-Stage Regression Analysis for the Effect of Customer Concentration on Total and Incremental Innovations

Y=	*Ln(Patent)* (1)	*Ln(Citations)* (2)	*Ln(Uncited)* (3)	*Ln(BackCite)* (4)	*Ln(SelfCite)* (5)	*Ln(KnownClass)* (6)	*TechProx* (7)	*Ln(Claims)* (8)
CC Residuals	0.215***	0.328***	0.114**	0.299***	0.142*	0.237***	0.076***	0.425***
	(0.05)	(0.10)	(0.05)	(0.11)	(0.08)	(0.06)	(0.02)	(0.11)
R&D	0.314***	0.340***	0.205***	0.509***	0.351***	0.334***	0.081***	0.473***
	(0.02)	(0.03)	(0.01)	(0.03)	(0.02)	(0.02)	(0.01)	(0.03)
Size	0.006***	0.012***	-0.002	0.014***	0.009***	0.003	0.001	0.010***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
FirmAge	-0.070**	-0.100*	-0.035*	-0.086	-0.007	-0.078***	-0.018	-0.084
	(0.03)	(0.05)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.06)
Leverage	-0.226	0.065	-0.534***	-0.354	-0.161	-0.233	0.020	-0.419
	(0.17)	(0.37)	(0.13)	(0.36)	(0.22)	(0.18)	(0.08)	(0.38)
CapEx	-0.024	0.250**	-0.159***	0.204	0.039	-0.028	0.020	0.055
	(0.06)	(0.12)	(0.04)	(0.13)	(0.08)	(0.06)	(0.03)	(0.13)
Tobin's Q	-0.043	-0.002	-0.050***	-0.059	-0.022	-0.053**	-0.008	-0.055
	(0.03)	(0.05)	(0.02)	(0.06)	(0.03)	(0.02)	(0.01)	(0.06)
CashHolding	0.516***	0.616***	0.292***	0.890***	0.499***	0.491***	0.109***	0.852***
	(0.08)	(0.15)	(0.05)	(0.15)	(0.09)	(0.08)	(0.03)	(0.15)
ROA	0.025	-0.181***	-0.108***	-0.089*	0.246***	0.143***	0.028***	-0.145***
	(0.02)	(0.04)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.05)
Constant	0.042	2.690***	-0.588***	1.318***	-1.371***	-0.964***	-0.192*	1.914***
	(0.14)	(0.34)	(0.09)	(0.38)	(0.22)	(0.17)	(0.11)	(0.33)
Observations	10,621	10,621	10,621	10,621	10,621	10,621	10,621	10,621
Adj. R-squared	0.779	0.670	0.774	0.639	0.751	0.794	0.494	0.619
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the robust tests of the effect of customer concentration on firms' total and incremental innovations, using two-stage regression methodology. The dependent variable is a series of total innovation measures, including *Ln(Patent)* and *Ln(Citations)*, and incremental innovation measures, including *Ln(Uncited)*, *Ln(BackCite)*, *Ln(Selfcite)*, *Ln(KnownClass)*, *TechProx*, and *Ln(Claims)*, corresponding to the results from column (1) to column (8), separately. The independent variable of interest is the residual of customer concentration (*CC_Residual).* Following Patatoukas (2012), *CC_residual* is calculated from annual cross-sectional regressions of customer concentration on a vector of characteristics evaluated for the firm including: (1) natural logarithm of market capitalization, (2) natural logarithm of firm age, (3) annual percentage sales growth, (4) an indicator variable equal to 1 if the firm reports at least two business segments, and (5) the annual change in the Herfindahl-Hirschman index of competition in the firm's two-digit SIC industry. Column (1) to Column (8) present the second stage results for above innovation measures, separately. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 9 Regression Results Testing the Interaction Effect between

Customer-base Concentration and Investment Irreversibility on Total and Incremental Innovation

Y=	*Ln(Patent)* (1)	*Ln(Citations)* (2)	*Ln(Uncited)* (3)	*Ln(BackCite)* (4)	*Ln(SelfCite)* (5)	*Ln(KnownClass)* (6)	*TechProx* (7)	*Ln(Claims)* (8)
CC	0.204***	0.218**	0.165***	0.255**	0.153**	0.233***	0.071***	0.344***
	(0.05)	(0.10)	(0.04)	(0.11)	(0.07)	(0.05)	(0.02)	(0.10)
InvestIrreverse	-0.214	-0.167	-0.474*	-0.492	-0.210	-0.327	-0.178	-0.545
	(0.39)	(0.76)	(0.28)	(0.79)	(0.50)	(0.40)	(0.16)	(0.79)
CC#InvestIrreverse	1.732**	-1.413	3.176***	2.372	3.226***	2.560***	0.225	1.257
	(0.80)	(1.58)	(0.69)	(1.58)	(1.05)	(0.83)	(0.34)	(1.60)
R&D	0.474***	0.548***	0.264***	0.843***	0.435***	0.448***	0.098***	0.798***
	(0.07)	(0.14)	(0.05)	(0.15)	(0.08)	(0.08)	(0.04)	(0.15)
Size	0.294***	0.310***	0.195***	0.475***	0.321***	0.313***	0.076***	0.447***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.02)	(0.01)	(0.03)
FirmAge	0.011	-0.220***	-0.094***	-0.103**	0.233***	0.131***	0.027***	-0.176***
	(0.02)	(0.04)	(0.02)	(0.04)	(0.03)	(0.02)	(0.01)	(0.04)
Leverage	-0.074***	-0.105**	-0.034*	-0.093*	-0.020	-0.080***	-0.018	-0.096*
	(0.03)	(0.05)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.06)
CapEx	-0.227	-0.032	-0.465***	-0.434	-0.132	-0.287*	-0.051	-0.423
	(0.15)	(0.35)	(0.12)	(0.34)	(0.20)	(0.16)	(0.08)	(0.36)
Tobin's Q	0.006***	0.011***	-0.001	0.012***	0.008***	0.003*	0.001	0.009**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CashHolding	-0.043	0.215*	-0.158***	0.164	0.011	-0.058	0.000	-0.005
	(0.05)	(0.12)	(0.04)	(0.12)	(0.08)	(0.06)	(0.03)	(0.12)
ROA	-0.050*	-0.017	-0.052***	-0.068	-0.030	-0.063**	-0.014	-0.069
	(0.03)	(0.04)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.06)
Constant	-0.080	2.605***	-0.823***	1.117**	-1.454***	-1.152***	-0.283**	1.635***
	(0.21)	(0.46)	(0.14)	(0.50)	(0.29)	(0.24)	(0.13)	(0.47)
Observations	11,940	11,940	11,940	11,940	11,940	11,940	11,940	11,940
Adj. R-squared	0.772	0.660	0.769	0.626	0.749	0.789	0.485	0.606
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the moderating effect of investment irreversibility on the effect of customer concentration on firms' total and incremental innovations. The dependent variable is the a series of total innovation measures, including *Ln(Patent)* and *Ln(Citations)*, and incremental innovation measures, including *Ln(Uncited)*, *Ln(BackCite)*, *Ln(Selfcite)*, *Ln(KnownClass)*, *TechProx*, and *Ln(Claims)*, corresponding to the results from column (1) to column (8), separately. The independent variables are 1). Customer concentration (*CC),* defined as the Herfindahl-Hirschman Index of major customer's sales to firm, and 2). Investment Irreversibility (*InvestIrreverse*), defined as the firm's asset redeployability score multiplies -1. Asset redeployability score is calculated as the value-weighted average of the industry-level redeployability index across the business segments. Industry-level redeployability is calculated as the value-weighted average of the asset-level redeployability scores from Bureau of Economic Analysis (BEA) 1997 capital flow table. The key variable of interest is the interaction term of customer concentration and investment irreversibility (*CC#InvestIrreverse*), capturing the moderating effect. *CC* and *InvestIrreverse* are mean-centered to ease the coefficients interpretation. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA*. Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 10 Regression Results Testing the Interaction Effects between Customer-base Concentration and Investment Irreversibility on Radical Innovation

Y=	Ln(NewClass)				Ln(Top1Citations)			
	t	t+1	t+2	t+3	t	t+1	t+2	t+3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CC	0.045	0.006	0.005	-0.066	0.024*	0.012	-0.009	0.004
	(0.04)	(0.06)	(0.07)	(0.08)	(0.01)	(0.02)	(0.02)	(0.03)
InvestIrreverse	0.242	-0.059	0.495	0.768	-0.125	-0.032	0.116	0.155
	(0.32)	(0.39)	(0.45)	(0.51)	(0.11)	(0.15)	(0.17)	(0.20)
CC#InvestIrreverse	-1.178*	-1.969*	-2.572**	-2.458*	0.412*	0.350	-0.619	-0.497
	(0.71)	(1.04)	(1.18)	(1.31)	(0.23)	(0.34)	(0.38)	(0.60)
R&D	0.128**	-0.017	-0.057	-0.079	0.013	-0.017	-0.015	-0.018
	(0.06)	(0.08)	(0.09)	(0.10)	(0.01)	(0.02)	(0.02)	(0.02)
Size	0.078***	0.045***	-0.012	-0.032	0.010**	0.004	0.010*	0.010
	(0.01)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)	(0.01)	(0.01)
FirmAge	-0.068***	0.057**	0.042	0.042	0.007	0.008	0.008	0.006
	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Leverage	-0.027	-0.025	-0.001	-0.012	-0.005	-0.002	0.000	0.020**
	(0.02)	(0.02)	(0.03)	(0.04)	(0.00)	(0.01)	(0.01)	(0.01)
CapEx	0.200	0.423**	0.408**	0.561***	-0.010	0.049	0.047	-0.025
	(0.13)	(0.16)	(0.20)	(0.21)	(0.04)	(0.06)	(0.06)	(0.06)
Tobin's Q	0.003**	0.001	0.002	0.008***	-0.000	0.000	0.002**	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CashHolding	-0.010	0.063	-0.034	0.077	-0.001	-0.010	-0.005	0.037
	(0.05)	(0.06)	(0.07)	(0.08)	(0.01)	(0.02)	(0.02)	(0.02)
ROA	-0.009	0.014	0.003	0.035	-0.002	-0.003	0.000	0.009*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	0.856***	0.181	0.876***	0.930***	-0.051	0.019	0.051	0.068
	(0.18)	(0.22)	(0.25)	(0.27)	(0.05)	(0.07)	(0.08)	(0.09)
Observations	11,940	8,908	7,154	5,788	11,940	8,908	7,154	5,788
Adj. R-squared	0.239	0.230	0.218	0.221	0.454	0.440	0.444	0.426
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the moderating effect of investment irreversibility on the effect of customer concentration on firms' total and incremental innovations. The dependent variable is a series of radical innovation measures, including *Ln(NewClass)* and *Ln(Top1Citations)*. Column (1) to column (4) reports the dynamic effects of customer concentration on *Ln(NewClass),* from t to t+4 correspondingly. Column (5) to column (8) reports the dynamic effects of customer concentration on *Ln(Top1Citations)*, from t to t+4 correspondingly. The independent variables are 1). Customer concentration (*CC*), defined as the Herfindahl-Hirschman Index of major customer's sales to firm, and 2). Investment Irreversibility (*InvestIrreverse*), defined as the firm's asset redeployability score multiplies -1. Asset redeployability score is calculated as the value-weighted average of the industry-level redeployability index across the business segments. Industry-level redeployability is calculated as the value-weighted average of the asset-level redeployability scores from Bureau of Economic Analysis (BEA) 1997 capital flow table (Kim and Kung 2017). The key variable of interest is the interaction term of customer concentration and investment irreversibility (*CC#InvestIrreverse*), capturing the moderating effect. *CC* and *InvestIrreverse* are mean-centered to ease the coefficients interpretation. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 11 Tests to Rule out Spillover Effects from Major Customers as an Alternative Explanation for the Effect of Customer Concentration on Total and Incremental Innovations: Controlling for Major Customers' Innovations

Y=	*Ln(Patent* (1)	*Ln(Citations* (2)	*Ln(Uncited* (3)	*Ln(BackCite* (4)	*Ln(SelfCite* (5)	*Ln(KnownClass* (6)	*TechPro* (7)	*Ln(Claims* (8)
CC	0.262***	0.389***	0.168***	0.411***	0.196*	0.254***	0.075**	0.497***
	(0.07)	(0.14)	(0.06)	(0.15)	(0.10)	(0.07)	(0.03)	(0.14)
R&D	0.278***	0.267***	0.203***	0.450***	0.324***	0.303***	0.082***	0.394***
	(0.02)	(0.04)	(0.02)	(0.04)	(0.03)	(0.02)	(0.01)	(0.04)
Size	0.006*	0.008	-0.001	0.011*	0.007*	0.005	0.001	0.012**
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)
FirmAge	-0.058*	-0.119**	-0.025	-0.043	0.002	-0.059**	-0.009	-0.078
	(0.03)	(0.06)	(0.02)	(0.06)	(0.04)	(0.03)	(0.02)	(0.07)
Leverage	-0.129	0.161	-0.526***	-0.078	-0.040	-0.078	0.117	-0.241
	(0.21)	(0.48)	(0.17)	(0.46)	(0.27)	(0.20)	(0.09)	(0.48)
CapEx	-0.056	0.161	-0.143**	0.105	0.076	-0.059	0.015	-0.023
	(0.07)	(0.16)	(0.06)	(0.17)	(0.10)	(0.07)	(0.03)	(0.17)
Tobin's Q	-0.038	-0.007	-0.037**	-0.047	-0.009	-0.030	0.005	-0.058
	(0.03)	(0.05)	(0.02)	(0.06)	(0.03)	(0.02)	(0.01)	(0.06)
CashHolding	0.460***	0.641***	0.291***	0.843***	0.501***	0.414***	0.099***	0.784***
	(0.10)	(0.19)	(0.06)	(0.20)	(0.11)	(0.09)	(0.04)	(0.21)
ROA	0.140***	0.222***	-0.169***	0.215**	0.317***	0.133***	-0.006	0.262***
	(0.04)	(0.08)	(0.04)	(0.08)	(0.06)	(0.04)	(0.02)	(0.08)
Corresponding Innovation Var.	-0.004	-0.006	0.027**	-0.011	0.003	0.038***	0.084***	-0.013
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	-0.361	1.188**	-0.514***	-0.256	-1.481***	-0.703***	0.031	0.273
	(0.25)	(0.59)	(0.11)	(0.53)	(0.27)	(0.25)	(0.12)	(0.63)
Observations	7,970	7,970	7,970	7,970	7,970	7,970	7,970	7,970
Adj. R-squared	0.787	0.681	0.784	0.653	0.754	0.811	0.543	0.637
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the tests of the effect of customer concentration on firms' total and incremental innovations controlling for major customer's innovations, to rule out the alternative explanation that our main effect on innovations are driven by spillovers of major customers. The dependent variable is a series of total innovation measures, including *Ln(Patent)* and *Ln(Citations)*, and incremental innovation measures, including *Ln(Uncited)*, *Ln(BackCite)*, *Ln(Selfcite)*, *Ln(KnownClass)*, *TechProx*, and *Ln(Claims)*, corresponding to the results from column (1) to column (8), separately. The independent variable of interest is customer concentration (*CC),* defined as the Herfindahl-Hirschman Index of major customer's sales to firm. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* We add major customer's corresponding innovation variables in *t-1* as control variables in each column. Major customer's corresponding innovation variables are calculated as the sum of sales-weighted innovation for each major identified customer. For example, we add natural logarithm of one plus identified major customer's sales-weighted total patent number in *t-1* (i.e., lagged major customer's *LnPatent*) as a control variable in column (1) regression, in which the dependent variable is natural logarithm of one plus supplier's total patent number (*LnPatent*). We apply the similar fashion from Column (2) to column (8) for the rest of innovation variables. Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 12 Tests to Rule out Spillover Effects from Major Customers as an Alternative Explanation for the Effect of Customer Concentration on Total and Incremental Innovations: Subtracting Supplier's Patents Citing Major Customers' Patents

Y=	*NonCustomer* (1)	*NonCustomer* (2)	*NonCustomer* (3)	*NonCustomer* (4)	*NonCustomer* (5)	*NonCustomer* (6)	*NonCustomer* (7)	*NonCustomer* (8)
CC	0.201***	0.281***	0.132***	0.310***	0.133*	0.210***	0.076***	0.407***
	(0.05)	(0.10)	(0.04)	(0.11)	(0.07)	(0.05)	(0.02)	(0.11)
R&D	0.272***	0.283***	0.181***	0.487***	0.324***	0.285***	0.076***	0.460***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.02)	(0.01)	(0.03)
Size	0.004*	0.008*	-0.001	0.009**	0.007***	0.002	0.001	0.007
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
FirmAge	-0.083***	-0.112**	-0.045**	-0.118**	-0.027	-0.087***	-0.018	-0.104*
	(0.03)	(0.05)	(0.02)	(0.06)	(0.03)	(0.03)	(0.01)	(0.06)
Leverage	-0.205	-0.028	-0.415***	-0.430	-0.159	-0.261	-0.067	-0.433
	(0.15)	(0.35)	(0.11)	(0.36)	(0.20)	(0.16)	(0.08)	(0.37)
CapEx	-0.027	0.226*	-0.145***	0.153	0.006	-0.048	-0.001	0.006
	(0.05)	(0.12)	(0.04)	(0.12)	(0.08)	(0.06)	(0.03)	(0.13)
Tobin's Q	-0.052**	-0.016	-0.054***	-0.074	-0.032	-0.062**	-0.013	-0.065
	(0.03)	(0.04)	(0.02)	(0.06)	(0.03)	(0.02)	(0.01)	(0.06)
CashHolding	0.464***	0.556***	0.248***	0.896***	0.448***	0.435***	0.110***	0.876***
	(0.07)	(0.14)	(0.05)	(0.15)	(0.08)	(0.07)	(0.04)	(0.16)
ROA	0.003	-0.219***	-0.094***	-0.114**	0.229***	0.120***	0.022**	-0.185***
	(0.02)	(0.04)	(0.02)	(0.05)	(0.03)	(0.02)	(0.01)	(0.04)
Constant	0.117	2.783***	-0.558***	1.273***	-1.360***	-0.878***	-0.207*	1.797***
	(0.14)	(0.35)	(0.09)	(0.38)	(0.22)	(0.17)	(0.11)	(0.34)
Observations	11,940	11,940	11,940	11,940	11,940	11,940	11,940	11,940
Adj. R-squared	0.767	0.650	0.764	0.621	0.748	0.786	0.481	0.600
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the tests of the effect of customer concentration on firms' total and incremental innovations, subtracting supplier's patents citing major customers' patents, to rule out the alternative explanation that our main effect on innovations are driven by spillovers of major customers. The dependent variable is the a series of "adjusted" form of total innovation measures, including *NonCustomer_Ln(Patent)* and *NonCustomer_Ln(Citations)*, and incremental innovation measures, including *NonCustomer_Ln(Uncited)*, *NonCustomer_Ln(BackCite)*, *NonCustomer_Ln(Selfcite)*, *NonCustomer_Ln(KnownClass)*, *NonCustomer_TechProx*, and *NonCustomer_Ln(Claims)*, corresponding to the results from column (1) to column (8), separately. "Adjusted" means that we exclude the patents that are citing from one of identified major customers in suppliers current patent portfolio for above innovation measures. For example, *NonCus_Ln(Patent)* is defined as the natural logarithm of one plus the number of patents that are not citing from one of identified major customers. We apply the similar fashion from column (2) to column (8) for the rest of dependent variables. The independent variable of interest is customer concentration (*CC*), defined as the Herfindahl-Hirschman Index of major customer's sales to firm. The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 13 Robust Tests for the Main Effect of Customer Concentration on Total and Incremental Innovations: Using *RankCC* as Alternative Measure of Customer Concentration

Y=	*Ln(Patent)*	*Ln(Citations)*	*Ln(Uncited)*	*Ln(BackCite)*	*Ln(SelfCite)*	*Ln(KnownClass)*	*TechProx*	*Ln(Claims)*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RankCC	0.142***	0.088	0.150***	0.198***	0.186***	0.172***	0.043***	0.169**
	(0.04)	(0.07)	(0.03)	(0.07)	(0.05)	(0.04)	(0.02)	(0.08)
R&D	0.477***	0.555***	0.265***	0.846***	0.434***	0.451***	0.099***	0.806***
	(0.07)	(0.14)	(0.05)	(0.15)	(0.08)	(0.07)	(0.04)	(0.15)
Size	0.295***	0.310***	0.196***	0.476***	0.322***	0.314***	0.076***	0.448***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.02)	(0.01)	(0.03)
FirmAge	0.012	-0.227***	-0.088***	-0.100**	0.242***	0.134***	0.027***	-0.179***
	(0.02)	(0.04)	(0.02)	(0.04)	(0.03)	(0.02)	(0.01)	(0.04)
Leverage	-0.077***	-0.105**	-0.038**	-0.097*	-0.024	-0.084***	-0.019	-0.100*
	(0.03)	(0.05)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.06)
CapEx	-0.246	-0.041	-0.491***	-0.464	-0.157	-0.312*	-0.058	-0.449
	(0.15)	(0.35)	(0.12)	(0.34)	(0.20)	(0.16)	(0.08)	(0.36)
Tobin's Q	0.006***	0.011***	-0.001	0.012***	0.008***	0.004*	0.001	0.009**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CashHolding	-0.042	0.217*	-0.158***	0.164	0.008	-0.058	0.001	-0.002
	(0.05)	(0.12)	(0.04)	(0.12)	(0.08)	(0.06)	(0.03)	(0.12)
ROA	-0.051**	-0.015	-0.055***	-0.071	-0.033	-0.065***	-0.015	-0.070
	(0.03)	(0.04)	(0.02)	(0.05)	(0.03)	(0.03)	(0.01)	(0.06)
Constant	-0.046	2.658***	-0.697***	1.236***	-1.461***	-1.086***	-0.226**	1.814***
	(0.14)	(0.34)	(0.09)	(0.38)	(0.22)	(0.17)	(0.11)	(0.34)
Observations	11,940	11,940	11,940	11,940	11,940	11,940	11,940	11,940
Adj. R-squared	0.772	0.660	0.769	0.626	0.749	0.789	0.485	0.606
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

This table reports the robust tests of the effect of customer concentration on firms' total and incremental innovations. The dependent variable is a series of total innovation measures, including *Ln(Patent)* and *Ln(Citations)*, and incremental innovation measures, including *Ln(Uncited)*, *Ln(BackCite)*, *Ln(Selfcite)*, *Ln(KnownClass)*, *TechProx*, and *Ln(Claims)*, corresponding to the results from column (1) to column (8), separately. The independent variable of interest is the rank of customer concentration (*RankCC*), defined as the decile rank of customer concentration (*CC*) from 0(the lowest) to 1(the highest). The control variables include *R&D, Size, FirmAge, Leverage, CapEx, Tobin's Q, CashHolding,* and *ROA.* Definitions of all variables are detailed in the Appendix A. Firm- and year- fixed effects are included in all regressions. Robust standard errors are reported in parentheses below the coefficient estimates. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.