Is Innovation Always Beneficial?

Externalities of Innovation on Product Market Relationship

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ABSTRACT

This paper investigates negative externalities of innovation along supply chain by analyzing the effect of customer's innovation on supplier's trade credit provision. I find that supplier extends more trade credit after customer makes innovation, and the effect is robust after controlling for various firm characteristics and industry-specific market conditions, and, to potential endogeneity issues. The effect is mainly driven by the holdup channel as opposed to the demand channel and the financing channel. Next, I document that the technological relatedness between customer's innovation and supplier's innovation downsizes the positive sensitivity of supplier's trade credit provision to customer's innovation. Lastly, I find that supplier adopts more conservative financial policy and produces more innovation by learning from customer's innovation.

1. Introduction

Technology innovation has been regarded as an important corporate investment decision and outcome (e.g., Schumpeter, 1911; Solow, 1957; Hall et al., 2009; Hsu et al., 2014). While previous studies highlight the role of innovation in firm productivity, growth and survival, a firm's innovation also can affect the other stakeholders as well as the firm itself and its security holders. In other words, stakeholders, such as its supplier, customer, competitor, employee, and even government, can be affected through their economic relationship with the innovative firm even if they don't have direct monetary stake in the innovative firm. While the innovation literature mostly focuses on the spillover effect of innovation on customer or supplier firm, the literature has so far paid little attention to how innovation shapes the dynamics between customer and supplier. [1] This paper helps bridge that gap by investigating how a firm's innovation affects the relationship with its customer or supplier firm as the innovation changes its bargaining power.

The relationship between Apple and Samsung illustrates how innovation of one party is critical to its counterparty in the trade relationship. With its advanced screen technology, Samsung has been the major supplier of Apple and now Apple relies heavily on the OLED screens supplied by Samsung because the supplier has a technological merit that it is the only supplier which can mass-produce OLED screens. [2] The growing dependence of Apple on Samsung implies its weak bargaining power against Samsung, for instance, over its pricing on OLED screens (in fact, this component is said to be one reason why iPhone X has a steep price tag). Samsung could charge the price of its OLED at least to the price of OLED from alternative suppliers. Also, we would expect Apple to be granted less trade credit or allowed for shorter payment delay by Samsung due to its stronger dependence on Samsung than before.

[1] For example, one source of such externality takes place in the technology dimension. More specifically, Hsu (2011) finds that firms can save innovation costs by taking advantage of innovation made by their competitors or geographically close firms. Bloom et al. (2013) investigates a positive effect from knowledge spillovers and negative business stealing effects from rival firms. Li (2018) finds that supplier experience improved performance from its customer innovation and emphasizes the positive externality of innovation. Whereas, my paper focuses on the negative externality from the innovator's bargaining power.

[2] In fact, the market demand of iPhone XR (a more budget friendly version in the iPhone X lineup) fell short of expectations, and which is allegedly due to the lower quality of display (LCD screen) and camera compared to the previous iPhone X lineup (X and XS). As a result, Apple is looking to drop LCD screens from its iPhone lineup (starting with the 2020 iPhone) and switching to OLED screens.

The changed dynamics stemming from one party's innovation can show up in various ways; for instance, trade credit (or payment delay), cash before delivery (or advanced payment), delivery delay, pricing on traded product, length of customer-supplier trade relationship, or long-term supply contract can appear or be affected as relative bargaining power between two firms changes. In this paper, I specifically focus on trade credit for the following reasons. To the extent that trade credit proxies for relative bargaining power as documented in the literature, it can also be a good measure for identification process of this paper. Also, given that contract-level variables (such as product price or contract terms) are not observable, trade credit, which is observable in annual filings, can be the important measures of bargaining power. Additionally, as the importance of trade credit in the balance sheet of US firms grows, investigation of determinants which potentially influence the trade credit policy is interesting in its own right. [3]

On this ground, I investigate how a firm's innovation affects the trade credit provision of its supplier.[4] First, customer's more active innovation can generate higher degree of appropriation of quasi-rent and lead to more extension of trade credit from supplier ("holdup channel"). The innovation can generate completely new technology and products which enable the innovator to switch to another trade relationship and end up terminating the current relationship. [5] Meanwhile, note that this quasi-rent is not necessarily identical to the monopoly rent as explained in Klein et al. (1978). Going back to Apple and Samsung case, Apple cannot give up OLED-screen iPhones since the next best use of the devices (before installing screens) is only through equipping the devices with LCD screens, and which couldn't satisfy consumers just as turned out in the poor sales record of iPhone XR. Thus, we can say that Apple's assets (i.e., iPhone devices) are specialized to Samsung's product (i.e., OLED screen). Also, there is no market closure or restriction on other screen makers in the OLED screen market. Even if free and open competition for entry is possible, other screen suppliers cannot just catch up Samsung's technology because it

[3] Freeman (2018) documents that trade credit constitutes 73% of short-term liabilities among Compustat firms as of 2016.

[4] In this paper, I only focus on the innovation from the customer side because the Compustat segment file provides important customers of each supplier (i.e., customers comprising 10% or more of each supplier's total sales). Hence, the data only identifies whether a firm is an important customer of a firm, but not whether a firm is an important supplier of a firm.

[5] However, it is not clear whether it is supplier or customer that leads to the decision of increased trade credit; customer firm may demand more trade credit with its strengthened bargaining power, but it is also possible that supplier may voluntarily offer more trade credit. Even if it is the decision of supplier side, the explanation is still consistent with the holdup hypothesis. Unfortunately, this is not observable even in the 10-K filings.

is too costly for them.[6] In other words, their lack of innovation enables Samsung to be the major supplier of Apple. Even if the example demonstrates the holdup of Apple ("customer") by Samsung ("innovative supplier"), the inverse relation (i.e., holdup of supplier by innovative customer) is also applicable.

To the extent that the customer innovation creates holdup problem, the effect should be more pronounced for suppliers with higher asset specificity (i.e., more relationship-specific investments) compared to those with lower asset specificity (i.e., less relationship-specific investments). This is because, as Klein et al. (1978) claims, specialized assets create quasi-rents that are appropriable by counterparties due to their low salvage value.

On the other hand, it is also possible that supplier is able to extend more trade credit with increased demand from customer ("demand channel"). Customer's innovation can lead to more active transactions with its supplier and thus more solid trade relationship between them if the innovation increases customer's demand for input products and/or decreases supplier's cost when supplier has a fixed cost of production. Accordingly, the supplier might be willing to extend more trade credit to customer. If then, supplier's provision of trade credit increases mechanically after customer's innovation, and which has nothing to do with the change in relative bargaining power supported by the holdup channel. If this channel is at work, then we should expect that the supplier's sales to the customer or the customer's cost of goods sold increases after customer's innovation.

Another possibility arises from the monetary innovation cost of customer; after innovation, the customer might ask more trade credit to cover its innovation cost ("financing channel"). If the customer lacks liquidity and cannot pay its supplier in full before it recoups the innovation cost from its final sales, then it might request more trade credit. This channel is accounted for by the change in the liquidity, not change in the bargaining power, from the innovation. If this channel holds, then we should observe that the supplier extends even more trade credit to innovative customer which is more credit- or cash-constrained.

[6] In fact, Apple is collaborating with LG Display as another supplier to break its reliance on Samsung, but this strategy is not going as planned due to technological limitations. Apple needs smaller, power-efficient displays, which require a different manufacturing process from the one LG uses to create its larger OLED panels.

My approach to this study is as follows. I first document descriptive statistics on the sample to how customer and supplier in the sample differ in firm characteristics dimensions. Also, using a firm's patenting activity as the proxy for its innovation level, I report how suppliers whose customer has no innovation activity and those whose customer has positive innovation activity differ. As for the main result, I find that supplier extends more trade credit 1, 2, and 3 years after its customer increases innovation activity and the effect is both statistically and economically significant. Since industry-specific market condition can shape the trade credit, I perform a battery of additional tests using different combination of fixed effects, such as supplier industry-year fixed effect. Next, because the possible channels (i.e., holdup, demand, and financing channel) predict the same outcome and are not mutually exclusive, I examine which mechanism drives the result using cross-sectional heterogeneity tests. Given that the impact of customer innovation on supplier's trade credit is stronger when the supplier's asset specificity is high, it is likely that holdup problem between customer and supplier drives the main effect. Whereas, I do not observe any result which is implied by the demand and financing channel.

A potential concern with the main result is that a supplier may motivate its customer to increase innovation activity with its ability to provide a large amount of trade credit. Alternatively, a supplier being capable of extending much trade credit could attract innovative customers. Another concern is that customer innovation could be correlated with unobservable confounding factors such as product market or political conditions that affect supplier's trade credit decision. To further limit the potential effect of endogeneity, I conduct two-stage least squares (2SLS) regression with two instrumental variables (IVs) following Hsu et al (2015). More specifically, I use average R&D expenditures per patent and average duration from application filing to issue or grant of patent in customer's industry level as the two IVs. Because these two measures proxy for monetary cost and time cost of innovation at customer's industry level, respectively, they should affect customer's incentive to innovate but are unlikely to be related to supplier's trade credit policy. The 2SLS test confirms that the observed main effect is not driven by potential endogeneity.

Next question I address is whether the technological class of customer's innovation affects the positive sensitivity of supplier's trade credit provision to customer's innovation. If the customer's innovation is closely related to the supplier's existing product technology, and hence, is likely to be relationship-specific, then it should mitigate the holdup problem. Consistent with this prediction,

I find that the positive sensitivity of supplier's trade credit to customer innovation decreases when customer's patent cites supplier's existing patent, or, customer's patent class overlaps with existing patent classes of supplier. On the other hand, it is not observed that the sensitivity changes when customer's patent cites its own existing patents, or, its patent class overlaps with its original patent classes. Again, these results are consistent with the holdup channel. In addition, the results highlight the difference between "product innovation" and "process innovation". The innovation literature (Levin and Reiss, 1988; Cohen and Klepper, 1996; Lin and Saggi, 2001; Lin, 2009) classifies corporate innovation into two types: innovation to generate new product (i.e., product innovation) and innovation to increase the productivity of existing assets (i.e., process innovation). Customer's product innovation can give the customer the opportunity to switch to another supplier and increase its bargaining power against its original supplier. To the extent that deviation of customer's technology space from that of supplier is interpreted as customer's making product innovation, the result implies that product innovation can cause holdup problem. In the meantime, it is not clear whether customer's process innovation increases or decreases its bargaining power. On one hand, customer, for instance, can develop a new product with its extra resources attained additionally from its process innovation. In turn, the customer will be able to hold up its supplier with the new product. On the other hand, it is also possible that customer's process innovation increases its production efficiency and lowers its production costs where the extra surplus can be appropriated by its supplier. To the extent that the overlapping between new technology space and original technology space within a firm implies process innovation, the result indicates that process innovation neither increases nor decreases bargaining power.

Next, I explore how customer innovation shapes financial and investment decision of supplier. A supplier, when faced with holdup by its customer, might change its financial and investment policy to protect itself from the holdup. The supplier might need to maintain conservative policies to cover the increased trade credit provision, cover the cost of searching new customer, build a new factory line for self-production of final product, prepare the cost of vertical acquisition of the customer, and so on. At the same time, it can increase its own innovative activity to increase bargaining power against its customer. It may also learn from customer's innovation for the purpose of providing input products customized for customer's new product, and thus, preventing the customer from switching to another supplier. In fact, the result shows that suppliers seem to adopt more conservative financial policy through holding higher cash holdings and lessening

payout when customers innovate. At the same time, suppliers increase their own innovation activities after their customers innovate. Moreover, their patents cite patents of their customers more frequently, that is, they learn from customers' innovation.[7] This analysis implies that customer innovation influences supplier's internal policy as well as its policy in the dimension of interfirm relationship (i.e., trade credit policy).

This paper contributes to the literature in three ways. First, my study emphasizes the negative externality of innovation, which has not been much documented in the innovation literature. Some studies (e.g., Hall et al (2010)) note that a firm's innovation can affect the productivity of other firms within the same industry, or, even other firms in distant regions. In this paper, I focus on the impact of innovation along the supply chain. Li (2018) finds that customer innovation increases the profitability of its supplier through the knowledge diffusion channel and demand channel. On the contrary, this paper emphasizes that customer innovation can cause negative externalities on supplier through the holdup channel. Also, this paper is related to the product market literature which investigates the externalities along the supply chain. It documents that customer-supplier relationship is influenced by various dimensions of counterparty risk: downstream merger activities (Fee and Thomas, 2004), bankruptcy risk (Hertzel et al., 2008), takeover risk (Cen et al., 2012), and so on. This paper argues that customer-supplier relationship, as measured by trade credit, is affected by counterparty's innovation. Lastly, this paper explains post-contractual opportunistic behavior, which is emphasized in the transaction cost theory literature (Klein et al., 1978; Williamson, 1979; Rhodes-Kropf and Robinson, 2008), especially after innovation.

The remainder of the paper is organized as follows. Section 2 describes used database and sample construction procedure. In Section 3, I provide empirical results to test the hypotheses given above. Section 4 summarizes the results and provides concluding remarks.

[7] In an untabulated logistic regression, it is not more likely for customer-supplier relationship to be terminated after customer innovation. In fact, only 15 customer-supplier pairs out of 13,093 pairs execute vertical integrations in my sample. Thus, it is plausible that suppliers try to maintain their trade relationship with customers even after customer innovation (which potentially results in holdup problem) by adopting conservative financial policy and customizing their innovation for customers.

2. Data Description

The data for customer-supplier relationship is obtained from Compustat which is collected for Cohen and Frazzini (2008). It is based on Compustat Segment file and uses a phonetic matching algorithm to match customer names with their PERMNOs. The data for patenting activity is collected for Kogan et al (2017) and is based on Google Patents Data[8]. It has an advantage that it includes more detailed information about patent (e.g., patent class code, citation information) relative to the US Patent Office (USPTO) data. I first define *Principal Customer* as the customer which takes the largest sales portion of each supplier in each year to construct customer-supplier pairs.[9] Next, I merge the customer-supplier data with the patent data at the *Principal Customer* level. Observations are treated as zero patents when patent information is missing. The database of Cohen and Frazzini (2008) covers the period from 1980 to 2011, and, the patent data of Kogan et al (2017) has the period from 1926 to 2010. Thus, my sample period spans from 1980 to 2010 and my sample consists of 39,003 customer-supplier-year observations (13,093 customer-supplier pairs).

The main dependent variable, *Trade Credit*, is the proportion of supplier's trade receivable attributable to its Principal Customer and is calculated as

$$Trade\ Credit_t = \frac{Trade\ Receivable_t \times \frac{Sales\ to\ Principal\ Customer_t}{Total\ Sales_t}}{Total\ Assets_t}$$

The main independent variable, *Customer Innovation*, is measured by Principal Customer's patenting activities and is calculated as

$$Customer\ Innovation_t = log\ (1 + The\ Number\ of\ Patents\ of\ Principal\ Customer_t)$$

[8] The patent data is provided on Noah Stoffman's website. The website address is https://kelley.iu.edu/nstoffma/

[9] I focus only on principal customers because they are likely to be most influential in supplier's corporate policy (e.g., trade credit provision) among all customers with their greatest sales portion. Also, SFAS No. 14 requires suppliers report customers which take at least 10% of total sales, and thus, I exclude customers other than principal customers to minimize the selection bias.

[Insert Table 1 here]

Table 1 shows summary statistics for my sample. Customer and supplier firms are different in various dimensions as documented in Panel A. For example, customer firms are larger in size, more profitable (i.e., higher ROA), and hold less cash balances. In Panel B, suppliers with positive customer innovation are larger, less levered, and hold more cash than those with zero customer innovation. Also, suppliers undertake more R&D and make more innovation when they have customers with positive innovation. On the other hand, suppliers extend more trade credit when customers have positive innovative activities, but the difference is not significant.

3. Empirical Results

In this section, I perform various regression tests to analyze the hypotheses explained in Section 1.

3.1. Base Line Results: Customer Innovation and Supplier's Trade Credit

In this section, I test whether supplier extends more trade credit after customer innovation using panel OLS regressions. The regression models include $Customer\ Innovation$ (the main independent variable) and several supplier firm characteristics such as size, MTB, and ROA measured at year t. Also, the models contain year fixed effects and supplier-industry fixed effects (3-digit SIC code) to control for economic conditions. The dependent variable, $Trade\ Credit$, allows time lags of 1 to 3 years since it might take time for customer innovation to take effect along supply chain. In addition, all models control for serial correlation by clustering the standard errors at customer-supplier pair level.

[Insert Table 2 here]

Table 2 exhibits that customer innovation induces more trade credit provided by supplier. The coefficients of $Customer\ Innovation$ are both statistically and economically significant in all specifications. For example, a one standard deviation increase in $Customer\ Innovation$ leads to 0.319% increases in $Trade\ Credit$ after 3 years. Given that the dependent variable $Trade\ Credit$ is scaled by supplier's total assets, the effect size is substantial.

[Insert Table 3 here]

Further, to rule out the possibility that industry-specific market condition can be correlated with both customer innovation and supplier trade credit, I perform a battery of additional tests using different combination of fixed effects such as supplier's industry-year fixed effects and customer's industry-year fixed effects. In all specifications, the coefficients of $Customer\ Innovation$ is statistically significant at a 1% level. Therefore, the result implies that the baseline effect is robust after controlling for time-varying customer or supplier industry effects.

3.2. Mechanisms

In Section 3.1., I observe that supplier provides more trade credit after customer innovates. Since the possible channels (i.e., holdup, demand, and financing channel) predict the same outcome and are not mutually exclusive, I examine which mechanism drives the result using cross-sectional heterogeneity tests.

3.2.1. Holdup Channel

According to the holdup channel, customer's more active innovation can generate higher degree of appropriation of quasi-rent and lead to more extension of trade credit from supplier. Customer

innovation can generate completely new technology and products which enable the customer to switch to another supplier and end up terminating the current relationship.

Klein et al. (1978) explains that holdup problem becomes more serious as the assets of exploited party are more relationship-specific since specialized assets create quasi-rents that are appropriable by counterparties due to their low salvage value. Thus, the holdup channel predicts that supplier with higher asset specificity extends even more trade credit when faced with customer innovation.

To measure supplier's asset specificity, I introduce four proxies of asset specificity since it is hard to observe how much firms' assets are relationship-specific individually.[10]

$$Asset\ Specificity_1 = \frac{Sales\ to\ Principal\ Customer}{Average\ Sales\ to\ all\ Customers}$$

$$Asset\ Specificity_2 = \frac{1}{log\ (1 + The\ Number\ of\ Alternative\ Customers)}$$

$$Asset\ Specificity_3 = 1 - \frac{Tangible\ Assets}{Total\ Assets}$$

$$Asset\ Specificity_4 = log\ (1 + The\ Number\ of\ Years\ of\ Trade\ Relationship\ with\ Principal\ Customer)$$

$Asset\ Specificity_1$ and $Asset\ Specificity_2$ utilize the information of customer firms of each supplier as identified in the Cohen and Frazzini (2008) data. $Asset\ Specificity_1$ measures the current sales dependence on $Principal\ Customer$ and is likely to be positively associated with the degree of specificity of supplier's assets to its $Principal\ Customer$. $Asset\ Specificity_2$ measures inverse of the number of $Alternative\ Customers$. Here, $Alternative\ Customers$ of a supplier are the customer firms which are in the same industry as $Principal\ Customer$ and whose suppliers are in the same industry as the supplier, and hence, $Alternative\ Customers$ are the firms which the supplier can potentially switch to without adjusting its current product line.

[10] Fan (2000) focuses on a single industry ("petrochemical industry") and estimates asset specificity of a firm in the industry using its input material.

On the other hand, $Asset\ Specificity_3$ is related to intangible assets which are likely to be specific. For example, a supplier's knowledge or human capital can be already specific to current customer. The last measure, $Asset\ Specificity_4$, measures the length of trade relationship with $Principal\ Customer$ in the sense that supplier's assets could have been specialized to its customer through years of trade relationship.

Using each measure of asset specificity, I first divide the sample into "High" asset specificity and "Low" asset specificity group with its median value. I then compare the coefficients of $Customer\ Innovation$ estimated in the two groups.

[Insert Table 4 here]

In Column 1 and 2 of Table 4, the coefficient of $Customer\ Innovation$ is statistically significant only among the high asset specificity group when $Asset\ Specificity_1$ is used. Even if Column 3, 5, and 7 show that the coefficients of $Customer\ Innovation$ are significantly positive among low asset specific group, but the magnitude is smaller than that among high asset specific group in Column 4, 6, and 8. In the meantime, note that the result in fact contradicts an alternative story which is seemingly related to, but not perfectly in accordance with, the holdup explanation; when a firm's customer makes innovation, it may spontaneously extend trade credit as an investment expecting some benefit, such as technological spillover, from the customer's innovation.[11] This can simultaneously occur even when the supplier faces (potential) threat from customer arising from its greater bargaining power (i.e., when the holdup problem arises), and thus, this explanation differs from the holdup mechanism. However, the result of Table 4 doesn't support this story in that both high and low asset specificity groups can enjoy the same benefits according to the story. On the other hand, consistent with the holdup channel, Table 4's results imply that it is high asset specificity firms that can enjoy more benefit (or avoid more potential losses from the holdup problem) by extending more trade credit rather than low asset specificity firms. Overall, the results

[11] This alternative explanation is based on the benefits which are different from the avoidance of losses from holdup problem; in other words, the benefits don't include, for instance, the continuation of the current trade relationship which is endangered under the holdup problem.

are consistent with the prediction of holdup channel that supplier with high asset specificity extends even more trade credit when faced with customer innovation than that with low asset specificity.

3.2.2. Demand Channel

Previous section exhibits the results which are consistent with the holdup channel, but an alternative mechanism, demand channel, might be at work. Customer innovation can lead to more active transactions with its supplier and thus more solid trade relationship between them if the innovation increases customer's demand for input products and/or decreases supplier's cost when supplier has a fixed cost of production. Accordingly, the supplier might be willing to extend more trade credit to customer. If then, supplier's provision of trade credit increases mechanically after customer's innovation, and which has nothing to do with the change in relative bargaining power supported by the holdup channel. If this hypothesis holds, then we should expect that the supplier's sales to the customer or the customer's cost of goods sold increases after customer's innovation. More specifically, I construct two customer-level variables as follows and test whether they are affected by Customer Innovation.

$$Customer\ Sales = Sales\ to\ Principal\ Customer$$

$$\frac{COGS}{TA} = \frac{Principal\ Customer's\ Cost\ of\ Goods\ Sold}{Principal\ Customer's\ Total\ Assets}$$

[Insert Table 5 here]

In the regressions, I run regressions with customer-level control variables (e.g., size, MTB, ROA) and customer industry fixed effects because the dependent variables are measured at customer-level. Also, I allow up to 3 years of time lag because the effect could show up with some time lag.

Table 5 shows that neither $Customer\ Sales$ nor $\frac{COGS}{TA}$ is influenced by $Customer\ Innovation$. The coefficients are not significantly different from zero and effect is not observed even after 3 years of time lag. In sum, the demand channel is not supported by the regression results.

3.2.3. Financing Channel

Prior results support the holdup channel and disprove the demand channel, but there is also another possibility of financing channel. After innovation, the customer might ask more trade credit to cover its innovation cost. If the customer lacks liquidity and cannot pay its supplier in full until it recoups the innovation cost from its final sales, then it might request more trade credit. If this hypothesis holds, then we should observe that the supplier extends even more trade credit to innovative customer which is more credit- or cash-constrained.

To test whether this hypothesis is true, I use three customer-level financial measures: cash ratio, payout, and leverage. The financing channel predicts that supplier extends even more trade credit when its customer has low cash ratio, high payouts, and/or high leverage. To check these possibilities, I run regression with interaction between $Customer\ Innovation$ and each customer-level financial measure.

[Insert Table 6 here]

In Table 6, none of the interaction variables is significantly different from zero. Thus, the results imply that the sensitivity of supplier trade credit to customer innovation doesn't vary across firms with different liquidity. Overall, the financing channel is not supported by the results.

3.3. Endogeneity

A potential concern with the prior result is that a supplier may motivate its customer to increase innovation activity with its ability to provide a large amount of trade credit. Alternatively, a supplier being capable of extending much trade credit could attract innovative customers. Also, it

could be case that customer innovation could be correlated with unobservable confounding factors such as product market or political conditions that affect supplier's trade credit decision. To further limit this potential endogeneity, I conduct 2SLS regression with two IVs following Hsu et al (2015). More specifically, I use average R&D expenditures per patent and average duration from application filing to issue or grant of patent in customer's industry level as the two IVs. Because these two measures proxy for monetary cost and time cost of innovation at customer's industry level, respectively, they should affect customer's incentive to innovate but are unlikely to be related to supplier's trade credit policy. To check whether the baseline result is robust to endogeneity problems, I re-estimate the OLS coefficients of Customer Innovation in Table 2 using 2SLS regressions.

[Insert Table 7 here]

Table 7 reports the second stage of 2SLS regression and shows that the coefficients of Customer Innovation are significantly positive in year t+1, t+2, and t+3.[12] Thereby, the results confirm that the observed baseline effect is robust to endogeneity issues.

3.4. Technological Space of Customer Innovation

In this section, I examine whether the technological class of customer's innovation affects the positive sensitivity of supplier's trade credit provision to customer's innovation. If the customer's innovation is closely related to the supplier's existing product technology, and hence, is likely to be relationship-specific, then it should mitigate the holdup problem. To measure the relatedness of customer's innovation to supplier's technology, I use the citation and technology class information recorded in Kogan et al (2017)'s data. More specifically, $Cite_t$ is the indicator variable which equals to 1 if a customer's patent (issued in year t) cites any of its supplier's patent (issued previously as of year t). $Class\ Overlap_t$ is the indicator variable which equals to 1 if technology

[12] The first stage regression is not reported for brevity.

class of customer's patent (issued in year t) overlaps with historical technology classes of supplier's patents (issued previously as of year t).

[Insert Table 8 here]

In Table 8, the interaction between $Customer\ Innovation$ and $Cite_t$ has negative associations with $Trade\ Credit$ even though it is significantly negative only in Column 1. On the other hand, the interaction between $Customer\ Innovation$ and $Class\ Overlap_t$ has negative associations with $Trade\ Credit$ in all specifications. Consistent with this prediction, I find that the positive sensitivity of supplier's trade credit to customer innovation decreases when customer's patent cites supplier's existing patent, or, customer's patent class overlaps with existing patent classes of supplier. Again, these results are consistent with the holdup channel.

[Insert Table 9 here]

On the other hand, it is not observed that the sensitivity changes when customer's patent cites its own existing patents, or, its patent class overlaps with its original patent classes. In Table 9, the interaction between $Customer\ Innovation$ and $Cite_t^{Own}$ (or $Class\ Overlap_t^{Own}$) is not significantly different from zero.

Arguably, the results in Table 8 and 9 may highlight the difference between "product innovation" and "process innovation". The innovation literature (Levin and Reiss, 1988; Cohen and Klepper, 1996; Lin and Saggi, 2001; Lin, 2009) classifies corporate innovation into two types: innovation to generate new product (i.e., product innovation) and innovation to increase the productivity of existing assets (i.e., process innovation). Customer's product innovation can give itself the opportunity to switch to another supplier and increase its bargaining power against its original supplier. To the extent that deviation of customer's technology space from that of supplier is interpreted as customer's making product innovation, the result implies that product innovation can cause holdup problem. In the meantime, it is not clear whether customer's process innovation

increases or decreases its bargaining power. On one hand, customer, for instance, can develop a new product with its extra resources attained additionally from its process innovation. In turn, the customer will be able to hold up its supplier with the new product. On the other hand, it is also possible that customer's process innovation increases its production efficiency and lowers its production costs where the extra surplus can be appropriated by its supplier. To wit, increased production efficiency can enable the supplier to hold up the customer. To the extent that the overlapping between new technology space and original technology space within a firm implies process innovation, the result indicates that the impact of customer's process innovation on its bargaining power is neutral.

3.5. Financial and Investment Decision of Supplier

In this section, I explore how customer innovation shapes financial and investment decision of supplier. A supplier, when faced with holdup by its customer, might change its financial and investment policy to protect itself from the holdup. The supplier might need to maintain conservative policies, for instance, to cover the increased trade credit provision, cover the cost of searching new customer, build a new factory line for self-production of final product, prepare the cost of vertical acquisition of the customer, and so on. At the same time, it can increase its own innovative activity to increase bargaining power against its customer. It may also learn from customer's innovation for the purpose of providing input products customized for customer's new product, and thus, preventing the customer from switching to another supplier.

To examine these possibilities, I test whether supplier's financial variables (i.e., cash ratio, payout, leverage) and investment variables (i.e., R&D expenditures, Supplier Innovation, Technology Spillover). $Supplier\ Innovation$ is the logarithm of 1 plus the number of patents of supplier. $Technology\ Spillover$ is defined as the logarithm of the ratio of the number of customer's past patents cited by supplier's patent at year t over the number of supplier's patent at year t.

[Insert Table 10 here]

Table 10 demonstrates that suppliers seem to adopt more conservative financial policy through holding higher cash holdings and lessening payout when customers innovate. The sensitivity of supplier's leverage to customer's innovation is not significantly different from zero. At the same time, Column 5 shows that suppliers increase their own innovation activities after their customers innovate. Moreover, Column 6 implies that their patents cite patents of their customers more frequently, that is, they learn from customers' innovation. However, the impact of customer's innovation on supplier's R&D expenditures is positive but statistically insignificant. This analysis implies that customer innovation influences supplier's internal policy as well as its policy in the dimension of interfirm relationship (i.e., trade credit policy). [13]

4. Conclusion

This paper investigates negative externalities of innovation along supply chain by analyzing the effect of customer innovation on supplier trade credit. Main finding of this paper is that supplier extends more trade credit after customer makes innovation, and the effect is robust after controlling for various firm characteristics and industry-specific market conditions, and, to potential endogeneity issues.

Second, I analyze three possible channels (i.e., holdup, demand, and financing channels) which can derive the main effect. My results are only consistent with the holdup channel which predicts the stronger effect size of high asset specificity group than low asset specificity group.

Next, I claim that the technological relatedness of customer's innovation to supplier's innovation downsizes the positive sensitivity of supplier's trade credit provision to customer's innovation.

[13] In an untabulated logistic regression, it is not more likely for customer-supplier relationship to be terminated after customer innovation. In fact, only 15 customer-supplier pairs out of 13,093 pairs execute vertical integrations in my sample. Thus, it is plausible that suppliers try to maintain their trade relationship with customers even after customer innovation (which potentially results in holdup problem) by adopting conservative financial policy and customizing their innovation for customers.

Also, this result highlights that product innovation causes holdup problems, whereas process innovation neither strengthens nor weakens holdup problems.

Lastly, I find that supplier adopts more conservative financial policy (i.e., higher cash holdings and less payouts) and produces more innovation by learning from customer's innovation. Thereby, I conclude that customer innovation impacts supplier's internal policy as well as its policy in the dimension of interfirm relationship (i.e., trade credit policy). However, the trade relationship per se doesn't seem to terminate after customer innovation.

Overall, my results propose a unique channel through which corporate innovation can influence upstream or downstream firms. While this paper emphasizes the negative externalities of innovation along supply chain, a firm's innovation can have externalities on its other stakeholders such as employee, union, and government, and which is not deeply studied in the literature. For instance, a firm's innovation might endow its management with its increased bargaining power against its employees in the midst of wage negotiation process. I believe this research contributes to a better understanding of this topic.

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Table 1: Summary Statistics

Panel A	Customer		Supplier		(3)	
Firm Variables	$Mean$	$Std.Dev.$	$Mean$	$Std.Dev.$	$Diff$	t
$Size$	9.199	2.229	4.332	2.231	4.87***	(299.47)
MTB	1.818	3.976	2.294	6.487	-0.48***	(-11.11)
ROA	0.136	0.614	0.015	0.664	0.12***	(25.92)
$Leverage$	0.253	0.177	0.279	0.527	-0.03***	(-9.12)
$Cash/TA$	0.096	0.117	0.191	0.226	-0.10***	(-73.22)
$CAPEX/TA$	0.075	0.056	0.073	0.098	0.00*	(2.17)
$R\&D/TA$	0.046	0.067	0.080	0.234	-0.03***	(-26.48)
$Innovation$	2.314	2.593	0.446	0.996	1.87***	(132.78)
Observations	39003		39003		78006	

Panel B	$Customer\ Innovation = 0$		$Customer\ Innovation > 0$			
Supplier Variables	$Mean$	$Std.Dev.$	$Mean$	$Std.Dev.$	$Diff$	t
$Size$	4.204	2.166	4.439	2.278	-0.24***	(-10.42)
MTB	2.272	4.311	2.313	7.852	-0.04	(-0.60)
ROA	0.011	0.809	0.018	0.514	-0.01	(-1.00)
$Leverage$	0.291	0.478	0.270	0.565	0.02***	(4.02)
$Cash/TA$	0.173	0.211	0.205	0.236	-0.03***	(-13.90)
$CAPEX/TA$	0.075	0.114	0.072	0.082	0.00**	(3.24)
$R\&D/TA$	0.067	0.245	0.090	0.224	-0.02***	(-9.58)
$Innovation$	0.334	0.854	0.539	1.091	-0.21***	(-20.88)
$Trade\ Credit$ (%)	4.206	5.171	4.236	4.876	-0.03	(-0.48)
Observations	17673		21330		39003	

Table 2: Baseline Regression

VARIABLES	(1) $Trade\ Credit_{t+1}$	(2) $Trade\ Credit_{t+2}$	(3) $Trade\ Credit_{t+3}$
$Customer\ Innovation_t$	0.122***	0.123***	0.123***
	(0.000)	(0.000)	(0.001)
$Size_t$	-0.671***	-0.635***	-0.632***
	(0.000)	(0.000)	(0.000)
MTB_t	0.003	-0.008	-0.027
	(0.424)	(0.142)	(0.527)
ROA_t	1.159***	0.220	-0.546
	(0.000)	(0.677)	(0.393)
$CAPEX/TA_t$	-2.940***	-3.077***	-3.499***
	(0.000)	(0.000)	(0.001)
$Leverage_t$	-0.111	0.011	-0.053
	(0.631)	(0.972)	(0.875)
$Cash/TA_t$	-3.734***	-3.395***	-3.187***
	(0.000)	(0.000)	(0.000)
$R\&D/TA_t$	0.960	-0.011	-0.936
	(0.284)	(0.991)	(0.461)
$Constant$	6.978***	6.960***	7.142***
	(0.000)	(0.000)	(0.000)
Observations	19,042	13,973	10,450
R-squared	0.206	0.210	0.228
Year FE	Y	Y	Y
Industry FE	Y	Y	Y

Table 3: Fixed Effects Regression

VARIABLES	(1) $Trade\ Credit_{t+1}$	(2) $Trade\ Credit_{t+1}$	(3) $Trade\ Credit_{t+1}$	(4) $Trade\ Credit_{t+1}$	(5) $Trade\ Credit_{t+1}$
$Customer\ Innovation_t$	0.122***	0.143***	0.134***	0.149***	0.132***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
$Constant$	6.978***	8.107***	4.979***	5.478***	6.232***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	19,042	19,042	19,042	19,042	19,042
R-squared	0.206	0.167	0.239	0.388	0.316
Firm Controls	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	N	N
Supplier Industry FE	Y	N	Y	N	Y
Customer Industry FE	N	Y	Y	Y	N
Supplier Industry X Year FE	N	N	N	Y	N
Customer Industry X Year FE	N	N	N	N	Y

Table 4: Holdup Channel

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$Asset\ Specificity_1$		$Asset\ Specificity_2$		$Asset\ Specificity_3$		$Asset\ Specificity_4$	
VARIABLES	Low	High	Low	High	Low	High	Low	High
$Customer\ Innovation_t$	0.036	0.157**	0.153***	0.181***	0.100***	0.176***	0.102***	0.153***
	(0.262)	(0.013)	(0.003)	(0.000)	(0.008)	(0.001)	(0.002)	(0.001)
$Constant$	1.961**	4.937***	6.641***	5.795***	3.720***	1.671	4.832***	4.650***
	(0.014)	(0.007)	(0.000)	(0.000)	(0.000)	(0.495)	(0.000)	(0.000)
Observations	3,605	3,727	5,449	5,932	9,464	9,578	7,771	8,590
R-squared	0.391	0.357	0.216	0.285	0.288	0.291	0.231	0.313
Firm Controls	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Supplier Industry FE	Y	Y	Y	Y	Y	Y	Y	Y
Customer Industry FE	Y	Y	Y	Y	Y	Y	Y	Y

Table 5: Demand Channel

VARIABLES	(1) $Customer\ Sales$	(2) $Customer\ Sales$	(3) $Customer\ Sales$	(4) $COGS/TA_{t+1}$	(5) $COGS/TA_{t+2}$	(6) $COGS/TA_{t+3}$
$Customer\ Innovation_t$	6.383	9.182	7.547	0.014	0.012	0.009
	(0.408)	(0.283)	(0.420)	(0.141)	(0.280)	(0.465)
$Constant$	-179.135**	-226.049**	-243.517**	2.027***	1.942***	1.951***
	(0.027)	(0.022)	(0.044)	(0.000)	(0.000)	(0.000)
Observations	12,288	9,024	6,714	17,621	17,278	16,920
R-squared	0.195	0.314	0.342	0.695	0.756	0.755
Customer Controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Customer Industry FE	Y	Y	Y	Y	Y	Y

Table 6: Financing Channel

VARIABLES	(1) $Trade\ Credit_{t+1}$	(2) $Trade\ Credit_{t+2}$	(3) $Trade\ Credit_{t+3}$	(4) $Trade\ Credit_{t+1}$	(5) $Trade\ Credit_{t+2}$	(6) $Trade\ Credit_{t+3}$	(7) $Trade\ Credit_{t+1}$	(8) $Trade\ Credit_{t+2}$	(9) $Trade\ Credit_{t+3}$
$Customer\ Innovation_t$	0.115***	0.145***	0.172***	0.118***	0.125**	0.125**	0.125***	0.127***	0.115**
	(0.005)	(0.002)	(0.001)	(0.009)	(0.019)	(0.034)	(0.002)	(0.006)	(0.023)
$Customer\ Innovation_t$	0.067	-0.015	-0.099						
$\times\ Customer\ Leverage_t$	(0.652)	(0.923)	(0.535)						
$Customer\ Innovation_t$				0.115	0.128	0.166			
$\times\ Customer\ Cash/TA_t$				(0.537)	(0.576)	(0.535)			
$Customer\ Innovation_t$							-0.124	-0.041	0.518
$\times\ Customer\ Payout_t$							(0.688)	(0.911)	(0.198)
$Customer\ Leverage_t$	-0.586*	-0.346	-0.270						
	(0.092)	(0.307)	(0.449)						
$Customer\ Cash/TA_t$				-0.536	-0.750	-1.234			
				(0.366)	(0.339)	(0.184)			
$Customer\ Payout_t$							3.229***	3.914***	1.433
							(0.005)	(0.006)	(0.368)
Constant	5.084***	5.097***	5.141***	5.055***	5.150***	5.281***	4.938***	5.016***	5.151***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	18,948	13,923	10,414	18,970	13,937	10,424	18,980	13,944	10,429
R-squared	0.240	0.247	0.268	0.239	0.247	0.268	0.240	0.248	0.269
Firm Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Supplier Industry FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Customer Industry FE	Y	Y	Y	Y	Y	Y	Y	Y	Y

Table 7: 2SLS Regression

VARIABLES	(1) $Trade\ Credit_{t+1}$	(2) $Trade\ Credit_{t+2}$	(3) $Trade\ Credit_{t+3}$
$Customer\ Innovation_t$	1.313***	1.331***	1.093***
	(0.000)	(0.000)	(0.000)
$Constant$	2.038	1.560	1.907
	(0.250)	(0.406)	(0.319)
Observations	15,910	11,578	8,541
R-squared	-0.149	-0.149	-0.012
Firm Controls	Y	Y	Y
Year FE	Y	Y	Y
Industry FE	Y	Y	Y

Table 8: Overlapping of Technology Space between Customer and Supplier

VARIABLES	(1) $Trade\ Credit_{t+1}$	(2) $Trade\ Credit_{t+2}$	(3) $Trade\ Credit_{t+3}$	(4) $Trade\ Credit_{t+1}$	(5) $Trade\ Credit_{t+2}$	(6) $Trade\ Credit_{t+3}$
$Customer\ Innovation_i$	0.248***	0.271***	0.291***	0.278***	0.308***	0.341***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Customer\ Innovation_i$	-0.190*	-0.130	-0.131			
$\times Cite_t$	(0.065)	(0.314)	(0.374)			
$Customer\ Innovation_i$				-0.159**	-0.185**	-0.234**
$\times Class\ Overlap_t$				(0.027)	(0.032)	(0.018)
$Cite_t$	0.647	0.447	0.498			
	(0.259)	(0.526)	(0.541)			
$Class\ Overlap_t$				0.779**	1.071***	1.421***
				(0.012)	(0.005)	(0.001)
$Constant$	4.866***	4.832***	5.113***	4.873***	4.801***	4.987***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	11,464	8,530	6,380	11,464	8,530	6,380
R-squared	0.259	0.260	0.274	0.259	0.261	0.275
Firm Controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Supplier Industry FE	Y	Y	Y	Y	Y	Y
Customer Industry FE	Y	Y	Y	Y	Y	Y

Table 9: Overlapping of Technology Space between Customer and itself in the past

VARIABLES	(1) $Trade\ Credit_{t+1}$	(2) $Trade\ Credit_{t+2}$	(3) $Trade\ Credit_{t+3}$	(4) $Trade\ Credit_{t+1}$	(5) $Trade\ Credit_{t+2}$	(6) $Trade\ Credit_{t+3}$
$Customer\ Innovation_t$	0.374**	0.451***	0.538***	0.185***	0.201***	0.211***
	(0.014)	(0.004)	(0.008)	(0.000)	(0.001)	(0.004)
$Customer\ Innovation_t$	-0.149	-0.196	-0.258			
$\times\ Cite_t^{Own}$	(0.317)	(0.206)	(0.197)			
$Customer\ Innovation_t$				0.060	0.079	0.084
$\times\ Class\ Overlap_t^{Own}$				(0.179)	(0.132)	(0.150)
$Cite_t^{Own}$	0.216	0.261	0.307			
	(0.408)	(0.383)	(0.387)			
$Class\ Overlap_t^{Own}$				-0.206	-0.291	-0.085
				(0.245)	(0.154)	(0.699)
$Constant$	4.852***	4.731***	4.945***	5.175***	5.162***	5.354***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	11,464	8,530	6,380	11,464	8,530	6,380
R-squared	0.258	0.260	0.274	0.258	0.260	0.274
Firm Controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Supplier Industry FE	Y	Y	Y	Y	Y	Y
Customer Industry FE	Y	Y	Y	Y	Y	Y

Table 10: Financial and Investment Decision of Supplier

VARIABLES	(1) $Cash/TA_{t+1}$	(2) $Payout_{t+1}$	(3) $Leverage_{t+1}$	(4) $R\&D/TA_{t+1}$	(5) $Supplier\ Innovation_{t+1}$	(6) $Tech\ Spillover_{t+1}$
$Customer\ Innovation_t$	0.001***	-0.001***	-0.001	0.001	0.012**	0.026***
	(0.001)	(0.009)	(0.502)	(0.214)	(0.019)	(0.000)
$Constant$	0.014	-0.001	0.041	0.074***	-0.225	-0.059
	(0.168)	(0.785)	(0.435)	(0.001)	(0.284)	(0.758)
Observations	26,072	26,078	26,040	16,560	27,931	27,931
R-squared	0.751	0.053	0.418	0.214	0.362	0.282
Firm Controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y