<u>Informational Costs of Integration</u>

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Abstract

To understand how vertical integration impacts knowledge spillovers, we need a theory that takes into account the impact of integration on all market participants instead of a theory that focuses only on the two merging firms. This paper addresses this problem by proposing a value capture model showing that vertical integration hinders the integrated firm's ability to acquire information spillovers from outside producers, even when the information flowing from producers to the supplier is only useful to the supplier. Analysis of patent citation lags indicates that vertically integrated suppliers cite producers' patents with an extra delay of more than eight months. This suggests that integrated suppliers are receiving less information from outside producers after integration, corroborating the theoretical model.

Introduction

Knowledge spillovers are the dominant source of value creation from innovation (Hall, Mairesse, and Mohnen, 2010), making it critical for managers to understand what factors impact the firm's ability to get spillovers from other organizations. In line with that fact, the literature has identified many important determinants of the capacity one firm has to benefit from knowledge produced by other organizations. One set of determinants is linked with firms' characteristics such as absorptive capacity (Cohen and Levinthal, 1990), organizational routines (Dyer and Hatch, 2006), the relative amount of knowledge (Knott, Posen, and Wu, 2009), and resources (Katila, Rosenberger, and Eisenhardt, 2008). Other determinants are related to market and network features such as strength of intellectual property protection (Dushnitsky and Shaver, 2009), the composition of the knowledge networks in which the firm is located (Dyer and Singh, 1998; Pahnke *et al.*, 2015), geographical agglomeration (Alcácer and

Chung, 2007; Jaffe, Trajtenberg, and Henderson, 1993), and cooperation between firms such as joint ventures and alliances (Mesquita, Anand, and Brush, 2008; Schildt, Keil, and Maula, 2012; Vasudeva and Anand, 2011).

Despite the effort dedicated to understanding spillovers, researchers have yet to understand how vertical integration affects the firm's capability of accessing knowledge produced outside its boundaries. By integrating vertically, firms can solve coordination problems (Williamson, 1979), change their resource bundle (Barney, 1991; Wernerfelt, 1984), and impact how information is transmitted within the organization (Grant, 1996; Kogut and Zander, 1992; Nickerson and Zenger, 2004). For those reasons, vertical integration can represent a fundamental change in the firm's characteristics as a competitor. Therefore, the other players in this market should change how they view the integrated firm and behave accordingly.

The difficulties faced by Flextronics (Huckman and Pisano, 2010) illustrate how vertical integration can change the willingness of other agents in the market to share information with an integrated firm. As Huckman and Pisano (2010) describe, Flextronics was an OEM cell phone manufacturer who produced according to designs provided by its customers. Those designs contained customers' private information embedded in them, ranging from future demand expectations to technological innovation. Although Flextronics customers were direct competitors, they decided to share those designs with a common OEM; even when some of that information could help Flextronics to improve its manufacturing process - an improvement that could be made available to all its customers.

In 2001, Flextronics decided to manufacture phones based on its own designs. Although the experience of designing a phone was successful from a production point of view, the possibility of commercialization revealed to be a threat to Flextronics' existing business relationships. This case suggests that once Flextronics vertically integrated into the design space, existing customers felt uneasy about sharing information contained in the designs in the same way as before.

To shed light on the impact of vertical integration on spillovers, one needs to account for the impact of vertical integration on all market participants. Most of the theories of the firm[1] do not take into consideration the impact of integration on firms other than the merging organizations and thus present a partial equilibrium view. Those theories implicitly assume that the behavior of other market participants is constant. This paper inches towards a general equilibrium point of view, presenting a theoretical model that takes into account the impact of vertical integration on all firms in the market.

The model shows that markets with vertically disintegrated firms incentivize all producers to share information with suppliers. The market solution, however, does not usually provide incentives for any producer to share the optimal amount of information with the supplier. Relationships mediated through the market provide suppliers with a varied source of information, at the possible cost of some information hoarding by producers. Integrated suppliers, on the other hand, achieve optimal information flow from the producer to the integrated supplier – as it is expected from a transaction cost perspective. However, this increase in information sharing within the integrated firm is followed by the decrease of other producers' incentives to share information with the integrated supplier – even when the information shared by producers is *only* useful to the supplier.[2] Managers need to account for this informational cost when deciding if they should vertically integrate or not.

The paper empirically tests the model's implications by examining the impact of vertical integration on the information flow from producers. To achieve this objective, the paper looks at suppliers that get acquired by a producer and measures the amount of time it takes for suppliers to cite patents from external producers before and after the acquisition. If the producers that are

[1] Zenger et al. (2011) provides a literature review about theories of the firm.
[2] That is, the model does not allow any information to flow between producers.

competing with the internal producer withhold information from the integrated supplier, we should observe the citation of older patents on average. This is because, absent the informational flow, the integrated supplier will be slower to recognize and understand innovations from the downstream competitors. Results are consistent with the theory, showing that suppliers cite patents more than eight months older after vertical integration.

The paper helps explain why some industries have vertically integrated firms coexisting with disintegrated firms (Argyres and Bigelow, 2010; Helfat and Campo-Rembado, 2016; Kapoor, 2013; Kapoor and Adner, 2012). The paper shows that producers' choice to integrate depends critically on beliefs about the distribution of information in the marketplace. The use of markets stimulate sharing of information from all producers, being a better organizational structure when the manager believes that key information is spread among competitors. Integration, on the other hand, is better suited when the manager believes that information is focused in one producer. Therefore, managers with different beliefs about the distribution of information will make different choices about vertical structure.

Finally, this paper speaks to the link between organizational economics and firm heterogeneity. Argyres and colleagues (2012) argue that there is a need for theoretical work linking organizational economics and the development of firm capabilities. By choosing the vertical structure, the firm controls what are its sources of information, thus helping determine the firm's future capabilities. Vertically integrated suppliers get more information from the integrated producer, but less information from other producers.

Related Literature

The capacity of markets to aggregate information has been recognized since the founding work of Adam Smith. Markets generate incentives for individuals and firms to exchange many different types of information, from demand and supply expectations (Hayek, 1945) to problem solutions (Nickerson, Yen, and Mahoney, 2012; Nickerson and Zenger, 2004). On the other hand, we also know that firm organization can influence how information is transmitted within the firm (Demsetz, 1988; Kogut and Zander, 1996; Nickerson and Zenger, 2004). The incentives induced by the marketplace and by firm organization generate a pattern of information flows, molding the firm's knowledge set (Nonaka, 1994) and, thus, its future capabilities (Conner and Prahalad, 1996).

Those information flows can originate from many agents, both inside and outside the firm. A critically important informational flow for innovation is the information transmitted from producers of final goods to suppliers. Although producers and suppliers work in tandem to produce the same final good, they have different sources of information. Those differences in information come from the fact that both firms are situated in different markets, have different sets of competitors and customers, and hire different professionals. A survey conducted by Arora, Cohen, and Walsh (2016) documents that almost half of innovators report using external sources (such as suppliers and customers) for their most important innovation. In Europe, the Community Innovation Survey shows that almost four-fifths of the innovative enterprises used information sent by suppliers, and one-fifth of those firms classified this informational source as being highly important.

The model in this paper assumes that producers have some private information that is useful for improving the quality of the input sold by the supplier. That information can arise from a better understanding of the final consumer's needs or from an insight gained while assembling inputs into the final product. The existence of useful information from the producer to the supplier is consistent with the fact that some producers expand their information set to intersect knowledge areas belonging to the supplier (Brusoni, Prencipe, and Pavitt, 2001; Kapoor and Adner, 2012; Takeishi, 2002). Besides the evidence that producers have knowledge in areas pertinent to suppliers, Alcacer and Oxley (2014) show that suppliers learn from supplying to more and better producers, suggesting that suppliers do make use of knowledge from producers. Together, those papers demonstrate that the set of knowledge intersecting producers and suppliers is not empty and that suppliers learn from interacting with producers in equilibrium.

Since information is private, there should be an incentive for the producer to share it with the supplier. At the same time, sharing information enables the supplier to enhance input quality, which allows producers to create a final product with higher consumer valuation. However, once the information is used to improve the input, the supplier has the incentive to make that high-quality input available to all competitors. The expectation of information leakage to rivals decreases the incentives for producers to share information, a phenomenon studied in the context of supply chain (Anand and Goyal, 2009; Tan, Wong, and Chung, 2015), outsourcing (Baccara, 2007), venture capital (Pahnke *et al.*, 2015), and partnerships (Katila *et al.*, 2008). Although information leakage has been recognized in the literature, changes in producers' incentives to share knowledge once a competitor becomes vertically integrated have not been studied. This topic is of crucial importance for managers deciding whether to integrate or not, especially in industries that depend heavily on knowledge. Even if integration realizes production complementarities, it can be detrimental to the firm's future if it endangers the quantity and quality of information available to the supplier. This can be harmful not only to the integrated firm but to all firms that depend on the information-starved supplier.

This paper is related to the literature that explains why, in some industries, vertically integrated firms coexist with disintegrated firms. The early literature on this topic suggested that firms would tend towards disintegration over time because of returns to scale (Klepper, 1997) and modularization (Langlois, 2003). However, empirical studies that found persistence of both structural forms within industries (Argyres and Bigelow, 2010; Kapoor and Adner, 2012) put limits on the theory of uniform tendency towards disintegration. Helfat and Campo-Rembado (2016) explain this heterogeneity by arguing that, although integration is costly, it helps firms to implement systemic innovations because of its superior capabilities to combine knowledge. In equilibrium, some firms choose to bear the cost of a vertically integrated structure to reap the benefits during systemic innovation events. The explanation developed here focuses on when information is shared between firms, allowing for the study of the market's behavior in response to vertical integration.

The model is also connected to the literature on firm boundaries (cf. Zenger, Felin, and Bigelow, 2011), since it outlines the costs and benefits of bringing the relationship between the supplier and producer inside the firm. It shows that managers should be careful about integrating the vertical chain since integrated firms can lose important sources of information. I demonstrate that the use of the market incentivizes firms to share information with suppliers, even when the supplier sells the improved input to all competitors. The market, however, does not give incentives for firms to share information efficiently. By integrating, the producer has incentives to share information efficiently with the supplier. The downside is the diminished incentives for other producers to share information with the integrated supplier.

The following section presents most of the model assumptions. I then solve the model for the nonintegrated case, showing full information revelation. Next, I solve the model for the integrated market structures, showing the effect on information sharing. Finally, I present patent citation data that corroborates the hypothesis that integrated suppliers get less information from market participants. The last section concludes the paper.

Theory

Suppose that there are two producers $\mathrm{p} = \{1,2\}$, one supplier, and two isolated markets $m = \{1,2\}$. There is only one consumer on each market; consumer 1 lives in market 1 and consumer 2 lives in market 2.[3] Each consumer wants to purchase only one unit of the final good. Firms have no cost of producing, and all agents have an outside option that gives them zero value.

There are four stages in this game, as shown in Figure 1. In the informational stage, producers observe a piece of information that can be used to improve the quality of the input manufactured by the supplier. The producers decide simultaneously to share or not their piece of information with the supplier. If no producer shares information, the supplier cannot increase the input quality.

<Insert Figure 1 here>

In the innovation stage, the supplier observes the information sent and decides whether to use the information to improve the input or not. In the technology adoption stage, producers decide if they want to adopt the high quality input (if available) in *each* of the markets they are in. If producers decide to use the high quality input, they pay a non-contractible cost to process the new input.

Finally, in the bargaining stage, producers buy the input, manufacture the final product, and sell to customers. All individuals engage in a bargain to decide the allocation of rents. To simplify, the paper assumes that customers gain no surplus in order to focus on the bargaining among the two producers and the supplier.

For each market m, producer p acquires an input with quality I_p^m and uses that input to produce a final good. The consumer in market m evaluates the good sold by producer p as $Q_p^m + I_p^m$. The value Q_p^m can be interpreted as brand loyalty or as heterogeneity in final product characteristics. The paper assumes that $Q_{p=m}^m > Q_{p\neq m}^m$, that is, producer p is the leader in market $m = p$. In other words, the consumer in market 1 prefers the good produced by producer 1 if both producers are using inputs with the same quality.

[3] Since there is only one consumer in each market, we can use consumers and producers as interchangeable terms.

The supplier has the capacity to offer the standard quality input at any moment in any market. If the supplier acquires useful information from producers, it can increase the quality of the input sold to producers. Information from producer p allows the supplier to increase input quality by H_p. Thus, if both producers send information and the supplier decides to use all available information, the increase in input quality is $H_1 + H_2$.

For simplicity, the discussion ahead assumes that the consumer preference towards the market leader is so large that the consumer prefers to buy from the leader even if only the other producer adopts the high quality input. Thus, this paper focuses on innovations that are not big enough to disrupt the order of the producers in the market.[4] The other cases are similar and are discussed in the appendix.

In order to use the input with high quality in a specific market, a producer needs to pay a one-time *non-contractible* cost k. Changing inputs usually requires the producer to incur expenses that are hard to predict and hard to disentangle from normal expenditures. For example, new inputs require an optimization in the production line, demanding attention from workers and managers. Introduction of new inputs might require new machines, changes in marketing strategies, hiring new workers, training, or the design of new contracts. Also, adoption cost is usually sunk and non-redeployable (Hall and Khan, 2003), raising the classical problem of hold-up (Williamson, 1979). For those reasons, this paper assumes that the supplier cannot credibly write a contract to pay the adoption cost to the producer.

The game is solved using backward induction, following the biform games structure developed by Brandenburger and Stuart (2007). The first step in the backward induction argument is to determine

[4] That is, $Q^m_{p=m} - Q^m_{p\neq m} > H_1 + H_2$.

the equilibrium in the bargaining stage. To do that, we first need to determine the core allocation for each player given the set of strategies played in the previous stages.

The final payoff for each player in the bargaining stage is a linear combination of the player's core upper and lower bound. The weight used in the linear combination (α) represents the supplier's confidence index - how confident the supplier is in appropriating value given the constraints imposed by competition (Brandenburger and Stuart, 2007). Higher values of α indicate that the supplier can appropriate a value closer to its own core's upper bound. For simplicity's sake, the paper assumes that the confidence index for the supplier is the same in all markets and that the confidence index for either producer is equal to $(1-\alpha)$.

After determining the payoff in the bargaining stage, the usual backward induction technique is used. The paper first analyzes the equilibrium without integration, followed by the equilibrium with integration between the supplier and one producer. Throughout the paper, producers are assumed to extract customers' willingness to pay completely, so we can focus on the rent distribution across firms. This means that consumers choose their preferred option and the price is equal to consumer's willingness to pay.

No integration

Bargaining. The consumer in market 1 faces a choice between getting the product from producer 1 evaluated at $Q_1^1 + I_1^1$ or buying from producer 2 and getting $Q_2^1 + I_2^1$. Since $Q_1^1 - Q_2^1 > I_1^1 + I_2^1$ by assumption, consumer 1 will buy producer 1's good, and consumer 2 will buy producer 2's good.

The first step in finding the core is to calculate each player's added value. Added value for player i is the difference in value created by all players minus the value created by all players except player i. Thus, added value is a measure of how much value a player adds by entering the game. The added value for the supplier, producer 1 and producer 2 are $Q_1^1 + I_1^1$, $Q_1^1 + I_1^1 - Q_2^1 - I_2^1$, and zero, respectively. In the situation analyzed in this paper, the agent's added value is equal to the upper limit of the core allocation (Brandenburger and Stuart, 1996).

To fully describe the core allocation, we need to find the lower bound of the core set for each of the players. To do that, we need to consider all sub coalitions that can improve the situation of at least one player.[5] In any core allocation, the supplier needs to get at least $Q_2^1 + I_2^1$, since the supplier could get at least that much on a coalition containing only the supplier and producer 2. As for the lower bound from producers, we can construct a equilibrium where both of them get zero,[6] demonstrating that this is the lower boundary of their core set.

As a result, the bargain equilibrium in market 1 is the set of payoffs (1) for the supplier, producer 1 and producer 2, respectively.

$$\{\alpha(Q_1^1 + I_1^1) + (1-\alpha)(Q_2^1 + I_2^1),\ (1-\alpha)(Q_1^1 + I_1^1 - Q_2^1 - I_2^1),\ 0\} \tag{1}$$

The first term in this set represents the bargaining payoff for the supplier and is the result of the linear combination between the upper limit on the supplier's core $Q_1^1 + I_1^1$ and the lower limit on the core set $Q_2^1 + I_2^1$ using the confidence index α as the weight. The second term represents the payoff for producer 1, and it is calculated similarly. Finally, the third term in (1) is zero because the core set in market 1 for producer 2 only contains zero.

It is important to note that (1) is valid only when all firms participate on the market. If producer i leaves market 1, the bargaining solution will be the pair of values $\{\alpha\left(Q_{p\neq i}^1 + I_{p\neq i}^1\right),$ $(1-\alpha)\left(Q_{p\neq i}^1 + I_{p\neq i}^1\right)\}$ for the supplier and producer $p \neq i$. If the supplier leaves the market, all firms have zero payoffs. The equilibrium for market 2 is analogous.

[5] More details on Gans and Ryall (2017).

[6] For example, an allocation where the supplier gets $Q_1^1 + I_1^1$ while both producers get zero is an allocation that belongs to the core.

Adoption. If only the standard input is offered, all firms will buy it. In this case $I_1^m = I_2^m$ for all markets m. Suppose instead that the supplier offers a high quality input, and let $\Delta\mathrm{I}$ represent the increase in input quality due to the adoption of the high quality input. In equilibrium, the market leader (producer p in market $m = p$) gains $(1-\alpha)\Delta I$ by adopting the high quality input, and thus will adopt if condition (2) is satisfied. The non-leader producer has no incentive in adopting the high quality input in this market, since it will get zero value after adoption.[7]

$$\Delta\mathrm{I} > \frac{\mathrm{k}}{1-\alpha} \tag{2}$$

Notice the importance of the confidence index in the adoption decision by the producer. If the bargaining skills of the supplier are high (α close to one), no innovation will ever be adopted. This fact reveals the impact of firms' bargaining skills on information transfer, demonstrating one of the advantages of using a value capture model to model the information transfer problem.

Innovation. Since the value appropriated by the supplier in equilibrium (1) increases with input quality, the supplier will use all information available to increase input quality as much as possible.

It is important to note that this conclusion is valid only when both producers are in the market. If the supplier decides to offer the high quality input only, at least one producer will drop from each market,[8] weakening the supplier's bargaining position. If producer 2 leaves market 1, for example, the supplier's profits drop from $\alpha(Q_1^1 + I_1^1) + (1-\alpha)(Q_2^1 + I_2^1)$ to $\alpha(Q_1^1 + I_1^1)$. For this reason, the supplier will always offer the standard input alongside the high quality input on both markets.

[7] This situation is the only equilibrium if the consumer brand preference is large enough, see footnote 1. The complete discussion is in the appendix.

[8] Since the producer that gets zero value will prefer to leave the market rather than pay k to adopt the high quality input.

Information sharing. From the equilibrium calculated so far, we know that producers would prefer that a high quality input exists as long as (2) is satisfied.[9] Each producer recognizes this fact, and releases information to help fulfill condition (2).

In summary, both producers share information with the supplier. The supplier will use all the available information to produce the best input possible alongside the standard input, and producers will adopt the high quality input in the markets where they are the leaders.

Producers share information because, without integration, they do not have an incentive to increase competition on the markets where they cannot win. Each producer chooses to pay adoption costs only in the markets where they are the leaders. The non-contractability of the adoption cost decreases the adoption rate from the optimal adoption rate ($\Delta I > k$) to the adoption rate dictated by condition (2). This departure is, however, symmetric across producers.

Integration

Without loss of generality, suppose that producer 2 integrates with the supplier. The game timing remains the same, but now there is an integrated firm playing the roles of both supplier and producer. The integrated firm's payoff is the sum of the supplier's payoff with producer 2's payoff.

Bargaining. The merged firm will appropriate all surplus in the market 2 as long as producer 2 is the leader in that market. In market 1, the profits of the integrated firm are equal to the supplier's profits in the nonintegrated case. The total profit of the merged firm in both markets is equal to (3). In the bargaining stage, the value for producer 1 will remain the same as before.

$$\alpha(Q_1^1 + I_1^1) + (1-\alpha)(Q_2^1 + I_2^1) + Q_2^2 + I_2^2 \tag{3}$$

[9] Producers have a strictly increasing value function in the market where they produce in equilibrium. However, producers are indifferent about the input in the market where they do not produce, since they get zero value in equilibrium on those markets.

Adoption. In market 2, the integrated firm will adopt the innovation if the increase in customers' willingness to pay caused by the high quality is higher than k, that is, when $\Delta I > \mathrm{k}$. Note that the adoption is optimal in this case, as expected by the literature on transaction costs.

The most interesting change in equilibrium happens when we analyze market 1. In this market, the integrated firm can attain a better bargaining position by increasing the quality of the product sold by producer 2 in market 1 – *even if producer 2 does not sell anything in this market.* By adopting the high quality input in market 1, the integrated firm increases competition in this market, allowing for the extraction of more value from producer 1 by the supplier. Since the integrated producer gains $(1-\alpha)\Delta I$ with the adoption, it will adopt the innovation in market 1 whenever $\Delta I > k/(1-\alpha)$.

Producer 1 will have the same strategy as the nonintegrated case in terms of technology adoption. More specifically, given the adoption strategy of producer 2, producer 1 will also adopt the innovation if $\Delta I > k/(1-\alpha)$. The details are shown in the appendix.

Innovation. The integrated firm's profit (3) is increasing in I_p^m for all m and p. Consequently, all information available is used to produce a high quality input.

Information sharing. Producer 2 shares information with its integrated supplier for the same reason as before. The problem for the nonintegrated producer is more complicated.

As shown previously, when $\Delta I > k/(1-\alpha)$, both producers will adopt the high quality input. When both producers adopt the new input, the value appropriated by producer 1 in the bargaining is equal to its value appropriated when no producer adopts. Since there is a cost for adoption, it would be better for producer 1 to be in a situation where no innovation exists. By not sharing information with the supplier, producer 1 can decrease the chances an improved input is adopted by either producer.[10]

[10] Without the information from producer 1, the supplier can increase the input quality only by H_2 instead of $H_1 + H_2$.

If producer 1 could, it would give out knowledge with the condition that it could be applied only to the input to producer 1 in market 1. This contract would be hard to enforce since the integrated supplier has the incentive to adopt the high quality input in market 2 (via integrated producer). In summary, the integrated producer's competitor (producer 1) would not want to share information with the integrated supplier.

Empirical Evidence

The theory presented here makes two main predictions. First, the model shows that the integrated firm increases information transfer within the firm. Second, it shows that other producers in the market share less information with vertically integrated suppliers. The first prediction is hard to test empirically, since observing information transfer within firms is hard.

It is possible, however, to look at information transfer between firms by using patent citations as a proxy. The time lag between the application date of the citing patents and the application date of the cited patents can be used to measure the speed of information transfer between firms (Oxley and Wada, 2009). While patents are public rather than private information, the speed of diffusion depends on private information transmitted by the patent holders. The reason for this link is that firms filing patents have incentives to disclose the minimum amount of information required to get the patent granted. Therefore, receiving extra information about the patent from the filing firm helps the citing firm to understand better the patent, a critical step in applying the information contained there to other patents.

Moreover, there are many patents being granted at any point in time. Because of limits in attention, a firm might not be aware of all available patents, and thus information from the patent holder can alert the firm to that information. For those reasons, suppliers that receive information directly from producers will be faster at recognizing and using that information in their own innovations, decreasing the average lag of the citation. This leads to the following hypothesis to be tested using citation lag: *Once the supplier integrates with a producer, the time it takes for suppliers to cite patents from other producers (citation lag) increases.*

Data

To test the hypothesis, I gathered information about M&A operations from the S&P Capital IQ database. This dataset shows all mergers and acquisitions from companies and their subsidiaries since 1998.[11] The sample consists of the 1,200 biggest firms[12] in Information, 729 biggest firms in Capital Goods, and 256 biggest firms in Chemicals. The reason for the choice of industries is that firms in those industries generally use patents to protect their innovation.

To identify suppliers, I look at firms that were the target of an M&A and classify them as belonging or not to an upstream industry of the buyer's industry. To achieve that, I obtained each firm's primary and secondary[13] NAICS codes from LexisNexis. I then used the Bureau of Economic Analysis Input-Output direct requirements table from 2007 to indicate if the target firm belongs in an upstream industry from the point of view of the buyer firm. The direct requirements table measures the dollar amount of the input from each industry required to produce one dollar's worth of output. Following the literature (Atalay, Hortaçsu, and Syverson, 2014), I considered all industries that supply at least 1 percent to the final product to be in the producer's upstream. Results with different thresholds show consistent results.

To identify the buyer's competitors, I used the "quick competitors" list from Standard & Poors, which shows up to 10 pre-selected firms deemed comparable to the buyer firm. Finally, in order to measure information flows, I aggregated information from the USPTO patent database. The

[11] In North America. The database tracks European M&A since 2001, but selected deals are available before that.
[12] As classified by S&P Capital IQ.
[13] Up to five secondary NAICS codes were used.

database only uses utility patents and patents applied within 10 years of the acquisition date. In any case, regression results are robust to the inclusion of citations beyond the 10-year period.

The data yielded 274 buyer firms that acquired at least one of 529 target firms, from 1998 to 2017. From those targets, 176 belong to the buyer's upstream. In total, those targets applied for 25,495 patents in the period from 1989 to 2016.

Methods

The unit of observation is a citation i at date t by a target firm f that eventually gets acquired by buyer b. The equation for the basic model is (4), and its logic is illustrated by Figure 2.

$$TimeLag_{itfb} = \beta_t Acquired_t + \beta_i Cite\ Competitor_i + \beta_{it} Acquired_t * Cite\ Competitor_i + Controls_{itfb} + \lambda_t + \gamma_f + \delta_b + \epsilon_{itfb} \quad (4)$$

<Insert Figure 2 here>

Dependent variable. The dependent variable is the time lag between the application date of the patent by the target of the M&A and the application date of the cited patents. If firms receive information from the owners of the cited patents, we should expect that it would take less time for the citing firm to identify and understand that information. This should lead target firms to use more recent information in their patents, decreasing the lag between the patent's application date and the cited patents' application date.

Independent variables. The dummy *Acquired* gets value equal to one if the citing patent application date is posterior to the announcement of the M&A. The announcement is used because, from that date on, all competitors become aware of the likely integration and thus can act accordingly. The variable *Cite Competitor* indicates whether the citation refers to a patent filed by a competitor of the buying firm. Therefore, the treatment variable is *Acquired* while the treated group is identified by the dummy *Cite Competitor*.

Control variables. The regression needs to control for characteristics of the citing and cited patents. For citation characteristics, *Num Claims* counts the number of claims of every cited patent, a measure of patent broadness. *Num Citations* is the count of citations that refer to that specific patent, a measure of the cited patent's innovativeness. *Mean Lag* is the average lag over all patents that also cite that specific patent, and it is meant to capture the speed that such citation usually diffuses. For the citing patents, the estimations control for *Num Claims*, the number of claims of the citing patent, and *Num Citations Made* is the count of citations made by the patent. Finally, *daysafterbuy* is the difference between the M&A date and the application date for the patent.

Results

The summary statistics are presented in Table 1, and the correlation matrix is shown in Table 2. The mean time lag is over 10 years, showing that patents heavily cite old knowledge. About 35 percent of the citations in the data are made after the targets are acquired, and 5 percent of the citations refer to a buyer's competitor.

<Insert Table 1 and Table 2 here>

To further our understanding about the impact of supplier acquisition on citation lag, the paper uses the model (4), controlling for target, year of citing patent, and buyer fixed effects. Also, standard errors are clustered at the citing firm level, to account for correlation of the error terms among citations of the same firm (Bertrand, Duflo, and Mullainathan, 2004). Column 1 in Table 3 shows that the difference in citation lag between competitor citations versus other citations increases 316 days after the target is acquired. The p-value (in parenthesis) indicates that the coefficient is estimated with good precision, lending confidence in the result. Column 2 repeats the same exercise, but using only data from firms that do not belong in the buyer's upstream. Among those firms, the difference in citation lag is negative and not very precise. Both results indicate that there is an increase in lag to cite competitor patents in relation to other patents that cannot be explained by the M&A alone.

<Insert Table 3 here>

The third column in Table 3 makes the comparison between upstream and not upstream firms more precise by running a triple difference model. This means that column 3 is comparing the change in citation lag between competitors and other citations before and after acquisition (the usual difference in difference) for firms in the upstream with that change for firms not in the buyer's upstream. The results in column 3 are harder to interpret, but we can look at the marginal change calculated in Table 4. The regression indicates that, for a firm in the upstream, citation lag to competitors' patents increases 262 days after acquisition when compared to citation to other patents. This is a delay of more than eight months to use the information contained in competitors' patents – a rather substantial time interval.

<Insert Table 4 here>

As for control variables, all models seems to tell a similar story. Citations to patents that have narrower scope (proxied by the number of claims) and higher mean lag tend to be cited later on. The characteristics of the citing patent are more precisely estimated on the model using the data from the non-upstream firms and the triple difference model. In those cases, patents with narrower scope and more citations tend to cite older patents. The positive coefficient for *daysafterbuy* just means that as time goes by, older patents tend to be cited.

A key assumption of differences in differences models is the parallel trends hypothesis. One way to test this hypothesis is to run a leads and lags model (Angrist and Pischke, 2008). The result of the leads and lags interaction in the triple difference model is displayed in Figure 3. Before the acquisition, the 95 percent confidence intervals of the marginal effect of *Cite Competitor* on citation lag between upstream and non-upstream firms are mostly overlapping. Two years after acquisition, citation lags for upstream firms surpass lags for non-upstream firms in most of the years. It is important to note that the overlap between the two years after acquisition does not represent a big problem for estimation. The reason is that changes in information transfer take time to be translated into changes in citation patterns. At every point in time, the firm has a pipeline of projects in various stages of completion – and it is expected that projects that are close to become a patent will be little affected. The fact that the acquisition effects are felt progressively lends support to the idea that the changes are not due to shifts in citation patterns, but rooted in informational changes. In years nine and ten, the citation lag decreases substantially on the upstream firms. While I cannot explain those results, it is important to note that the data is more scarce in those years. From 128 competitor patents cited at the acquisition year, the data narrows down to 60 in year nine and 19 in year ten.

<Insert Figure 3 here>

Robustness

The first robustness is centered on the identity of the agent that included the citation. If the increase in lag is generated exclusively by citations added by agents other than the applicant, we might be suspicious that the mechanism that results in higher lags does depend on the information received by the target firm. Table 5 runs the same regression as Table 3, but considers only citations added by the patent applicant. The results are qualitatively similar as before, lending support to the conclusion that vertically integrated firms receive less information from competitor firms.

<Insert Table 5 here>

Another potential issue is the change in the type of innovation produced by the integrated firm after integration. Although the regressions control for the technology classification, this is not a perfect measure for the type of innovation going on in the firm. To have more fine control, we can include a fixed effect for the technology subclass of the patent, yielding 12,198 different subclasses.

Table 6 shows that the results hold qualitatively for this set of controls, although the p-value for the triple difference (*Acquired * Cite Competitor * Upstream*) increases somewhat.

<Insert Table 6 here>

Finally, one might worry that target firms cite the patents from competitors less often. Table 7 runs a simple linear probability model to show that this hypothesis does not seem to be supported by the data. The coefficient on *Acquired * Upstream* is positive, although not precisely estimated. This result makes sense if we remember that patents from downstream firms will likely continue to be important for a supplier even after integration. Therefore, a supplier will still cite competitors' patents even though it takes longer for the integrated supplier to do so.

<Insert Table 7 here>

Although some alternative explanations can be ruled out by the data, the results are not causal. The target firms were not acquired randomly, opening the possibility that some unobserved characteristic that evolves over time can be causing the results. While these results do not show causality, they are a robust indication that acquired upstream firms cite older competitors' patents, as predicted by the theory. This fact offers support to the theoretical model presented, increasing the confidence on its applicability to the real world.

Conclusion

The model proposed here identifies how vertical integration affects the information flow between producers and suppliers. In doing that, it also presents a step towards a general equilibrium theory of the firm by taking into account the response of all agents to vertical integration. By using a value capture model, this paper show managers how technological and bargain characteristics influence the availability of information flowing from producers to suppliers. In short, disintegrated industries allow suppliers to tap into the information from all producers more easily. Integration, on the other hand, enables the integrated firm to reap the full benefits of the integrated producer's knowledge, but often at the expense of knowledge contained in outside producers.

The main benefit of using markets to acquire inputs is the access to a wide variety of informational sources, as long as the supplier does not have a large bargaining ability advantage over producers. The benefit of getting information from a wide variety of sources is well known (Clemen and Winkler, 1986; Page, 2008; Palm and Zellner, 1992) and can be important for uncertainty mitigation, especially when managers face a highly uncertain environment. This can help explain why integrated firms can be perceived as slow movers in dynamic markets. As Michael Dell said (Magretta, 1998), "With vertical integration, you can be an efficient producer – as long as the world is not changing very much."

The results help to explain a series of empirical facts that the literature has identified so far. First, it sheds light on why some firms remain integrated while others move toward disintegration (Argyres and Bigelow, 2010; Helfat and Campo-Rembado, 2016; Kapoor, 2013; Kapoor and Adner, 2012). The model shows that suppliers with high bargaining ability find it difficult to persuade different producers to share information with them – even when using the market. Thus, a heterogeneous distribution of bargaining ability will define an unequal access to information even if all firms have the same technology and use the same organizational structure.

Besides differences in bargaining ability, the decision to integrate depends critically on the manager's belief about how the information is dispersed across the downstream firms. If information is scattered across multiple producers (because they sell to markets with very different consumers, for example), then the market solution will become an attractive alternative. Firms that keep the integrated structure need to have an informational advantage from the interface input/final product to balance the loss of information from competitors. This is consistent with the empirical finding that integrated firms have a bigger emphasis on systemic innovations (Kapoor, 2013).

The problem of why incumbent firms sometimes fail to adopt new technologies (Dosi, 1982; Henderson and Clark, 1990; Utterback and Acee, 2005) can also benefit from the intuition built from this model. Here, the wrong choice of organizational structure can decrease the quantity or quality of the information received by firms. Integrated firms will be isolated from the flow of outside information and, unless they are able to anticipate market movements by themselves, will have an informational disadvantage. Indeed, integrated firms takes more than eight months longer to cite relevant patents from outside producers. Overestimation of the integrated firm's capacity for producing knowledge or underestimation of the usefulness of competitors' information can lead to decrease in the firm's reaction speed. Alternatively, managers could fail to integrate when this structure would produce more information.

Finally, the model shows how internal organization can influence firm capabilities, responding to a call to integrate those two concepts (Argyres *et al.*, 2012). The way a firm organizes changes the flow of information from market participants to the firm. This difference in information flow can cause a difference in the firm's knowledge set, shaping the firm's future capabilities.

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Appendix

All demonstrations are done for market 1 only. The results for market 2 are analogous.

Adoption Decision for Non-integrated Firms.

No adoption. Suppose that there is no adoption by any producer. The producers' payoffs at the bargaining stage in this case will be equal to (A.1)

$$\begin{array}{l}\text{Producer 1: } (1-\alpha)\left(Q_1^1 - Q_2^1\right) \\ \text{Producer 2: } 0\end{array} \tag{A.1}$$

No adoption is a best response for producer 1 if the payoff gained by not adopting the high quality input, $(1-\alpha)(Q_1^1 - Q_2^1)$, is higher than the payoff producer 1 would get by adopting it, $(1-\alpha)(Q_1^1 + \Delta I - Q_2^1)$, minus the cost for adoption k. In other terms, producer 1 chooses not to adopt if (A.2) is true.

$$\Delta I < \frac{k}{1-\alpha} \tag{A.2}$$

For producer 2, we need to consider two cases. In the first, the adoption of the high quality input is not enough to make the consumer buy the final good manufactured by producer 2. This condition is reflected on the inequality (A.3).

$$\Delta I > Q_1^1 - Q_2^1 \tag{A.3}$$

If (A.3) holds, no adoption is a best response for producer 2 because no consumer buys from producer 2 even if producer 2 uses the high quality input. If (A.3) is not true, we need to compare the payoff producer 2 gets with and without the adoption. No adoption is a best response for producer 2 when the payoff gained by not adopting the high quality input (zero) is higher than the payoff producer 2 would get by adopting, $(1-\alpha)(Q_2^1 + \Delta I - Q_1^1)$, minus the cost for adoption k. Therefore, producer 2 is better off not adopting when (A.3) is false and (A.4) is true.

$$\Delta I < \frac{k}{1-\alpha} + Q_1^1 - Q_2^1 \tag{A.4}$$

Note that the condition (A.4) is less restrictive than (A.2) because $Q_1^1 > Q_1^2$. Therefore, condition (A.4) is irrelevant once (A.2) is satisfied. In summary, a no adoption equilibrium is possible if (A.2) is true.

Only producer 1 adopts. The payoffs at the bargaining stage in this case will be (A.5).

$$\begin{array}{l} \text{Producer 1: } (1-\alpha)(Q_1^1 + \Delta I - Q_2^1) \\ \text{Producer 2: } 0 \end{array} \tag{A.5}$$

Again, we need to compare the payoff of adoption minus k versus non-adoption. Adoption of the high quality input a best response for producer 1 in this scenario if (A.6) is true.

$$\Delta I > \frac{k}{1-\alpha} \tag{A.6}$$

As for producer 2, no adoption is always a best response in this case because producer 2 gets zero under any possible strategy (since the consumer will always prefer the final good manufactured by producer 1 when producer 1 uses the high quality input). In summary, an equilibrium with only producer 1 adopting is possible when (A.6) is true.

Only producer 2 adopts. The payoffs at the bargain stage will depend on the size of ΔI. If (A.3) is true, producer 2 is better off not adopting since it adoption will yield zero value for a cost k. Therefore, this is not an equilibrium. If (A.3) is false, the adoption of the high quality input by producer 2 gives it the edge over producer 1. In this scenario, the payoffs are shown in (A.7).

$$\begin{array}{l} \text{Producer 1: } 0 \\ \text{Producer 2: } (1-\alpha)(Q_2^1 + \Delta I - Q_1^1) \end{array} \tag{A.7}$$

In this case, the best response for producer 1 is not adopt if (A.8) holds.

$$\mathrm{k} > (1-\alpha)(Q_1^1 - Q_2^1) \tag{A.8}$$

Likewise, the best response for producer 2 is indeed to adopt if the payoff in (A.7) minus the adoption cost is better than not adopting and getting zero instead:

$$\Delta I > \frac{k}{1-\alpha} + Q_1^1 - Q_2^1 \tag{A.9}$$

In summary, an equilibrium with only producer 2 adopting is possible when (A.3) is false while (A.8) and (A.9) are true.

Both producers adopt. If both producers adopt the high quality input, the bargaining payoffs are described in (A.1). Notice that no equilibrium is possible because it is never a best response for producer 2 to adopt the high quality input in this case.

The equilibrium possibilities are shown on Table A.1

<Insert Table A.1 here>

Adoption Decision for Integrated Firms

Now, suppose that producer 2 merges with the supplier. The analysis for the case when producer 1 merges with the supplier is similar and will not be discussed here.

No adoption. Suppose that there is no adoption by any producer. The payoffs at the bargaining equilibrium in this case will be equal to (A.10)

$$\begin{aligned} &\text{Producer 1: } (1-\alpha)(Q_1^1 - Q_2^1) \\ &\text{Integrated Producer: } \alpha(Q_1^1 + I_1^1) + (1-\alpha)(Q_2^1 + I_2^1) \end{aligned} \tag{A.10}$$

No adoption is a best response for producer 1 if (A.2) is true.

If (A.3) is true, the integrated producer's best response is to not adopt if the payoff indicated at (A.10) is greater than the payoff for adopting, $\alpha(Q_1^1 + I_1^1) + (1-\alpha)(Q_2^1 + I_2^2 + \Delta I)$, minus the adoption cost k. This condition is shown in (A.11). Since (A.11) is equal to (A.2), this is a possible equilibrium.

$$\Delta I < \frac{k}{1-\alpha} \tag{A.11}$$

If (A.3) is not true, the integrated producer has to compare between no adoption or to adopt and get $Q_2^1 + I_2^2 + \Delta I$ while paying k as an adoption cost. The integrated producer will prefer not to adopt when (A.12) is true.

$$\Delta I < k + \alpha(Q_1^1 - Q_2^1) \tag{A.12}$$

Only producer 1 adopts. In this case, payoffs at the bargaining stage are represented by (A.13).

$$\begin{gathered}\text{Producer 1: } (1-\alpha)(Q_1^1 + \Delta I - Q_2^1) \\ \text{Integrated Producer: } \alpha(Q_1^1 + I_1^1 + \Delta I) + (1-\alpha)(Q_2^1 + I_2^1)\end{gathered} \tag{A.13}$$

Adoption of the high quality input is a best response for producer 1 if (A.6) is true.

As for the integrated producer, the best response is to not adopt if (A.11) holds. Condition (A.11) contradicts (A.6), yielding no equilibrium in this case.

Only producer 2 adopts. The payoffs will depend on the size of ΔI. If (A.3) is true, the payoffs are as shown in (A.14).

$$\begin{gathered}\text{Producer 1: } (1-\alpha)(Q_1^1 - Q_2^1 - \Delta I) \\ \text{Integrated Producer: } \alpha(Q_1^1 + I_1^1) + (1-\alpha)(Q_2^1 + I_2^1 + \Delta I)\end{gathered} \tag{A.14}$$

The best response for producer 1 is to not adopt if (A.15) holds.

$$\Delta I < \frac{k}{1-\alpha} \tag{A.15}$$

The best response for the integrated producer is to adopt if $\Delta I > {}^{k}/_{1-\alpha}$. Since this contradicts (A.8), this is not a viable equilibrium.

If (A.3) is false, adoption by the integrated producer generates the payoffs shown in (A.16).

$$\begin{gathered}\text{Producer 1: } 0 \\ \text{Integrated Producer: } Q_2^1 + I_2^1 + \Delta I\end{gathered} \tag{A.16}$$

In this scenario, producer 1 is better off not adopting if (A.17) holds true.

$$k > (1-\alpha)(Q_1^1 - Q_2^1) \tag{A.17}$$

The best response for the integrated producer is to adopt if (A.18) is satisfied.

$$\Delta I > k + \alpha(Q_1^1 - Q_2^1) \tag{A.18}$$

In summary, it is possible that an equilibrium with only producer 2 adopting if (A.3) is false and (A.17) and (A.18) are true.

Both producers adopt. If both producers adopt the high quality input, the payoffs are described in (A.19).

$$\begin{gathered}\text{Producer 1: } (1-\alpha)(Q_1^1 - Q_2^1) \\ \text{Integrated Producer: } \alpha(Q_1^1 + I_1^1 + \Delta I) + (1-\alpha)(Q_2^1 + I_2^1 + \Delta I)\end{gathered} \tag{A.19}$$

If (A.3) is true, the best response for producer 1 is to adopt if (A.6) is true. If (A.3) is false, producer 1 will want to adopt if (A.20) is true.

$$k < (1-\alpha)(Q_1^1 - Q_2^1) \tag{A.20}$$

The integrated producer will be better off adopting if $\Delta I > {}^{k}/_{1-\alpha}$ is true. The summary is presented in Table A.2.

<Insert Table A.2 here>

Information Sharing

Note that producer 1 cannot lose by sending out information to the supplier when there is no vertical integration. However, when there is market integration, the existence of a high quality input will never improve producer 1's situation. When producer 1 adopts, producer 2 will also prefer to adopt the new input. This cancels out the benefit from adoption by producer 1, but not the cost of adoption. Thus, producer 1 prefers no innovation in the input at all.

Figures and Tables

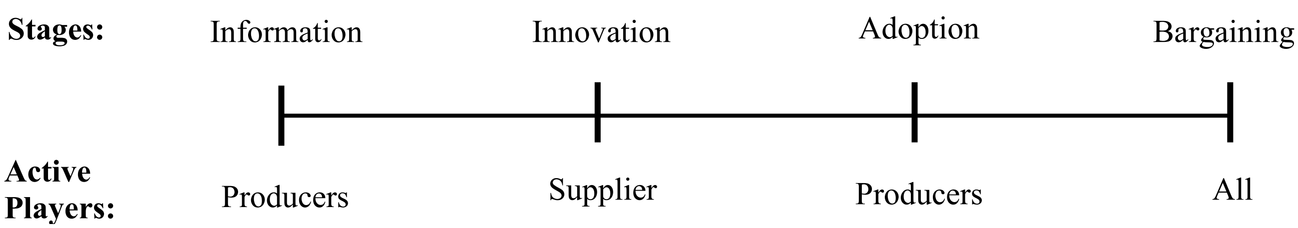

Figure 1: Timing of the game

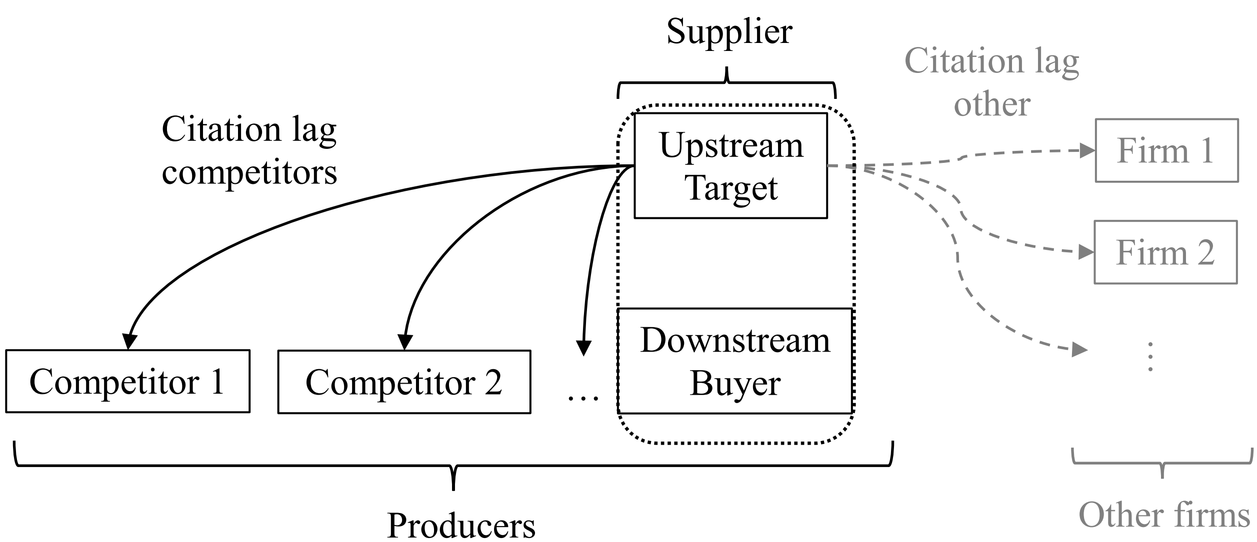

Figure 2: Capturing information flow using citation lag

Figure 3: Leads and lags, triple difference.

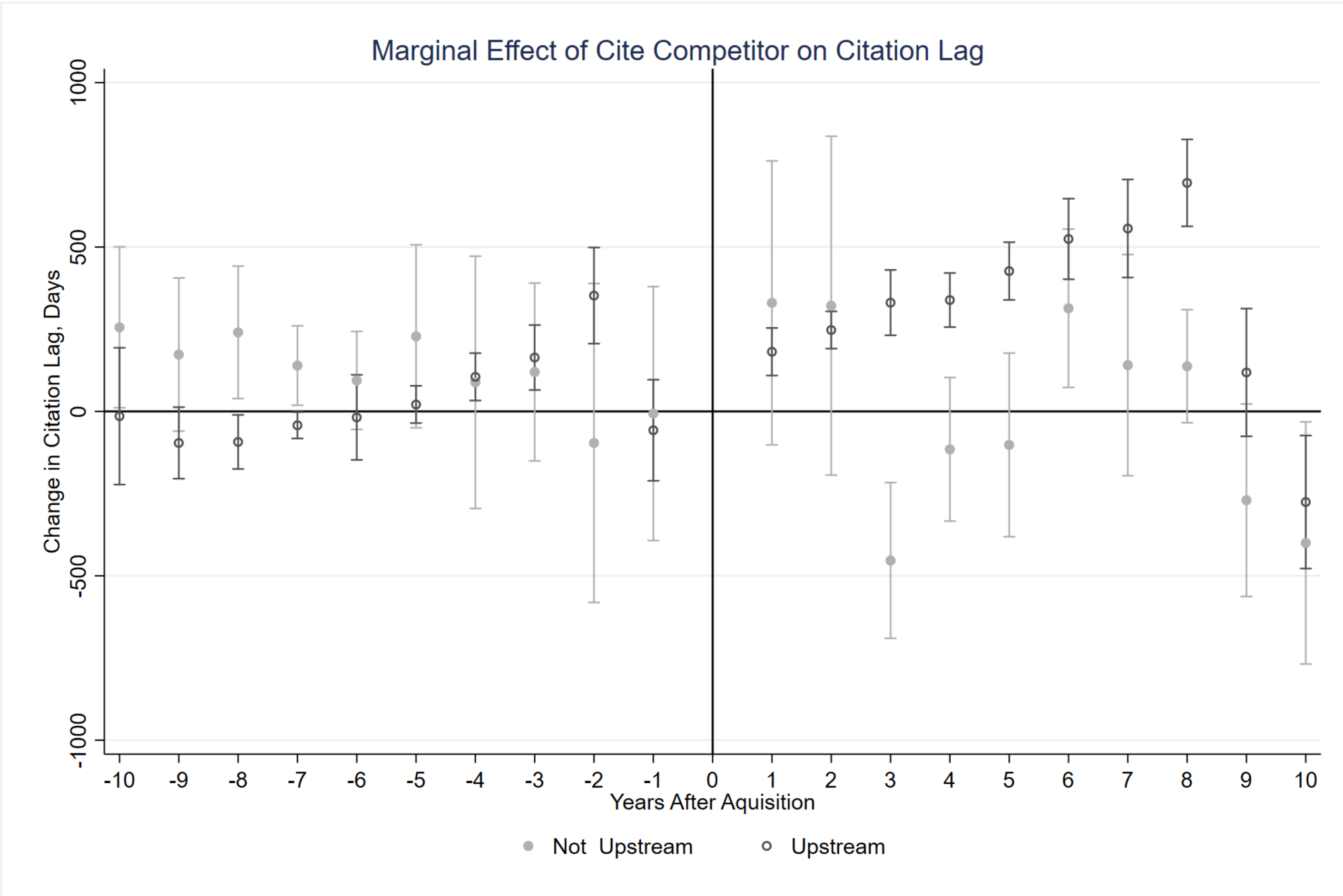

Table 1: Summary statistics

VARIABLES	N	mean	sd	min	max
Time Lag	498,167	3,962.88	2,595.11	0	15,463
Cite Competitor	498,167	0.05	0.23	0	1
Num Claims (citation)	498,167	20.14	17.50	1	868
Mean Lag (citation)	498,167	3,680.05	1,858.36	0	14,534
Num Citations (citation)	498,167	97.79	149.04	1	3,603
Num Claims (citing)	498,167	21.90	14.54	1	299
Num Citations Made (citing)	498,167	164.70	245.99	1	1,022
daysafterbuy	498,167	-799.04	1,960.03	-3,650	3,650
Acquired	498,167	0.35	0.48	0	1

Table 2: Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Time Lag	1.000								
Cite Competitor	0.091	1.000							
Num Claims (citation)	0.046	0.101	1.000						
Mean Lag (citation)	-0.138	-0.001	-0.013	1.000					
Num Citations (citation)	0.848	0.037	0.035	-0.132	1.000				
Num Claims (citing)	0.062	0.060	0.156	0.146	0.128	1.000			
Num Citations Made (citing)	-0.058	0.076	0.058	0.046	-0.007	0.076	1.000		
daysafterbuy	0.086	-0.086	0.039	0.002	0.057	0.101	0.021	1.000	
Acquired	0.109	0.863	0.060	0.008	0.024	0.046	0.062	-0.202	1.000

Table 3: Effect of acquisition on competitors' patents citation lag

VARIABLES	(1) Upstream	(2) Not upstream	(3) Triple difference
Num Claims (citation)	-2.89	-4.97	-3.97
	(0.002)	(0.000)	(0.000)
Mean Lag (citation)	1.18	1.21	1.19
	(0.000)	(0.000)	(0.000)
Num Citations (citation)	-0.09	-0.37	-0.30
	(0.758)	(0.112)	(0.100)
Num Claims (citing)	-0.52	-2.36	-1.59
	(0.430)	(0.001)	(0.008)
Num Citations Made (citing)	0.18	0.57	0.29
	(0.204)	(0.037)	(0.016)
daysafterbuy	0.74	0.59	0.09
	(0.000)	(0.000)	(0.000)
Acquired	-58.25	-18.21	-29.66
	(0.307)	(0.825)	(0.757)
Cite Competitor	-1.74	100.97	138.80
	(0.932)	(0.152)	(0.035)
Acquired * Cite Competitor	315.96	-26.40	-112.81
	(0.000)	(0.765)	(0.274)
Upstream			31.21
			(0.674)
Acquired * Upstream			-8.60
			(0.938)
Cite Competitor * Upstream			-133.01
			(0.055)
Acquired * Cite Competitor * Upstream			413.12
			(0.000)
Constant	488.61	-122.37	-271.44
	(0.000)	(0.196)	(0.002)
Target FE	YES	YES	NO
Citing year FE	YES	YES	YES
Buyer FE	YES	YES	YES
Tech Mainclass	YES	YES	YES
Observations	263,978	234,188	498,171
R-squared	0.86	0.83	0.84

Notes. Each data point is a citation. The dependent variable is the difference in application dates between the citing and the cited patents. Upstream firms are defined as firms supplying at least 1 percent of the final product. P-value in parentheses. Standard errors are clustered at the citing firm level. Column (1) only uses observations belonging to acquisition targets that are situated in the buyer's upstream. Column (2) only uses observations belonging to acquisition targets that **do not** belong to the buyer's upstream. Column (3) uses all observations.

Table 4: Marginal effect of acquisition on citation lag, triple difference model

Upstream	Cite competitor patent	Δ in citation lag after acquisition	Std. Error	95% Confidence Interval	
NO	NO	-29.73	(95.68)	-217.3	157.8
NO	YES	-142.6	(135.8)	-408.7	123.6
YES	NO	-38.32	(56.71)	-149.5	72.82
YES	YES	262.0	(68.79)	127.1	396.8

Notes. The marginal effects are calculated from the results in Table 3, column 3.

Table 5: Effect of acquisition on citation lag – patents added by applicant only

VARIABLES	(1) Upstream	(2) Not upstream	(3) Triple difference
Num Claims (citation)	-1.61	-2.96	-2.18
	(0.001)	(0.000)	(0.000)
Mean Lag (citation)	1.21	1.26	1.23
	(0.000)	(0.000)	(0.000)
Num Citations (citation)	1.08	0.61	0.83
	(0.019)	(0.051)	(0.007)
Num Claims (citing)	-0.76	-4.77	-1.00
	(0.344)	(0.004)	(0.227)
Num Citations Made (citing)	0.06	0.83	0.06
	(0.809)	(0.008)	(0.754)
daysafterbuy	0.94	0.79	0.08
	(0.000)	(0.000)	(0.024)
Acquired	-85.12	51.76	35.79
	(0.392)	(0.590)	(0.647)
Cite Competitor	7.00	215.37	247.64
	(0.893)	(0.032)	(0.020)
Acquired * Cite Competitor	362.39	112.05	86.07
	(0.000)	(0.324)	(0.492)
Upstream			100.31
			(0.373)
Acquired * Upstream			-130.92
			(0.236)
Cite Competitor * Upstream			-232.52
			(0.048)
Acquired * Cite Competitor * Upstream			253.53
			(0.064)
Constant	321.94	-97.67	103.77
	(0.000)	(0.403)	(0.273)
Target FE	YES	YES	NO
Citing year FE	YES	YES	YES
Buyer FE	YES	YES	YES
Tech Mainclass	YES	YES	YES
Observations	63,019	46,345	109,376
R-squared	0.88	0.88	0.88

Notes. Each data point is a citation added by the patent applicant. The dependent variable is the difference in application dates between the citing and the cited patents. Upstream firms are defined as firms supplying at least 1 percent of the final product. P-value in parentheses. Standard errors are clustered at the citing firm level. Column (1) only uses observations belonging to acquisition targets that are situated in the buyer's upstream. Column (2) only uses observations belonging to acquisition targets that do not belong to the buyer's upstream. Column (3) uses all observations.

Table 6: Effect of acquisition on citation lag – technology subclass

	(1)	(2)	(3)
VARIABLES	Upstream	Not upstream	Triple difference
Num Claims (citation)	-1.18	-2.77	-1.76
	(0.037)	(0.000)	(0.000)
Mean Lag (citation)	1.20	1.25	1.22
	(0.000)	(0.000)	(0.000)
Num Citations (citation)	1.11	0.77	0.94
	(0.012)	(0.013)	(0.001)
Num Claims (citing)	-3.33	-6.32	-3.32
	(0.079)	(0.002)	(0.007)
Num Citations Made (citing)	-0.08	2.17	-0.11
	(0.879)	(0.008)	(0.778)
daysafterbuy	1.12	1.26	0.28
	(0.000)	(0.000)	(0.001)
Acquired	33.99	193.69	-145.87
	(0.723)	(0.199)	(0.296)
Cite Competitor	-12.14	212.07	216.63
	(0.773)	(0.033)	(0.034)
Acquired * Cite Competitor	340.65	127.15	131.77
	(0.000)	(0.265)	(0.270)
Upstream			-698.03
			(0.009)
Acquired * Upstream			101.23
			(0.583)
Cite Competitor * Upstream			-228.65
			(0.035)
Acquired * Cite Competitor * Upstream			191.04
			(0.137)
Constant	401.28	-384.11	690.88
	(0.024)	(0.099)	(0.002)
Target FE	YES	YES	NO
Citing year FE	YES	YES	YES
Buyer FE	YES	YES	YES
Tech SubClass	YES	YES	YES
Observations	62,833	46,152	109,018
R-squared	0.90	0.90	0.90

Notes. Each data point is a citation. The dependent variable is the difference in application dates between the citing and the cited patents. Upstream firms are defined as firms supplying at least 1 percent of the final product. P-value in parentheses. Standard errors are clustered at the citing firm level. Column (1) only uses observations belonging to acquisition targets that are situated in the buyer's upstream. Column (2) only uses observations belonging to acquisition targets that **do not** belong to the buyer's upstream. Column (3) uses all observations.

Table 7: Probability to cite competitor's patents

VARIABLES	(1) All citations	(2) Cited by applicant
Num Claims (citation)	-0.0004	-0.0004
	(0.193)	(0.315)
Mean Lag (citation)	0.0000	0.0000
	(0.247)	(0.107)
Num Citations (citation)	0.0002	0.0002
	(0.172)	(0.105)
Num Claims (citing)	-0.0001	0.0003
	(0.232)	(0.434)
Num Citations Made (citing)	0.0001	0.0001
	(0.091)	(0.129)
daysafterbuy	0.0000	0.0000
	(0.547)	(0.033)
Acquired	0.0251	0.0014
	(0.056)	(0.875)
Upstream	0.0346	0.0207
	(0.093)	(0.033)
Acquired * Upstream	0.0028	0.0062
	(0.902)	(0.547)
Constant	-0.0150	-0.0220
	(0.679)	(0.564)
Citing year FE	YES	YES
Buyer FE	YES	YES
Tech Mainclass	YES	YES
Observations	498,167	109,376
R-squared	0.1581	0.1514

Notes. The dependent variable is a dummy equal to one if the patent cites a competitor's patent. Upstream firms are defined as firms supplying at least 1 percent of the final product. P-value in parentheses. Standard errors are clustered at the citing firm level. Column (1) considers all citations. Column (2) considers only citations included by applicants

Table A.2: Adoption decision when $\Delta I > Q_1^1 - Q_2^1$

	Non-integrated	Integrated
No adoption	$\Delta I < \frac{k}{1-\alpha}$	$\Delta I < \frac{k}{1-\alpha}$
Only producer 1	$\Delta I > \frac{k}{1-\alpha}$	No Equilibrium
Only producer 2	No Equilibrium	No Equilibrium
Both	No Equilibrium	$\Delta I > \frac{k}{1-\alpha}$

Table A.3: Adoption decision when $\Delta I < Q_1^1 - Q_2^1$

	Non-integrated	Integrated
No adoption	$\Delta I < \frac{k}{1-\alpha}$	$\Delta I < \frac{k}{1-\alpha}$ and $\Delta I < k + \alpha(Q_1^1 - Q_2^1)$
Only producer 1	$\Delta I > \frac{k}{1-\alpha}$	No Equilibrium
Only producer 2	$\Delta I > \frac{k}{1-\alpha} + Q_1^1 - Q_2^1$ and $k > (1-\alpha)(Q_1^1 - Q_2^1)$	$\Delta I > k + \alpha(Q_1^1 - Q_2^1)$ and $k > (1-\alpha)(Q_1^1 + Q_2^1)$
Both	No Equilibrium	$\Delta I > \frac{k}{1-\alpha}$ and $k < (1-\alpha)(Q_1^1 - Q_2^1)$