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Knowledge Assets and Firm Boundaries

Todd Stonitsch

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KNOWLEDGE ASSETS AND FIRM BOUNDARIES

BY

TODD STEPHEN STONITSCH

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ACCEPTANCE

This dissertation was prepared under the direction of the Todd Stephen Stonitsch's Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctoral of Philosophy in Business Administration in the J. Mack Robinson College of Business of Georgia State University.

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ABSTRACT

KNOWLEDGE ASSETS AND FIRM BOUNDARIES

BY

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Using a novel deal/patent dataset from 1986 through 2005, this paper explores the role of knowledge flow on the firm boundary decision. I use patent self-citations and cross-citations from the United States patent database as a proxy to measure knowledge flow between and within firms. When analyzing partnerships (strategic alliances and joint ventures), I find that firms with a higher percentage of patent self-citations are more likely to choose a more integrative boundary. Additionally, the level of integration chosen is positively related to the frequency of cross-citations between firms following the formation of the partnership. Firms in partnerships also see higher abnormal returns around the partnership announcement date when their partnering firm has a higher percentage of self-citations. I find weak to no evidence that these results hold for mergers/acquisitions. Overall, the evidence suggests that knowledge assets do play a pivotal role in the firm boundary choice.

Knowledge Assets and Firm Boundaries

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April 2014

Abstract: Using a novel deal/patent dataset from 1986 through 2005, this paper explores the role of knowledge flow on the firm boundary decision. I use patent self-citations and cross-citations from the United States patent database as a proxy to measure knowledge flow between and within firms. When analyzing partnerships (strategic alliances and joint ventures), I find that firms with a higher percentage of patent self-citations are more likely to choose a more integrative boundary. Additionally, the level of integration chosen is positively related to the frequency of cross-citations between firms following the formation of the partnership. Firms in partnerships also see higher abnormal returns around the partnership announcement date when their partnering firm has a higher percentage of self-citations. I find weak to no evidence that these results hold for mergers/acquisitions. Overall, the evidence suggests that knowledge assets do play a pivotal role in the firm boundary choice.

Keywords: Theory of the Firm, Knowledge Assets, Firm Boundaries

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1. Introduction

By integrating the boundary between firms, companies can focus on core skills and competencies while acquiring the capabilities they lack (Chan et al., 1997; Tavriverdi and Venkatraman, 2004). Firm integration is not dichotomous in nature, but instead exists among a set of strategic choices. These choices range from remaining independent firms and transacting with one another at "arms-length" to integrating via a merger/acquisition (Williamson, 1975, 1991; Hennart, 1993; Villalonga and McGahan, 2005). Alternative choices of integration include the formation of a partnership, such as a strategic alliance or joint venture. These forms of integration allow for a closer boundary between firms, while keeping the original firms intact.

As an example of the options available to firms, consider Microsoft, which has a long history of boundary formation changes to enhance the development of its software. In 2006, Microsoft and EMC Inc. officially announced a new strategic alliance that was forged to "commit to broader and deeper product inter-operability and service delivery…through the powerful combination of Microsoft's data center solutions and productivity applications and EMC's information infrastructure solutions…"[1] In 2000, Microsoft and Accenture Inc. (then Anderson Consulting) announced the creation of a new joint venture called Avanade[2] designed to develop business software based on a Windows platform that would be available for distribution through Accenture's business channels.

Theoretical work on the choice of boundary integration has often focused on the ownership of physical assets through transaction costs, such as the classic "hold-up"

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[1] From Microsoft Inc.'s February, 2009 press release.
http://www.microsoft.com/presspass/press/2009/feb09/02-03EMCRenewPR.mspx

[2] As of 2010, Avanade had U.S. $1bil in annual revenue.

problem (Williamson, 1975; Klein et al, 1978; Acemoglu et al., 2009). The role of knowledge assets in determining the boundary is less clear. Williamson (1975) and Klein et al (1978) suggest that the framework for the hold-up problem may not be applicable to knowledge assets. Physical assets are owned by the firm and therefore increasing the integration between firms also increases the shared control of those assets. Knowledge assets, on the other hand, are inevitably linked to human capital (Subramanian, 2008). Because humans cannot be owned by a firm, increasing integration may not result in an increase in shared control of knowledge assets. However, according to Jensen and Meckling (1992), the role of knowledge assets may be important when "value relevant knowledge is unevenly distributed through an economy as knowledge may become costly to transfer among agents." Integration acts as a mechanism to reduce this cost by allowing knowledge to flow more freely within the boundary of the firm. The question then becomes, how do firms decide to form their boundaries with other firms when economically relevant knowledge can not freely flow between them?

To address this question, this paper primarily focuses on deals relating to partnerships (strategic alliances and joint ventures), though I do dedicate a later portion of my analysis to mergers/acquisitions. There are a multitude of reasons to analyze strategic alliances and joint ventures in the setting of boundary integration. For one, partnerships allow for the traceability of knowledge flow even after a deal has been completed. Unlike mergers/acquisitions, where there is only one surviving firm after deal completion, all original firms still exist following a partnership deal. Therefore, knowledge assets in a partnership can be traced to an originating firm source even after deal completion. Second, I focus on partnerships due to the inherent differences in deal structure between partnerships and mergers/acquisitions. For strategic alliances and joint ventures, all entities remain in control of their existing knowledge assets following the deal. The level of ownership of these assets does not change, just the level of access granted to the partnering firm. In comparison, a merger/acquisition represents a transfer of ownership of knowledge assets from the target firm to the acquirer. Subramanian (2008) indicates that transfer of ownership during an acquisition does not necessarily increase the level of access to a knowledge asset. Therefore, by focusing on partnerships, I can analyze the integration choice based on access to knowledge assets without the possible confounding effects that could be brought on by a change in ownership.

The purpose of this paper is fourfold. First, while empirical literature has identified integration as a mechanism to reduce the hold-up problem between firms (Shenoy, 2012; Acemoglu, 2009), the role of knowledge flow on the level of integration chosen has not been examined carefully. In this paper, I strive to capture the integration choice more completely by examining whether or not knowledge flow affects the decision to form a more integrative boundary. Additionally I recognize that the choice of integration exists along a set of strategic alternatives. I therefore examine whether the level of knowledge flow between firms affects the level of integration chosen.

To do this, I use a collection of 3,119 deals from the Securities Data Corporation (SDC) Strategic Alliance and Joint Venture database and 1,349 mergers/acquisitions from SDC's Mergers & Acquisitions database between 1986 and 2005 as the setting for my tests. This data is then combined with patent and patent citation information from the United States Patent and Trademark Office (henceforth USPTO) from 1976 to 2005 to create two proxies to measure the level of knowledge flow between firms. The first proxy measures the frequency of patent self-citations within firms. Similar to the workings of Wang et al. (2009), I argue that firms with a higher percentage of self-citation have more firm-specific knowledge that cannot be easily transferred to other firms[3]. Additionally, following Seru (2010), I create a proxy to measure the average number of years until a firm's patent is able to be cited externally. All else being equal, patents that are difficult to access will take a longer time to understand and use in future patents and therefore the time it takes for knowledge to flow between firms will increase.

Consistent with the argument that knowledge flow is a key determinant of the level of integration between firms, I find that firms with a higher percentage of patent self-citation are more likely to form a partnership. A one standard deviation increase in percentage of self-citations raises the likelihood of a firm forming either a strategic alliance or joint venture by 5.2%. These results hold when using the average years to first patent citation as an alternative proxy to measure the restrictions to knowledge flow between firms. When a firm does choose to form a partnership, I find that firms with a higher percentage of patent self-citations select the more integrative joint venture boundary compared to a less integrative strategic alliance. A one standard deviation increase in percentage self-citations raises the likelihood of forming a joint venture over a strategic alliance by 7.4%. Furthermore, to avoid potential identification problems, I divide strategic alliances into sub-categories to test the impact of patent self-citations on the choice of strategic alliance type. I find that even within the strategic alliance definition, firms are more likely to select a more integrative form of a strategic alliance when the percentage of self-citations is higher. While my prior evidence suggests that

[3] Wang et al (2009) and Bena and Li (2012) use a similar measurement to calculate the degree of difficulty to replicate knowledge assets.

firms with a higher percentage of patent self-citations are more likely to form more integrative partnerships, it does so by looking at the choice of each firm individually. Since the partnership decision is not made by a single firm, but instead multiple firms jointly, I test the relation between the firm boundary choice and knowledge flow at the firm-pair level as well. My results find that firm-pairs with a higher combined average of percentage patent self-citations are more likely to form a more integrative boundary, consistent with the findings at the firm-level.

The second purpose of this paper is to address the question of whether the level of integration plays a pivotal role in the flow of knowledge between firms. Gomes-Casseres et al (2006) indicates that firms forming alliances are more likely to have an increase in patent cross-citations after the announcement date of the deal. Sevilar and Tian (2012), Anjos and Fracassi (2012), and Bena and Li (2012) look at mergers/acquisitions and find mixed results as to the level of increase in patent output following the deal completion. This paper analyzes whether or not the level of integration affects the degree of change in knowledge flow. If firms are forming more integrative boundaries to gain access to each other's knowledge assets, then the level of integration should positively affect the amount of knowledge able to flow between firms. I find that as the level of integration chosen by firm-pairs increase, so too does the level of patent cross-citations in subsequent years following the deal announcement date. Firms choosing a strategic alliance or joint venture see a 6.5% increase in the percentage of cross-citations compared to firms who remain independent and firms choosing a joint-venture see an 11.5% increase in cross-citation usage compared to firms forming a strategic alliance.

The third purpose of this paper is to analyze role of knowledge flow when ownership, and potentially access, is increased as is the case with the target selection in a merger/acquisition. Similar to Bena and Li (2012), I find that acquiring firms tend to target smaller companies with higher R&D intensity. However, I find only weak evidence that suggests that these firms are targeted due to the restriction of knowledge flow between the target and the acquirer. This evidence suggests that acquiring firms may primarily care about ownership of the target's assets rather than increasing access to these assets. I do find, however, that all else being equal, the likelihood of being a targeted firm versus an acquiring firm does increase as the percentage of patent self-citations increases.

Lastly, I analyze the market reaction to partnership and merger/acquisition deals to search for a possible link between the percentage of patent self-citations and announcement date effects. If forming more integrative firm boundaries allows companies to form synergies by gaining access to other firms' knowledge assets and increasing the knowledge flow between firms, then a deal announcement should result in positive abnormal returns for the firm. For partnerships, I find firms have higher abnormal returns when their partnering company has a greater percentage of patent self-citations indicating these firms are gaining increased access to these knowledge assets and improving knowledge flow to the firm. I find no evidence that this holds for mergers/acquisitions.

Overall, my findings indicate that the level of knowledge flow does play a crucial role in the determination of the firm boundary. The boundary choice of firms is both a frequent and non-trivial corporate decision. From 1986 and 2005, there were over 50,000 strategic alliances, 30,000 joint ventures, and 50,000 mergers/acquisitions in the United States alone[4], each representing a firm boundary choice. This paper aims to illustrate the importance and impact of knowledge flow in the boundary decision.

The remainder of this paper is organized as follows. Section 2 gives a brief literature review and develops the research questions. Section 3 describes the use of patent data and describes their value as a tool to measure knowledge flow. Section 4 explains the data and variable construction. Section 5 describes the empirical methodology used. Sections 6 and 7 present and discuss the results while Section 8 concludes.

2. Literature Review and Research Question Development

There is a growing body of literature that recognizes the importance of outside transactions costs in determining a firm's level of boundary integration. Several theoretical works have been devoted to the understanding of firm boundaries beginning with the seminal work by Coase (1937). In his paper, he theorized that a firm would form boundaries around costs deemed less costly internally rather than those found in outside markets. Subsequent theoretical literature was devoted to defining transaction costs that would cause firms to form more integrative boundaries including, agency costs (Jensen and Meckling, 1976; Jensen, 1986), costs born from asymmetric information (Balakrishnan and Koza, 1993), diversification costs (Jensen, 1986; Jensen and Murphy, 1990; Berger and Ofek, 1996) and organizational structure costs (Coase, 1937; Williamson, 1975 and 1985).

[4] From data provided by the Securities Data Corporation Strategic Alliance and Joint Venture database as well as the Securities Data Corporation Mergers and Acquisitions database.

Transaction cost theory stipulates that a firm chooses to acquire assets when the ongoing costs of conducting business in the market are higher than the organizing costs within the firm (Coase, 1937; Williamson, 1975; Klein et al, 1978). One such cost identified by Williamson (1975) results from the classic hold-up problem among economically related firms. When firms rely on assets held by another firm, the holder of those assets can renege on an agreement causing firms to under invest because of their ex-ante expectations of being held-up by the asset-owning firm. One solution presented in the literature is to form an integrated firm boundary. Acemoglu et al. (2009) used contract enforcement costs among various countries to empirically test this theory and found that firms in countries with high contracting enforcement costs have a greater propensity to vertically integrate. Shenoy (2012) also determined that vertical integration is primarily driven by efficiency.

Theoretical work by Rajan and Zingales (1998) and Subramanian (2008) stressed two mechanisms influencing the boundary decision of firms; ownership of assets and access to assets. They argue these two mechanisms are not analogous to one another and just because one has ownership does not mean it also has access to assets. Subramanian (2008) further argues that the transfer of ownership of knowledge assets during a merger/acquisition does not necessarily increase access to the knowledge assets purchased such as the case of the 2003 AOL acquisition of Netscape. During the Netscape acquisition, a large percentage of Netscape employees left en masse, leaving AOL with ownership of the Netscape browser, but the inability to use and further develop it. Subramanian (2008) argues that this could be one possible cause of failed mergers among high-tech industries.

On the empirical side, the literature has recognized that a boundary formation is not simply a binary choice between full integration and no integration, but instead exists among a set of strategic alternatives (Williamson, 1975). Associated literature that focuses on the formation of firm boundaries along a continuum generally falls into one of three categories: (1) boundary formation in specific industries such as auto-parts (Monteverde and Teece, 1982), bio-technology (Pisano, 1989) and pharmaceuticals (Pisano, 1990; Higgins, 2007): (2) choosing between alliances and acquisitions within the context of foreign market entry (Hennart and Reddy, 1997; Shaver, 1998; Dyer, Kale, and Singh, 2004): (3) firm characteristics to run a "horse-race" on competing theories of boundary formation (Villalonga and McGahan, 2005).

Research on the role of knowledge assets in corporate decisions and firm boundary formation has been limited, primarily because of the difficulty in obtaining accurate measures of knowledge flow between firms. In 1996, the National Bureau of Economic Research (NBER) released an electronic database of patents granted by the USPTO. This data has led to a growth in empirical literature examining the impact of knowledge flow on corporate decisions (see Benson, 2009 and Hall et al., 2001 for details on this dataset). Wang et al, (2009) find that increasing the equity based compensation of employees achieved an increased rate of self-citations within the firm. Ziedonis (2004) finds that there is a strategic issuance of patents in the product markets to inhibit innovation in competing firms. Studies of the relation between knowledge assets and the firm boundary have focused on knowledge innovation and firm value following the selection of a particular boundary. Gomes-Casseres et al. (2006) find that the number of patents increases following the formation of alliances and the source of new patents results from the cross-citations between firms. Many papers (Sevilar and Tian, 2012; Anjos and Fracassi, 2012; Bena and Li; 2012) focus on the change in corporate innovation following a merger/acquisition. They find mixed evidence that mergers do create synergies between firms, and only in some cases does a merger/acquisition subsequently increase the rate of firm innovation and patent generation. This paper compliments this growing body of literature by 1) analyzing the decision to form integrative boundaries among a set of boundary choices 2) analyzing the effect of the degree of integration on the change in knowledge flow between firms and 3) analyzing announcement date effects to see if firms gain value by partnering with other firms where the knowledge flow is restricted.

2.1 Theoretical Background

In a Coasian (1937) world without frictions or restrictions to the transfer of knowledge between firms, the boundary of the firm is of minor consequence. In such a world, knowledge can flow freely and two firms operating independently are able to gain access to each other's knowledge assets (Subramanian, 2008).[5] Assuming there are no costs to integrate, the choice of boundary in this world is independent to the flow of knowledge between firms since knowledge can flow freely for each boundary choice.

In a world with frictions, however, knowledge does not flow freely and access to knowledge assets becomes costly. Firms may purchase knowledge assets, including patents, from other firms; however the transfer of ownership does not imply the new owner is able to fully utilize and gain access the asset (Subramanian, 2008). Rajan and Zingales (1998) suggest that access to knowledge assets may be more important than the

[5] One can think of knowledge flow similarly to having access to knowledge assets as in Rajan and Zingales (1998) and Subramanian (2008).

actual ownership of these assets such as in a Grossman and Hart (1986) or Hart and Moore (1990) framework. In such a world, the boundary of the firm will determine the level of access to the knowledge asset. If two firms choose to remain independent, they may be unable to knowledge flow may remain restricted, thus minimal knowledge will be transferred between them. Alternatively, if firms choose to closely integrate, the various business units can further. The integration of firms can then facilitate the exchange of knowledge (Kogut and Zander, 1992). When these frictions exist in a Coasian world, the boundary of the firm is defined around those costs deemed less costly internally than the costs in the outside market. Consequently, the boundary between firms is defined around the costs of knowledge flow. When restrictions to knowledge flow exist, the internal cost of knowledge flow may be less costly than acquiring knowledge assets via the outside markets. Thus, firms may choose a higher level of integration to gain access to knowledge assets.

2.2 The Choice to Form a Partnership

In a world where the transfer of knowledge between firms is frictionless, the boundary choice of the firms is irrelevant absent of integration costs. Similarly, when firms possess knowledge assets which are easily transferable between firms, firms can share access without cost[6]. Other firms have little incentive to form integrative boundaries with companies with easily transferrable knowledge assets as doing so will not reduce the cost of acquiring knowledge since there is a pre-existing knowledge flow between the firms. Therefore, such firms are more likely to remain independent.

[6] Sending knowledge assets to other firms may not be voluntary. Knowledge flow between firms may occur due to technology spillovers or employees switching companies and bringing over their prior firms' knowledge set (Becker, 1962).

By contrast, when frictions exist that limit the knowledge flow between firms, there exist significant costs to transfer knowledge between firms. Access to the knowledge assets by another firm may require the formation of a more integrative boundary to facilitate a cost efficient transfer of knowledge. Partnerships act as a mechanism to integrate firms and allow greater access to assets between them. Therefore the probability of a partnership forming should increase when access to a firm's knowledge assets is limited thus restricting the knowledge flow from a firm.

2.3 The Choice of Firm Boundary

Firms with restrictions to knowledge flow may be more likely to form a partnership compared to firms with less restrictions. The question then becomes, what form of boundary should a pair of firms choose? Both strategic alliances and joint ventures facilitate access to one another's knowledge assets and each firm in the partnership retains the ownership to its existing knowledge assets in place. Cooperative agreements between partners in a strategic alliance are often established to offer access to technology and firm-specific assets for the sharing or co-development of new assets (Subramanian, 2008). The partners in a strategic alliance remain separate legal entities thus a strategic alliance most closely resembles an arms-length contract. Comparatively, a joint venture represents a more integrated form of business organization. Firms in a joint venture form a new legal entity in which each firm contributes equity, as well as access to technology and firm-specific assets. Similar to strategic alliances, joint ventures allow each firm to retain ownership of its existing knowledge assets.

Similar to the choice between a partnership versus no partnership, firms will choose their level of integration along two dimensions – the cost of forming a partnership against the benefits of gaining access to each other's knowledge assets. As the level of integration increases, so too does its cost (Villalonga and McGahan, 2005). Therefore, firms should form more integrative boundaries when the benefits of gaining access to key knowledge assets is significantly high to outweigh the potential integration costs. For firms with easily transferrable knowledge assets, the benefits of increasing the level of access are few. Alternatively, firms with restrictions to knowledge flow can accrue larger benefits by the formation of a more integrated partnership.

The acquirer's selection of a target firm may not be as straight-forward. On one hand, a merger/acquisition represents the most integrated form of boundary as an entire firm is merged into a single entity. This change in ownership may grant the greatest level of access relative to partnerships. On the other hand, Subramanian (2008) argues that a change in ownership of knowledge assets does not necessarily represent an increase in access and it may in fact decrease the access. Unlike partnerships, where ownership of existing knowledge assets does not take place, mergers and acquisitions face this confounding factor. Therefore the implications of the level of knowledge flow on the acquirer's selection of a target remain an empirical question which could go in multiple ways.

2.4 Changes in Boundaries and Firm Cross-Citations

If firm-pairs decide to form more integrative boundaries to increase the knowledge flow, then the level of integration should be positively related to the increase in knowledge flow between firms following the boundary change. Gomes-Casseres et al. (2006) find that alliances facilitate an increase in the flow of technical knowledge between firms. Sevilar and Tian (2012), Anjos and Fracassi (2012), and Bena and Li

(2012) have found limited evidence to suggest that mergers are followed by an increase in patent creation and corporate innovation. I extend these findings by proposing that the level of integration determines the level of knowledge shared between firms.

Paired firms effectively form a single firm entity with a defined boundary around and between them. Both firms determine the boundary by selecting from a set of boundary choices. Firm-pairs with an existing free flow of knowledge should form a less integrative boundary. Consequently, the level of knowledge flow should remain relatively constant when the firm boundary changing to a weakly integrated boundary (or no boundary change at all). When a restriction to knowledge flow exists, firms should form a more integrative boundary. This integration should facilitate an increase in knowledge between the firms. Essentially, the level of integration functions as a valve to knowledge flow. As the level of integration increases, so too does the knowledge flow between firms.

2.5 Announcement Date Effects

The final question this paper addresses is how the market reacts to announcements of a boundary change. Theoretical literature often discusses the potential synergies created by bringing two firms together, yet empirical results find that, on average, acquiring firms in a merger/acquisition have negative cumulative abnormal returns. Synergies between firms can be created when integration facilitates access to knowledge assets that could not be obtained by remaining independent. If the market believes that synergies can be created in a partnership (and/or merger/acquisition) and by integrating firms can gain access to another firms' knowledge assets, then that firm should have positive cumulative abnormal returns. If a merger/acquisition only acts as a change in ownership of knowledge assets instead of acting as an increase in access, then the market may react negatively or little on the announcement date and thus the cumulative abnormal returns may be of negative or have little significant difference from zero. If a merger/acquisition acts as an increase to knowledge flow between firms, then the market should have a positive cumulative abnormal return on the announcement date.

3. Using Patents to Measure Knowledge Flow[7]

I use United States patents frequently throughout my analysis to measure the levels of knowledge flow between firms and the ability to access knowledge assets. A patent is a set of exclusive rights granted by a country to an inventor or a corporate assignee for a limited period of time in exchange for public disclosure of the invention or procedure. In the United States, patents are granted by the United States Patent and Trademark Office (USPTO), but not every patent applied for is granted. While data on the acceptance rates of patents are unavailable, all accepted patent applications must meet the following criteria to be granted by the USPTO: 1) The invention must be novel over prior works; 2) The invention must be non-obvious in that the invention must be an innovative step; 3) The invention must be useful. In the United States, a patent is awarded to the first 'person to invent.'[8]

If the USPTO agrees that a patent application has satisfied all the criteria, a patent is granted to the inventor(s) of the patent. The inventor is not a corporation, but a person(s). For most firms in the United States, all ownership rights to the patent are forfeited to the employer and the corporation of the employee is recorded as the assignee of the patent. Multiple assignees can exist for the same patent. Several key pieces of

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[7] A special thanks to Spahr, Andrews & Ingersoll, LLP for the information provided in this section.
[8] This changed on March 16, 2013, after the sample period, to "first to file".

information are disclosed to the public in a granted patent: 1) the inventor(s) – or the persons responsible for the patent, 2) the assignee(s) – a unique identifier of the corporation/employer that is assigned to the patent at the time of the patent being granted, 3) a written description – including any drawings of the invention/process, and 4) a list of patent citations used to identify prior patents whose information was useful in the patent development. This list of patent citations of previously granted patents need not come from the patenting firm/individual. It is estimated that approximately half of the patent citations are attached by the USPTO, not the firm/individual creating the patent.

The choice to use patents to analyze knowledge flow is appealing for many reasons. Patents can only be granted if the application is innovative and useful, thus helping to eliminate patent applications that have little economic value. Additionally, attached to a granted patent is a list of patent citations, ranging from zero citations, on rare occasions, to as high as 785 citations. This list of patent citations offers tangible tracking of the knowledge innovation between and within firms. Since the citation lists are examined and augmented by the USPTO, the tracking of knowledge flow is not censored by the firms/individuals creating the patents. Consequently, an economically relevant list of knowledge assets can be credibly tracked.

It should be noted that corporate patents are not the only source of corporate innovation. Certain firms and industries might not participate in the patent process as firms may possess proprietary information that they do not wish to disclose. The use of patents is often clustered in certain industries where knowledge is considered a valuable asset and where the speed of innovation is relatively high. Additionally, clustering occurs in industries in which the legal ramifications for patent violations are higher. This clustering is often due to the trade-offs faced by firms applying for patents. Although firms benefit from patent usage by being granted exclusive rights to use, sell, and prevent importation of the innovation within the United States for a period of 20 years, patents require the disclosure of details about the innovation/process. The disclosure requires that enough information is provided in the body of the patent to enable a person of ordinary skill within the field to replicate the innovation.

4. Data and Variable Construction

4.1 Sample Construction

For partnerships, I collect a sample of strategic alliance and joint ventures from the Securities Data Corporation (SDC) from 1986 to 2005 that are matched with firms not forming an alliance from the COMPUSTAT database. Each observation in the SDC database represents an event when either a strategic alliance or joint venture has been announced. Strategic alliances and joint ventures offer an ideal setting in which the relation between knowledge flow and firm boundaries can be tested as each deal is a partnership between firms towards a common purpose/project. This symmetry allows the analysis to be completed on both a firm level and paired-firm level basis. The sample from SDC includes 3,119 completed deals which comprises 2,563 strategic alliances and 556 joint ventures among 1,908 unique firms that represent a change in the boundary between firms. The data for partnerships is constructed using the process described below.

I collect firm and deal-level data from SDC's Joint Venture and Strategic Alliance database for deals with an announcement date between 1986 and 2005. The SDC data is not exhaustive and does not include all deals completed during this time period due to inadequate reporting requirements. The database, however, is the most comprehensive source of information on such deals (Subramanian, 2008). Each deal in the database includes a list of participating firms, select firm characteristics, and deal-specific characteristics. To simplify the analysis of the relation between participating firms, I restrict the sample to strategic alliances and joint ventures involving two participants. Additionally, both firms must be domiciled in the United States. This exclusion addresses two issues: 1) many international deals are for the purpose of market entry and risk sharing rather than for the sharing of assets (Villalonga and McGahan, 2005) and 2) only limited financial information exists for foreign corporations and joint ventures. Additionally, SDC is more comprehensive for domestic firms compared to foreign firms.

Any strategic alliance that includes an equity transfer as part of the alliance agreement is eliminated thereby confirming that only joint ventures contain an equity stake in the deal. This step ensures that the study only samples strategic alliances that were formed for the purpose of establishing a partnership rather than sampling those alliances in which one firm is compensated for access to another firm's assets. I further restrict the sample by eliminating any observations in which one or both of the firms in the deal could be designated as a firm in the financial industry (identified by having an SIC code in the 6000's). Of the remaining observations, I only retain deals where both participants can be matched to the COMPUSTAT database in the year prior to the deal announcement, thus resulting in 3,119 deals within 59 two-digit SIC defined industries.

I use this set of observations to create two samples for analysis. The first sample comprises individual firm observations. Although each strategic alliance and joint venture is composed of two firms, the firm-level analysis examines the individual firms comprising each pair; thus each firm represents a unique observation. Consequently, a more detailed firm-level analysis is achieved compared to that which could result from analyzing the firms as a paired unit. Because there were 3,119 deals, the analysis at the firm level yielded twice that number of observations, or 6,238 firm-year observations during the sample period.

The second sample comprises units of paired firms. Since the data were restricted to deals between two firms only, every deal in the sample is its own observation. This type of sample has the advantage of being able to analyze the relation between firms comprising the pair instead of only analyzing firm-specific characteristics. However, unlike firm-pair analysis in other strains of finance literature (such as mergers/acquisitions), strategic alliances and joint ventures are relatively symmetric in nature. Deals often lack a dominant member (such as an acquirer firm versus a target firm in an M&A deal) thus limiting applicability of firm-specific characteristics at the firm-pair level. For example, industry fixed effects cannot be included in the firm-pair analysis because multiple industries are represented in one observation. Similar to the firm-level sample, there are 3,119 deals which lead to 3,119 observations at the firm-pair level.

For mergers/acquisitions, only successful deals from the SDC Mergers & Acquisitions database from 1986 to 2005 are included. While data exists for mergers/acquisitions as far back as 1971, the time period in the sample is identical to that used in the SDC's Strategic Alliance and Joint Venture database. All observations from SDC's Merger & Acquisitions database must meet the following criteria to be included in the final sample; (1) both the target and acquirer firms must be located in the United

States (2) consistent with Kale, Kini, and Ryan (2003), each acquirer must hold less than 50% of the target shares prior to the deal announcement and must have acquired at least 15% of the target shares during the deal and (3) the acquirer must have a stake larger than 50% after the merger. The second condition ensures that the transaction between the two firms was economically relevant. The second and third conditions ensure that the acquirer changed from a minority holder of the target's knowledge assets to a majority holder. Additionally, to be included in the sample, both the target and acquirer firm must be able to be matched to the COMPUSTAT database. This results in a sample of 1,349 mergers/acquisitions.

4.2 Firm Boundary Definitions

Joint ventures and strategic alliances are firm boundaries that exist among a set of governance modes (Williamson 1975, 1991; Klein et al., 1978; Hennart, 1993; Villalonga and McGahan, 2005). At one extreme, firms can remain independent of one another thereby allowing each firm to remain in control of its own assets. At the other extreme, firms may merge into a single entity in which case assets of both original firms are controlled by the new merged firm. In the middle of this set, though, lie strategic alliances and joint ventures. Strategic alliances are typically mutual agreements to share firm resources as defined in the scope of an alliance agreement. Though resources may be shared, all assets remain in control of the original firms. Joint ventures, by comparison, not only provide for the sharing of resources, but also call for equity infusion into the venture resulting in a closer boundary than the strategic alliance. Thus, these two organization forms provide a basis for defining the level of integration between each pair of firms in the sample. For each observation, a pair of firms chooses to remain independent, form a strategic alliance, or form a joint venture.[9] I define the variable *Structure* as a monotonically increasing variable in terms of the level of firm-pair integration. The variable takes a value of '0' if the firms remain independent. The variable takes the value of '1' if the firm-pair forms a strategic alliance. The value of '2' is assigned to those firm-pairs that form a joint venture which is the most integrative boundary defined for partnerships.

Following Villalonga and McGahan (2005), I also sub-divide the definition of an alliance for further analysis. Four sub-categories among the alliances are created and are defined as follows (in increasing order of boundary integration): 1) licensing arrangements; 2) non-equity alliances in marketing; 3) non-equity alliances in technology, research and development, or manufacturing; and 4) joint ventures. I then create the variable *Structure2* to correspond to the degree of firm integration. The variable takes on the value of '0' when no alliance is formed and increases to a value of '4' when a joint venture is formed. Later, I examine the sensitivity of the main results by using this expanded boundary definition to analyze the boundary choice within the original boundary definitions. It should be noted that these definitions hold for both the firm and the firm-pair level analyses.

Unlike partnerships, mergers/acquisitions have a clear separation between the firm types that comprise a deal. While partnerships can be thought of as more symmetric in nature, with each firm joining the partnership for a common purpose/project, a merger/acquisition is more asymmetrical in nature. I create the variable *Target* to denote whether or not a firm is a target firm. The variable takes the value of '1' if a firm is a

[9] For the purposes of this paper, firms remaining independent will still be said to entering into a deal. Instead of a deal to integrate, the firms agree to remain independent. Please see section 6.1 for more information on how matched firms enter the sample.

target firm and '0' if other. Depending on the model specification, the variable either takes the value of '0' for a non-target firm matched in COMPUSTAT or for the acquiring firm in the deal.

4.3 Restriction to Knowledge Flow

4.3.1 Patent Self-Citations

Patents act as a reservoir of existing knowledge that a firm has previously accumulated. Patent citations provide direct evidence of the path of the knowledge flow between firms and within firms, as each patent typically identifies other patents constituting the technology on which the patent builds (Wang et al, 2009). Therefore, the frequency of patent citations by the same or different firms can be tabulated. Prior literature has used self-citations as a proxy to measure the amount of firm-specific knowledge within a firm (Wang et al, 2009; Subramanian, 2008). Accordingly, the proxy can measure the amount of accumulated knowledge created using established knowledge assets (Cohen and Levinthal, 1989; Teece, 1986). The higher the percentage of internal accumulation, the more likely the firm's innovative knowledge is firm-specific. Moreover, a higher rate of self-citations signals a firm's capacity to access its own knowledge assets and conversely, the inability of outside firms to access those same assets thus an indication of a restriction to knowledge flow from the firm.

I use the United States patent data provided by Bronwyn Hall's website[10] from 1976 to 2006 to create proxies for knowledge flow between firms. Patents from the USPTO can be divided into two primary groups[11], design patents and utility patents. Design patents represent a change to the design, and not the functionality of a product

[10] http://elsa.berkeley.edu/~bhhall/bhdata.html
[11] Other patent definitions do exist, however, these are minimal in number.

(e.g. a logo change to a soft drink bottle). A utility patent represents a change to or an improvement in the functionality of an existing innovation. I focus my analysis on utility patents as they best exemplify the flow of innovative knowledge. For each patent, the USPTO provides a unique patent number along with a list of assignee numbers exclusive to the corporation(s) or individual(s) recognized for creating the patent. The assignee number is a static number given at the time the patent is granted by the USPTO. To capture the dynamic ownership of the patent over time, I combine Hall's database of United States patents, which matches assignee numbers to COMPUSTAT CUSIP and GVKEY numbers, with SDC's Merger and Acquisition database for verification. For each year, I track the GVKEY of the patent owner in Hall's dynamic table first, which tracks GVKEY changes over time. Next, I confirm whether or not the SDC Mergers and Acquisition database contains any acquisitions of greater than 50% of shares each year. If an acquisition took place, the GVKEY of the patent is changed for subsequent years to the new owner of the patent. Each patent includes a list of cited patents to which I similarly assign a GVKEY. The Hall dataset of patents granted from 1976 to 2006 represents 3,093,461 corporate patents containing 23,617,890 citations. Table I shows the USPTO took an average of 2.13 years to grant a patent from the date of application, and on average firms took 2.99 years to cite a patent for the first time. The average patent has 7.63 citations attached of which 6.67% are self-citations. Of firms holding at least one patent, firms hold an average of 191.8 patents.

The frequency of a firm's internal patent citations is used to measure how easily a firm's portfolio of patents can be accessed. Patents that are easily accessible to external firms – meaning a firm can apply the information contained in the original patent to subsequently develop a new innovation – can be traced by viewing the frequency with which outside firms cite a patent. If external firms can easily access a patent, the percentage of external citations should be high and thus knowledge flow is greater. Alternatively, if a patent is difficult to access, then only the firm who created the patent should be able to build upon that patent's existing knowledge, in which case the percentage of outside citations should be low.

Two proxies are created to measure the restriction of knowledge flow using a firm's portfolio of patents. The first method calculates the percentage of patent citations that are self-citations using a list of the firm's own patents. To measure this, for each firm I list all patents created by the firm within the past five years. Next, I develop from that list another list of all citations found in the patents. I then calculate the frequency of self-citations as the number of self-citations found in the patents divided by the total number of citations found in the patents. Such that:

$$RESTRICT1_{j,t=0} = \frac{\sum_{t=-5}^{t=-1} Self\ Citations_{j,t}}{\sum_{t=-5}^{t=-1} Total\ Citations_{j,t}} \quad (1)$$

Where *Self Citations* is the total number of self-citations a firm has accumulated over the previous five years and *Total Citations* is the total number of citations included in all patents created by firm *j* over the previous five years. This measure closely reflects the self-citations measure used in prior literature (Wang et al., 2009; Bena and Li, 2012).

The second measure examines the frequency with which self-citations are made on a firm's patents. To create this proxy, I first list all citations made to a firm's patents within the past five years, though the patent can be of any age. Citations on a firm's patents can come from two sources. A firm can cite itself (self-citation) or an external firm can cite the company. I calculate the frequency in which the citations to the firm are self-citations. The second measure is thus:

$$RESTRICT2_{j,t=0} = \frac{\sum_{t=-5}^{t=-1} Self\ Citations_{j,t}}{\sum_{t=-5}^{t=-1} Patent\ Citations_{j,t}} \quad (2)$$

where *Patent Citations* is the total number of citations made within the past five years on any of firm *j*'s patents. Appendix C provides an illustration of the differences between these two proxies, which have a correlation coefficient of 0.739.

4.3.2 Years to First Citation

In addition to patent self-citations, I also create a measure identifying the number of years it takes external firms to cite a firm's patents. I denote this measure as years to citation or *YTC*. The ease in knowledge can flow between firms is indicated by the speed in which the patent is cited and used by another firm. This is measured by calculating the average length of time until a patent's first citation by another firm. For each patent a firm applied for prior to the deal announcement date, I list patents that are cited both patents also prior to the announcement year of the deal.[12] For each citation, I calculate the difference between the citing year and application year of the firm's patent. I employ two methods of calculation if the patent has yet to be cited. The first is to ignore that patent from calculation. The second method, used in untabulated results, is to calculate the value as the difference between the deal year and the application year. For each patent, I then calculate a value representing the minimum number of years of all patents citing the firm's patent. This value is then averaged across all patents created by the firm prior to the announcement year of the deal such that:

[12] In untabulated results, I relax this restriction and create a list of citing patents even if they occur after announcement date of the deal.

$$YTC_{j,t=0} = \frac{\sum_{k=1}^{k=n}[\min(CitationDate_i - ApplicationDate_k)]}{n} \quad (3)$$

where n is the number of patents owned by firm j.

4.4 Patent Cross-Citations

In order to measure the effects of boundary integration on knowledge flow, I calculate the percentage of citations that are cross-cited between firms. While self-citations are attributable to a specific firm, cross-citations are attributable firm-pair. If knowledge flow between two firms increases, so too should the frequency in which firms cite one another's patents. The percentage of cross-citations between firms is calculated by first tabulating the number of citations in which either firm has cited the other within two years of the date of interest[13]. This figure is standardized by dividing aggregate number of citations of both firms during those two years to give a percentage of all citations which are cross-citations.

4.5 Vertical Relatedness/Horizontal Relatedness

I control for business connections by measuring vertical and horizontal relatedness. To control for vertical relatedness, I use data from the United States Bureau of Economic Analysis (BEA) which publishes the benchmark input-output accounts for the United States economy every five years. The BEA's 'Detailed Use' table provides a matrix of commodity flows to and from each pair of input-output industries. Fan and Lang (2000) IO-SIC concordance table is used to match the four-digit SIC codes of both parties in the sample to the six-digit IO codes provided by the BEA. Prior research suggests that firms move through industries over time (Kahle and Walkling, 1996) and that the input-output relations change over time (Shenoy, 2012); therefore I apply the

[13] A time frame of two years is used due to the time frame of the diff-in-diff methodology employed to measure changes in cross-citations.

‘Use’ tables in the following way. The 1987 ‘Use’ table is provided for announcements of deals made between 1986 and 1989. The 1992, 1997, and 2002 ‘Use’ tables provide the deal information for the years 1990-1994, 1995-1999, and 2000-2005 respectively.

To identify if the firms in the sample are vertically related, I employ the approach motivated by Fan and Goyal (2006) and Shenoy (2012). For every deal, I calculate a Vertically Related Coefficient (*VRC*) as follows: (i) For every dollar of Firm A’s industry total output, find the dollar flow from Firm A’s industry to Firm B’s industry (V1,AB), and the dollar flow from Firm B’s industry to Firm A’s industry (V1,BA), and (ii) For every dollar of Firm B’s industry total output, find the dollar flow from Firm A’s industry to Firm B’s industry (V2,AB) and the dollar flow from Firm B’s industry to Firm A’s industry (V2,BA). If Max[(V1,AB),(V1,BA)] or Max[(V2,AB),(V2,BA)] is greater than 2% then these firms are defined as vertically related.[14] Since prior research has shown that vertical relatedness can exist within the same industry, these firm pairs are not dropped from the above calculation.

Horizontal relatedness is defined by the SIC pairing between the firms. If the firms are within the same 4-digit SIC defined category, the variable *HOR* is defined as ‘4’. Likewise, if the two firms only share a 3-digit SIC code, *HOR* is defined as to ‘3’ and so on. If the firms do not fall into any of the same SIC industry codes, *HOR* is defined as ‘0’.

4.6 Market Prices and Announcement Dates

In order to calculate abnormal returns around the announcement dates of deals, I merge the SDC partnership and merger/acquisition data with the CRSP daily stock price data. Market adjusted returns are calculated at day intervals of t-1 to t+1, t-2 to t+2, and

[14] For robustness, the variable *VRC5* is also created to define vertical relatedness at the 5% level.

t-5 to t+5 where t=0 is the announcement date of the deal. I calculate abnormal returns using the market model. Since announcement dates in SDC are unreliable (Villalonga and McGahan, 2005), I attempt to verify dates through a combination of sources. I gather dates from SDC, Lexis-Nexis, as well as press releases from corporate and trade websites. When multiple dates are noted for the same deal, I use the dates found in news sources. If multiple dates exist among the various news sources, the first chronologic date is selected.

4.7 Other Control Variables

Since firms may choose to engage in alliances for purposes other than acquiring access to patents, a series of control variables is used. Because larger firms tend to have the resources available to form strategic alliances and joint ventures, firm size is controlled for by using the Total Assets (in $millions) variable found in COMPUSTAT. When using this measure (and all measures calculated at the firm-level), it is important to note that these firm-level variables do not apply for the firm-pair analysis. Unlike mergers and acquisitions, strategic alliances and joint ventures are more symmetric in nature and therefore the firm-level variables must also be converted to a firm-pair level variable. For example, the size variable cannot be put into an empirical model at the firm-pair level for Firm A and Firm B as either firm could be Firm A or Firm B. Therefore, following Lindsey (2008), and Villalonga and McGahan (2005), I calculate firm-pair variables at the firm-pair level by using either an average or a relative approach. The average approach takes the average of the two firm-level variables and is designated in this paper as *AVG('variable')* whereas the relative approach is calculated by dividing the larger of the two values by the smaller of the two values and is designated in this paper as *REL('variable')*.

It is also possible that firms may form partnerships due to the presence of growth opportunities. Since patents may be indicative of these growth opportunities, I include Tobin's Q as a control variable. Similarly, firms forming partnerships may be more R&D intensive. While R&D may be related to patent usage, this paper emphasizes the degree of restriction to knowledge flow conditional on the levels of R&D. I therefore control for R&D intensity by calculating R&D expenditures as a percentage of total assets. If firms do not list R&D expenditures, it is assumed to be zero. I also use the COMPUSTAT segment data to calculate the number of unique business segments in each firm.[15] Evidence found in Villalonga and McGahan (2005) suggests that firms with multiple business segments are likely to need outside sources of knowledge and are, thus, more likely to form an alliance.

Firms may form partnerships for other strategic purposes besides access to knowledge assets, including access to markets unavailable to them in their current geographic location. Alternatively, alliances may cluster in certain geographic locations such as the Silicon Valley or the northeastern United States (e.g. New York and Boston). I therefore control for the distance between firms as determined by miles "as the crow flies". Lastly, I control for profitability as measured by the firm's ROA. Variables are winsorized at the 2% level (results hold at 1% and un-winsorized) and are lagged one year from the announcement date of the deal.

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[15] For information of how I calculate the number of business segments, see the methods described in Berger and Ofek (1995).

5. Empirical Methodology

5.1 Boundary Choice

5.1.1 Defining the Observation

A natural design for the data setup would be one observation for each deal in the datasets. A deal comprises a joint decision by multiple firms (which I limit to two firms for testing purposes). For mergers/acquisitions, all firm- and deal-specific characteristics are retained in a single observation since there is a natural separation between target and acquirer firm (for example, I can include an industry fixed effect for target and industry fixed effect for acquirer). In partnerships, no natural separation exists between partnering firms thus firm-level characteristics must be converted to firm-pair characteristics. Variables such as firm size and R&D intensity must be replaced with the appropriate pair descriptors such as average or relative measurements. Industry fixed effects cannot be used in this case due to the firm specificity of the variable.

In order to resolve this issue, I use two methods to define the observation. The first method utilizes firm-level observations similar to Villalonga and McGahan (2005) in which each strategic alliance or joint venture produces two observations. The empirical structure of a deal is two observations for each deal:

$$y_{Deal,A,t} = \beta(Firm\ Specific\ Variables)_{Deal,A,t} + \beta(Fixed\ Effects)_{Deal,A,t}$$

and

$$y_{Deal,B,t} = \beta(Firm\ Specific\ Variables)_{Deal,B,t} + \beta(Fixed\ Effects)_{Deal,B,t}$$

where A and B represent the two respective firms in a partnership. Alternatively, I use a second method similar to that of Lindsey (2008) which analyzes all observations at the firm-pair level which yields one observation per deal. In this case, the empirical structure of a deal is:

$$y_{Deal,t}=\beta(Deal\ Specific\ Variables)_{Deal,t}+\beta(Relative\ Firm\ Specific\ Variables)_{Deal,t}+\beta(Fixed\ Effects)_{Deal,t}$$

where *Deal Specific Variables* are variables unique to the firm-pair (such as distance or vertical relatedness) and *Relative Firm Specific Variables* are firm-level variables converted to firm-pair descriptors (such as average size of firms and relative size of firms

5.1.2 Observation Matching within COMPUSTAT: The Primary Pool

Firm pairs that have completed deals comprise the samples from SDC's Strategic Alliance and Joint Venture and SDC's Mergers and Acquisitions datasets. The datasets, however, do not identify counterfactuals – firms that could have completed a deal, but did not. Although one method to identify a counterfactual may be to include all possible firm-pair combinations in a given year, the large number of potential observations and the dilution of the original set of completed deals would make this method infeasible and impractical. These next two sections are dedicated to the methodology and matching technique used to identify potential firms that were likely to form partnerships or mergers/acquisitions, but that did not. The techniques employed are valid for both the firm-pair and firm-level sample constructions.

While each firm-pair found in the data forms either a partnership or merger, there were many firms that could have entered into a deal with either firm, but chose not to. Thus, I have chosen to identify these firms as a matched sample. I follow a process in the spirit of Lindsey (2008) and Bena and Li (2012) in forming pair-wise matches. The process assumes that when firms enter a deal, they typically have a particular project in mind when deciding their partnering firm. These firms will seek partners possessing certain complimentary skill sets (Lindsey, 2008). Since there are two firms in each firm-pair observation, each firm in that pair seeks a particular set of skills. Consider, for example, a small IT/hardware company and a large software developer. The IT/hardware company may be looking to form an alliance with a large software developer (and vice versa) to bring a new product idea to market. The IT/hardware company can choose from a selection of software developers. Alternatively, the software developer can choose from a selection of IT/hardware companies. Therefore, for each firm-pair, I select two counter-factual observations, one for each firm in the firm-pair. Since each firm has a particular set of skills in mind, I match firms by industry as well as size characteristics.[16]

I define the SDC/COMPUSTAT matched dataset as the primary pool of matched observations as this will be the main dataset used throughout my analysis. I use COMPUSTAT to identify firms likely to engage in a strategic alliance or joint venture, but ultimately fail to do so. In order to match firms, I employ a propensity score match using the following procedure. For each firm in a firm-pair found in SDC, I compile a set of potential counterfactuals from COMPUSTAT based on the partner's industry and size. Industry is determined by the 4-digit SIC code. I run a propensity score match and select the closest matched firm that did not form an alliance. If no suitable match exists, I relax the restriction of a 4-digit SIC code to a 3-digit SIC code and re-run the propensity score. I continue to relax the industry restriction until a match is found. If no suitable matches can be made for either firm in a firm-pair, then the original firm pair is discarded from the sample. Using COMPUSTAT to identify counterfactuals has the advantage of providing

[16] In untabulated results, I also match for R&D intensity and patent usage one year prior to the deal announcement date. While doing so decreases the significance of R&D in subsequent multivariate tests, the main results remain relatively unchanged.

a wide selection of firms. Therefore, I am better able to find a close match using firm characteristics.

5.1.3 Observation Matching within SDC: The Secondary Pool

Because the primary pool of matched firms comes from the universe of COMPUSTAT, identification problems may still exist. The resulting matches may not be able to properly identify firms needing to form an alliance. The primary pool selects matches based on firms that could enter an alliance and not firms that would enter an alliance. To address this issue, a second matching scheme is developed to restrict matching to firms who will enter an alliance during a given time period. Instead of using COMPUSTAT to generate matches, matched firms are generated using the original dataset from SDC's Strategic Alliance and Joint Venture database.[17] The advantage of using this data restriction is that matches identifies matches that are already known to form an alliance. One disadvantage of this method is that the matching scheme can only be used in a firm-pair analysis because the matching requires re-using in-sample firms. If this dataset were used at the firm level analysis, counterfactuals would be brought into the sample that are the same observations as the original data. Another disadvantage is the potentially smaller number of matches resulting from the sample size of SDC firms compared to that of COMPUSTAT. This matched dataset is referred to as the secondary pool throughout the remainder of the paper.

To identify matches in the secondary pool, I use a multi-stage selection process similar to that of Lindsey (2008) and Bena and Li (2012). The goal of the matching process is to match a similar firm-pair as the original observation. Similar to the process

[17] Since this matching technique is restricted to firm-pair analysis of cross-citations which cannot be done using mergers/acquisitions, this sample is only used in the analysis of partnerships

for the primary pool, I create a list of matches for each firm in the firm pair by finding all firms in the SDC database with the same 4-digit SIC code as the partner firm. This list becomes a selection of firms who potentially could have formed an alliance, but did not. From the list of potential firms, I identify the industry of the actual partnering firm at the 2-digit SIC code level or higher. This ensures that the match is done by firms attempting to form an alliance and that the alliance is with a firm similar to the original.[18] If more than one firm exists at this stage, I then match by total assets. If no matches exist, I relax the restriction of matching to a 4-digit SIC code until a match is identified.

5.2 Changes in Knowledge Flow after Boundary Change

5.2.1 Differences in Differences

I use a difference-in-difference approach to identify the changes in knowledge flow before and after the announcement date of the alliance. The difference-in-difference method is done at the firm-pair level where I compare the knowledge flow between firm-pairs before and after the announcement date. To identify the untreated group, I use both the primary and secondary pool of matched observations to track those firm-pairs over the same window of time as the treated group. The treated group comprises those firms forming a strategic alliance or joint venture in which a boundary change is the identified treatment effect. Mergers/acquisitions are omitted from the analysis since I cannot track the change in cross-citations between the firm-pair after the merger has been completed since only one firm remains in the data. The empirical model is as follows:

$$\Delta\%CrossCitations = \beta_0 + \beta_1(Structure) + \beta_2(Deal\ Specific\ Controls) + \beta_3(\Delta Control) + \varepsilon \qquad (4)$$

[18] See Appendix B for a demonstration.

5.2.2 Incubation Bias

One issue with the difference-in-difference approach is that it requires an extended panel of data after the announcement date of the deal. When using information from the USPTO, a significant drop of observations is noticed in the latter part of the sample due to the incubation bias in the data. While patents may be applied for during a given year, it can take several years for the patents to be granted by the USPTO. Only granted patents show up in the dataset. Many patents will still be under review at the USPTO and not available in the patent database towards the end of the sample period even though they have been applied for. Therefore, when using the difference-in-difference approach, the data is truncated to only use those announcements prior to and including the year 2000. This restricts the data to a time period less affected by the incubation bias.

6. Summary Statistics

Analysis is done using two types of observations. Firm-year observations contain data specific to a single firm in the firm-pair during a given year (such as size, ROA, or Tobin's Q) while firm-pair year level data contains data specific to the firm-pair during a given year (such as existing cross-citations, structure formed, average size, etc.).

Table II reports the number of strategic alliances and joint ventures by year. It is interesting to note that there is a large increase in the number of deals observed in the 1990's during the time of the dot-com boom in the United States. Subramanian (2008) notes, however, that there could be fewer deals in the later 1980's due to the less stringent reporting details during that time. Table III reports strategic alliances and joint ventures by industry as well as patent usage among SIC 2-digit industries. Since each firm-pair comprises two firms that can be from differing industries, the analysis for Table III is done at the firm level. There is a clustering of observations for deals among certain industries such as Business Services (SIC 7300, 1,734 observations), Industrial and Machinery Equipment (SIC 3500, 893 observations), and Chemical & Allied Products (SIC 2800, 759 observations). In general, patent usage, or firms being granted at least one patent between 1976 and 2006, is clustered among the 2000 and 3000 4-digit SIC industry codes. However, other industries such as Engineering & Management Services (SIC 8700, 70.59% patent use) also exhibit higher levels of patent usage.

I pay close attention to the possibility of certain selection biases being introduced into the sample. Although the primary pool and secondary pool of matched firms attempt to create matched counterfactuals, the matching process eliminates firms from certain industries and with certain characteristics. Table IV presents five panels of descriptive statistics of several groups of firms. Panel A displays descriptive statistics of all COMPUSTAT firms from 1986 through 2005. Panel B presents descriptive statistics for all matched firms from the primary pool coming from COMPUSTAT. In general, matched firms are larger, more profitable, and are more R&D intensive than the firms in the general pool of COMPUSTAT firms.

Panels C through E examine the firm-level descriptive statistics for all firms in the sample who had either a strategic alliance or joint venture during the sample period. Panel C represents firms during the announcement year that entered into either a strategic alliance or joint venture during the sample period. Panel D and E look at the firms during the announcement year of the strategic alliances and joint ventures respectively. Firms in strategic alliances seem smaller, more likely to use patents, and more R&D intensive than firms in joint ventures.

My analysis is only appropriate for firms that use patents because the measurements of knowledge flow are created using patent data. Firms may not use patents for a variety of reasons, which, among others, includes a desire to keep their internally created knowledge assets private and out of the patent process. These firms may wish to render their knowledge assets as proprietary information. Alternatively, firms may not be knowledge intensive, thus having few potential patents to create. It is therefore difficult to say whether firms without knowledge assets actually create a significant restriction to knowledge flow or not. Firms may have few knowledge assets needed by other firms. Such observations will not show up in the multivariate analysis.

Tables VI and VII present descriptive statistics and differences along two dimensions: firms using/not using patents and firms forming/not forming a boundary. Panel A of Table VI presents descriptive statistics for firms who have engaged in at least one boundary change during the sample period and have at least one patent granted to them between 1976 and 2006. Panel B presents descriptive statistics for firms who have engaged in at least one boundary change during the sample period and who have not been granted any patents between 1976 and 2006. Panel C presents descriptive statistics for all COMPUSTAT firms not involved in a strategic alliance or joint venture during the sample period and have been granted at least one patent between 1976 and 2006. Finally, Panel D presents descriptive statistics of firms not engaged in a boundary change nor granted any patents by the USPTO. Not surprisingly, firms with patents do tend to be larger, more profitable, and more R&D intensive.

7. Results and Discussion

7.1 The firm's propensity to form a strategic alliance or joint venture

What firm characteristics drive a firm's choice to enter into a partnership with another firm? To answer this question, I first look at the univariate differences of firms forming a partnership versus those not forming a partnership during the same year. Firms not forming a partnership are matched using the primary pool of matched firms derived from COMPUSTAT.

Table VII presents univariate difference of sub-samples along two dimensions: firms forming boundaries and firms using patents at least once from 1976 through 2006. Firms using patents are significantly larger, have more growth potential (as measured by Tobin's Q), are more profitable, and not surprisingly, have higher R&D intensity. Firms forming boundary changes are also larger, suggesting it takes more resources to form a partnership. Firms forming partnerships also have a higher Tobin's Q, which is indicative of a partner selection based on a firms' perceived growth potential. Additionally, firms forming partnerships are more profitable and more R&D intensitve. Without the use of patents, I cannot examine the differences in the restrictions to knowledge flow between those firms who use patents and those who do not. The univariate differences of restrictions to knowledge flow between firms forming a partnership and the matched sample of firms that do not are positive and significant for the two proxies using percentage of self-citations (*RESTRICT1* and *RESTRICT2*). Thus, firms with a higher frequency of self-citations and more firm-specific knowledge are also more likely to form a partnership. The univariate difference for years to first citation (*YTC*) tells another story, with no significant difference between the two samples. This is not surprising for two reasons. First, there is a sizable negative correlation between R&D intensity and years to first citation. Since firms that do not form partnerships are also firms with low R&D intensity, the confounding effects are exhibited at the univariate level. Second, unlike using percentage of self-citations, which is standardized by the total number of citations, years to first citation is not standardized, which introduces the confounding effect of the economic relevance of the patent which would weaken the results.

Table VIII presents coefficient estimates of the probability to form a partnership in a multivariate framework. I employ two econometric models to estimate the propensity of firm to enter into either a strategic alliance or joint venture. The first method I use is a binary probit model. A probit model allows me to estimate unbiased consistent estimators when fixed-effects are not included due to the non-linear nature of the probit model. However, the omission of fixed-effects may be problematic. The data suggest time-varying changes in the use of patents as well as the clustering of patent usage within certain industries. Results using a non-linear model without fixed-effects may be spurious due to these unobserved characteristics. To address this issue, I also employ a linear probability model that permits year and industry fixed-effects. While the use of a linear probability model assumes that the dependent variable is continuous, the model still presents unbiased estimators at the cost of efficiency. Maddala (1985) contends that results from a linear probability model tend to be over-rejected.

Table VIII uses a modification of the variable *Structure* (called *Boundary*) as the dependent variable. *Boundary* takes the value of '0' if the firm in the sample forms neither a strategic alliance nor a joint venture and takes the value of '1' if it does.

Columns (A) – (C) utilize the binary probit model to estimate the probability of forming a partnership while Columns (D) – (F) utilize the linear probability model with industry fixed-effects set at the 2-digit SIC level. In all specifications, using all measures of knowledge flow restriction, I show that firms are more likely to form a partnership when their knowledge assets are more difficult for other firms to access. In five of the six model specifications, the coefficients of knowledge flow restriction are significant at the 1% level. Similar to the univariate results, the years to first citation measure is weaker than that of the percentage of self-citation measures.

A large portion of the firms sampled from the SDC database form strategic alliances rather than joint ventures. I next show that the results for the propensity to form a partnership based on restrictions to knowledge flow is not driven solely by either boundary type. In Table IX, I repeat the analysis from Table VIII using binary probit models over two sub-samples. Columns (A) – (C) use the sub-sample of strategic alliances and their respective match from the primary pool of matched firms. Columns (D) – (F) use the sub-sample of joint ventures and their respective matched firms. Once again I use the dependent variable *Boundary* to estimate the probability of forming a given partnership. I continue to find a positive and highly statistically significant relationship between knowledge flow restrictions and the propensity to form a partnership regardless of the sub-sample chosen. It is worth noting that while R&D intensity and Tobin's Q appear to have a positive association with the propensity to form a strategic alliance, the results are less robust for joint ventures. My results indicate that explanatory variables may not be directionally monotonic across boundary choices.

7.2 Choice of Firm Boundary

Is the restriction to knowledge flow associated with the level of integration chosen for partnerships? In order to answer this question I separate boundary selections based on the choice between strategic alliances and joint ventures. Analyzing strategic alliances and joint ventures allows me to examine two business organization structures that increase the level of access to knowledge assets as integration increases, but leave the level of ownership of existing knowledge assets unchanged. Unlike a merger/acquisition, there is no asymmetric transfer of ownership of knowledge assets between firms in a partnership.

Table X presents two sets of empirical models exploring the boundary choice of firms. Columns (A) – (C) show a binary probit model using the dependent variable *JVSA* which takes the value of '1' for a joint venture and '0' for strategic alliance. Though counterfactuals are eliminated from these tests, results do allow for a direct comparison between strategic alliances and joint ventures. I show that for all measures of knowledge flow restriction, I find a positive association between firms' knowledge flow restrictions and the probability of these firms forming a more integrative boundary. I show similar results in Columns (D) – (F) using an ordered probit model which include matched firms from the primary pool of COMPUSTAT firms.

It is worth noting that the relation between R&D intensity and Tobin's Q switch signs between the two model specifications. This is an indication that suggests that firms can choose different levels of integration for different reasons and not all explanatory variables are directionally monotonic in nature. Coefficient estimates for an ordered probit model assume the choice between lower levels of integration is similar in direction to the choice between higher levels of integration.

In Table XI, I run a two-stage selection model (similar to a Heckman model). A binary probit model containing only strategic alliances and joint ventures is a model conditional on a partnership being formed. An ordered probit including the matched sample does not condition on a partnership being formed, but does assume correlations will remain in the same direction between various boundary choices. I use a probit model to estimate the first-stage likelihood of forming a partnership. I instrument for the boundary choice by using the number of segments a firm has. Firms with multiple segments are more likely to need external sources of knowledge and are therefore likely to form a partnership. Firms with multiple segments have been found to have a high likelihood to form mergers/acquisitions (Villalonga and McGahan, 2005), but there is less correlation between the choice of strategic alliance and joint venture. In the regression analysis, I use the results from Column (A) – (C) of Table VIII for the first stage model and use a linear probability model with and without fixed effects for the second stage. The results hold irrespective of model specification.

In terms of robustness with previous results, the analysis is repeated over various alternative model specifications. Columns (A) – (B) of Table XII use a multinomial conditional logit model to take advantage of the full power of the sample. The model sets non-alliance firms as the base case and models the choice of both a strategic alliance and joint venture against the base. Columns (C) – (D) repeat the ordered probit specification found in Table X, Columns (D) and (F), using a linear probability model with industry and year fixed-effects. Additionally, since not all industries rely on patents as their source of knowledge assets, I restrict the sample in Columns (E) – (F) to industries with high patent use as these are the firms in which access to knowledge assets may matter most. I restrict the sample to those firms found in the SIC 2000 and SIC 3000 1-digit industries and employ a linear probability model with industry and firm fixed-effects. In all specifications, prior results hold as the level of knowledge flow restrictions has a positive relation to the level of integration chosen in a partnership.

Next, I focus on the knowledge flow restrictions at the firm-pair level. Unlike the firm-level analysis that consisted of two observations for each deal, the firm-pair level analysis consists of one observation per deal. For a partnership, all firm-pair observations consist of firm-pair characteristics. I re-run the empirical tests to estimate the probability of each firm-pair forming a partnership and include firm-pair characteristics such as vertical relatedness, distance, and horizontal relatedness between firms in each observation. A binary probit model is used in Columns (A) – (C) in Table XIII to show that the inclusion of firm-pair level characteristics minimally affects the relation between knowledge flow restrictions and the choice between strategic alliance and joint venture. Similarly, an ordered probit model is used in Columns (D) – (F) to show that the results hold with the inclusion of the primary pool of matched observations.

Since the boundary choice between strategic alliance and joint venture may be influenced by unobserved boundary effects, I use the definitions of Villalonga and McGahan (2005) to create sub-boundary definitions within strategic alliances. Strategic alliances are broken up into three different groups, listed in order of boundary integration: licensing agreements, marketing agreements, and R&D / Technology / Manufacturing agreements.

Using a series of probit models presented in Table XIV I show that even within the strategic alliance definition, the level of restriction to knowledge flow affects the likelihood of forming a more integrative boundary. An ordered probit model is used in Columns (A) and (C) across the full sample using the dependent variable *Structure2* as the range of options (from no partnership, to the sub-types of strategic alliances, and to joint ventures). An ordered probit model is also used in Columns (B) and (D), but limits the sample to strategic alliance sub-types only. R&D / Technology / Manufacturing agreements are those agreements most likely to involve knowledge intensive firms with knowledge assets that may be the most difficult to access and utilize by other firms. Binary probit models in Columns (E) – (F) appear to indicate that it is still more likely that firms with higher restrictions to knowledge flow will form joint ventures rather than these narrowly defined strategic alliances. I re-run my analysis at the firm-pair level in Table XV and find similar results.

7.3 Patent creation changes pre/post partnership

One of the goals a firms has in creating a new relationship with a partnering firm is to create synergies to further gain a competitive advantage in the product market (Hoberg and Philips, 2010). By gaining access to knowledge assets, a firm, and its partner, can expand on both firms' existing assets to create new corporate innovations. If two firms form a partnership due to a lack of access to each other's knowledge assets and an impedance to knowledge flow, a more integrative boundary should cause an increase in the level of cross-citation post partnership. Alternatively, firm-pairs with little impedance to the knowledge flow between them should choose a less integrative form of firm boundary and the impact of a partnership (or lack thereof) should minimally affect the level of patents cross-cited in the partnership.

I employ a difference-in-difference model to measure the changes in firm-pair attributes around a window of +/- two years of the announcement date of the partnership. I use the two-year period to calculate the percentage of firm cross-citations to ensure that the summation of cross-citations does not include cross-citations prior to the announcement date of the partnership. Since the dependent variable and the variable of interest (the level of firm integration) are both firm-pair specific attributes, I can employ two different matched samples. The first sample is the primary pool of matched samples which has been used widely in the analysis. The second source of matched firms is the secondary pool which draws from the SDC Strategic Alliance and Joint Venture database. By using the secondary pool of matched firms, I can match by firms that not only could form a partnership, but, in fact did so, albeit with another firm. Each matched dataset acts as the untreated group, while those firm-pairs who did form a partnership act as the treated group in the diff-in-diff.

Panels (A) – (D) in Table XVI shows the univariate changes over time by the boundary choice selected. A comparison of the change in cross-citations in Panel (A) and (B), clearly shows that firms forming partnerships are more likely to cross-cite other firms who form partnerships. Firms forming partnerships have 53.0% more cross-citations with other firms forming partnerships as compared to the matched firms from COMPUSTAT. I show in Panels (C) and (D) that an increase in the level of boundary integration causes a larger, univariate change in percentage of cross-citations between firms. Firms forming strategic alliances exhibit an 84.8% increase in the percentage of cross-citation change as compared to the COMPUSTAT matched firms. Joint ventures are even higher at 180.3% higher than their COMPUSTAT counterparts.

The diff-in-diff approach in Table XVII shows that the level of boundary integration affects the level of cross-citations between firms. Firms remaining independent of each other exhibit a smaller increase in the percentage of cross-citations, compared to both strategic alliances and joint ventures. Additionally, strategic alliances exhibit a smaller increase in the percentage of cross-citations after the deal announcement as compared to firms forming joint ventures. The results hold regardless of whether the matched firms come from COMPUSTAT (Columns (A) – (B)) or SDC's Strategic Alliance and Joint Venture database (Columns (D) – (E)).

7.4 Mergers and Acquisitions

Mergers/acquisitions represent a deal structure distinct from a partnership. Partnerships represent a symmetric deal where both parties agree to enter into an agreement without losing ownership of their existing knowledge assets. Typically, neither firm is compensated for entering the partnership. Even with joint ventures, equity stakes are only carved out for the newly created legal entity and not an ownership stake in the partnering firm. Mergers/acquisitions represent asymmetrical deals with one party (the acquirer) compensating the other party (the target) in return for ownership of the target firm's assets. While partnering firms form a strategic alliance or joint venture for a common goal/project, it is the acquiring firm who is searching for certain firm characteristics in a target and typically not vice-versa (Subramanian, 2008).

Table XVIII illustrates the differences between firms in a merger/acquisition and COMPUSTAT firms. It shows that acquirers are typically larger firms with growth potential who seek out small, R&D intensive firms with low profitability. Despite having high R&D intensity, target firms have lower levels of restriction to knowledge flow compared to acquirer firms. Bena and Li (2012) find consistent results in their data and argue that acquirers buy R&D intensive target firms before they are able fully develop and bring their research to the patent stage.

Table XIX shows the median relative differences between firms of strategic alliances, joint ventures and mergers/acquisitions. Since relative measures can cause large outliers in the data, I focus on medians rather than averages. Strategic alliances are typically the smallest in scope for a firm, often revolving are a subset of firms operations (such as R&D or marketing). This allows for a wide range of firms to form an alliance and often results in a wider divergence of firm-characteristics than joint ventures and mergers/acquisitions. Relative Tobin's Q, the difference in R&D intensity, and the difference in ROA, are all highest for strategic alliances compared to both joint ventures and mergers/acquisitions. However, relative size is still less divergent for strategic alliances than for joint ventures which are the least divergent in firm-characteristics in almost every category except ROA, where both mergers/acquisitions and joint ventures have nearly identical differences. Mergers/acquisitions are the most divergent in terms of firm size and knowledge flow restrictions. Mergers/acquisitions also have a median horizontal relatedness value of 3.0, meaning the majority of mergers/acquisitions in the sample seem to be more horizontally related deals within the same 3-digit SIC defined industry. Compared to medians of 1.0 for both strategic alliances and joint ventures, mergers/acquisitions may be more likely to be chosen as the vehicle to acquire competitors in the product market whereas strategic alliances/joint ventures may be more likely chosen as the vehicle to interact with outside industries.

My first set of tests focus on whether or not acquirers select targets to relieve restrictions to knowledge flow. Columns (A) through (C) of Table XX present results of a binary probit model in which the dependent variable takes the value of ‘1’ if the firm is a target firm in a merger and acquisition and ‘0’ if the firm is a matched firm from COMPUSTAT found in the primary pool sample. Results indicate that while acquirers do seek out high R&D firms, they do not seem to select firms to reduce the restrictions in knowledge flow between them. These results may seem contradictory at first, but it seems to indicate that acquirers seem to target firms to purchase products that have been in development at the target firm rather than to gain access to the knowledge embedded in the target firm. This is further backed up by evidence which suggests that acquirers are targeting firms with fewer growth opportunities as indicated by Tobin’s Q.

Lastly, I estimate the likelihood a firm will be a target firm versus an acquirer. There is no clear indication of how restrictions to knowledge flow should relate to a choice between firm types. On one hand, univariate differences have shown that acquirer firms already have a larger degree of impedance to knowledge flow than target firms. On the other hand, acquirer firms may be seeking out firms to alleviate restrictions to knowledge flow. I estimate a binary probit model in Columns (D) – (F) in Table XX to estimate the likelihood of being a target firm versus an acquirer firm with the dependent variable taking the value of ‘1’ for Target and ‘0’ for Acquirer. I show that once size and R&D intensity are controlled for, higher levels of knowledge flow restriction indicate a higher likelihood of being a target firm versus an acquiring firm. The results seem to indicate that while acquirers do not seem to target a firm specifically to alleviate restrictions to knowledge flow, the acquiring firm is integrating with firms with more restrictions than itself.

7.5 Announcement Date Effects

Does the market react when a deal is announced for partnerships and mergers/acquisitions based on restrictions to knowledge flow between firms? If firms form partnerships and mergers/acquisitions for synergistic gains, then significant restrictions to knowledge flow should also represent a greater potential to realize these gains. To clarify the announcement date effects, I first identify the announcement date using various press sources. Since SDC's announcement dates can be unreliable (Villalonga and McGahan, 2005), I search Lexis-Nexis as well as online corporate press releases to identify the dates. However, because announcement dates can vary significantly even among press sources, I set the window around the announcement date to three different time periods, t-1/t+1 days, t-2/t+2 days, and t-5/t+5 days where t=0 is the identified announcement date. Using the CRSP value-weighted returns for the market return[19], I show the market adjusted returns for partnering firms and acquiring firms over these periods in Table XXI.

In Table XXII Columns (A) – (C) I use an OLS model to show that firms forming partnerships have a positive abnormal return around their announcement date when their partnering firm has knowledge assets that are difficult to access. Results are weakest using the t-1/t+1 window and get stronger as the window expands. This suggests that the market may not assimilate the information of the deal announcement into the price

[19] In untabulated results, I also used the CRSP equally-weighted index for the market return and found similar results.

immediately, which is not surprising given the uncertainty found in the press as to the actual announcement date of the deal. In Columns (D) – (F), I use the same OLS model to show that these results do not hold for mergers/acquisitions. Overall, my results support the idea that partnerships often act as a vehicle to augment access to another firms' knowledge assets. Firms with knowledge assets that are difficult to access are more likely to be involved in the formation of an integrative boundary which increases access to the partnering firm which leads to an increase in cross-citations between firms. When integration also includes the transfer of ownership, as is a merger/acquisition, the benefits of integration seem to be greatly reduced.

8. Concluding Remarks

In this paper, I examine 3,119 partnership announcements and 1,349 merger/acquisition announcements between 1986 and 2005 to study how knowledge flow can affect the firms' boundary decision. By employing a dataset composed of SDC strategic alliances, joint ventures, and mergers/acquisitions, I am able to merge data from NBER's USPTO patent citation database to measure the knowledge flow of alliance firms before and after the deal. My empirical evidence supports the idea that knowledge assets act as a key determinant in the corporate decision to expand the boundary of the firm and that the degree to which firms expand their boundary is positively related to the degree of restriction to knowledge flow of a firm. These results hold true over various definitions of restriction to knowledge flow including 1) the frequency in which firms can access knowledge assets and 2) the speed at which knowledge assets can be accessed. Empirical evidence also suggests that the level of impedance to the firm affects the level at which firms will cross-cite each other after a partnership has taken place.

Additional research is needed in this area. This paper recognizes the differences in the comparison between partnerships and mergers/acquisitions, but what remains is to reconcile the role of knowledge assets between these two distinct deal structures. Additionally, I have yet to explore the directional relation between knowledge flow and boundary choice. Currently, my measure for cross-citations remains agnostic as to which firm cites whom. In reality, the direction of knowledge flow might at times be unidirectional instead of the implied two-way flow in this study. Lastly, this paper only looks at one channel through which knowledge may be transferred: patents. In reality, patents are just one of many forms a knowledge asset may take. Therefore, these results may actually understate the role that knowledge assets have on the boundary formation decision, especially in industries where patent use is low and other mechanisms are used. Though firms using patents are currently concentrated in certain industries, the role of knowledge assets is only set to expand as economies become more knowledge intensive. This paper hopes to illustrate how firms may make strategic corporate decisions now, and in the future.

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Appendix A

Definition of main variables

Variable Name	Description	Definition	Source*
Structure	Alliance type formed by firm-pair (broad definition)	=0 if no alliance; =1 if strategic alliance; =2 if joint venture	SDC
Structure2	Alliance type formed by firm-pair (detailed definition)	=0 if no alliance, =1 if licensing agreement, =2 if marketing agreement; =3 if manufacturing, R&D or technology agreement; =4 if joint venture	SDC
Boundary	Partnership versus independent firms	=0 if no alliance, =1 if either strategic alliance or joint venture	SDC
Target	Target firm versus non-target firm in a merger/acquisition	=1 if Target, =0 if other	SDC
JVSA	Strategic Alliance/Joint Venture identifier	=1 if the alliance is a joint venture and 0 if a strategic alliance	SDC
% CrossCitation	Percentage of a firm-pairs citations which are cross cited within the prior two years	$=\frac{\sum_{t=-2}^{t=-1} Cross\ Citations_{j,t}}{\sum_{t=-2}^{t=-1} Total\ Citations_{j,t}}$	USPTO
RESTRICT1	% of all citations from firm *j*'s patents that are self-cited by firm *j*	$=\frac{\sum_{t=-5}^{t=-1} Self\ Citations_{j,t}}{\sum_{t=-5}^{t=-1} Total\ Citations_{j,t}}$	USPTO
RESTRICT2	% of firm *j*'s citations from all firms that are self-cited	$=\frac{\sum_{t=-5}^{t=-1} Self\ Citations_{j,t}}{\sum_{t=-5}^{t=-1} Patent\ Citations_{j,t}}$	USPTO
YTC	The average of the minimum time until a patent is cited in years	$=\frac{\sum_{k=1}^{k=n}[\min(CitationDate_i - ApplicationDate_k)]}{n}$	USPTO

Appendix A - Continued

Variable Name	Description	Definition	Source*
Patent	Dummy if firm has ever used a patent throughout the sample period	=1 if a firm has used a patent; =0 otherwise	USPTO
Hor	Degree of horizontal relatedness between firms in a firm-pair	=4 if pair has same 4-digit SIC; =3 if pair has same 3-digit SIC; =2 if pair has same 2-digit SIC; =1 if pair has same 1-digit SIC; =0 otherwise	SDC/ Compustat
VRC	Dummy for vertical relatedness between firms in a firm-pair	See paper for full description	BEA
Assets	Size of firm	Assets of firm ($mil)	Compustat
Q	Tobin's Q measure of firm's growth potential	$= \frac{Market\ Value\ of\ Equity + Assets + Book\ Value\ of\ Equity}{Assets}$	Compustat
R&D	R&D expenditures as a % of firm assets	$= \frac{R\&D\ (\$mil)}{Assets\ (\$mil)}$	Compustat
ROA	Return on Assets (%)	$= \frac{EBITDA\ (\$mil)}{Assets\ (\$mil)}$	Compustat
Segments	Number of business segments in a firm	=Number of Business Segments	Compustat Segment Tape
MRet (1,2 &5)	Market-adjusted return over 1,2 and 5 day windows around the announcement date using the CRSP value-weighted index as the market return.	=Percent Change in market adjusted price	CRSP

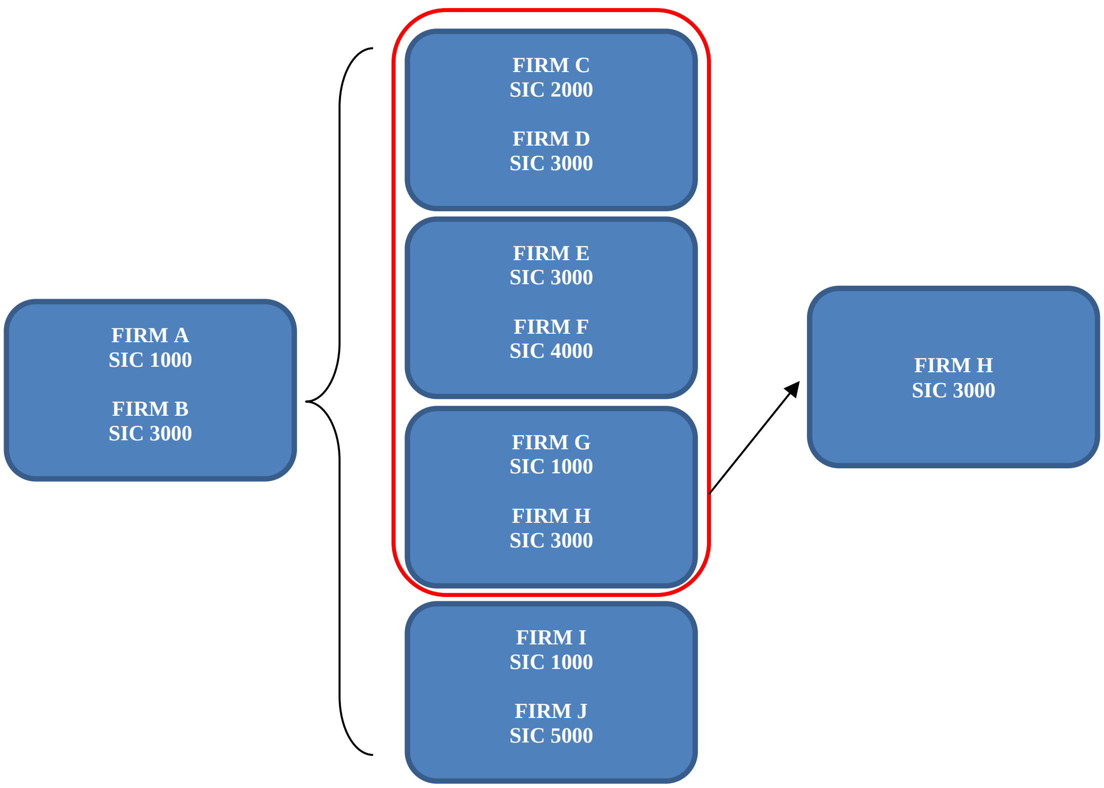
*Sources are described in the text: USPTO = United States Patent and Trademark Office database of United States patents; SDC = The Securities Data Corporation's Strategic Alliance and Joint Venture Database or Mergers/Acquisition Database; BEA = the United States Bureau of Economic Analysis' Input-Output Industry tables; Compustat = Standard and Poors' Compustat database of financial and operating data. CRSP = The Center for Research in Securities Prices.

Appendix B

Description of matched sample creation

Below is a graphical representation of the creation of the Secondary Pooled Sample using a simple framework. The original firm pair found in the SDC sample is Firm A and B. Firm A is in industry 1000 while firm B is in industry 3000. To identify a counterfactual firm to Firm B, I identify any firm-pair where a firm is in the same industry as Firm B. In the example below, three firms are identified, Firm D, Firm E and Firm H. Of the three firms, I identify whether to partnering firm is in the same industry as Firm A. Only one firm-pair matches this criterion. Firm H is in the same industry as Firm B and Firm G is in the same industry as Firm A. Thus Firm H is selected as the counterfactual to Firm B. The firm-pair of Firm A and Firm H would enter into the sample an identified as forming no alliance.

ORIGINAL FIRM-PAIR	MATCH BY FIRM B SIC	MATCHED FIRM



Appendix C

Knowledge Asset Inaccessibility Measure Example Calculations

Below is an example of the calculations to measure patent inaccessibility via patent self-citations. Panel A lists the patent numbers, year of patent application and the firm creating the patent. In addition, Panel A lists the citations attached to the patent including the year the cited patent was applied for and the owner of the patent. Panel B uses the information provided in Panel A to create the *RESTRICT1* calculation for Firm A as of the year 2001. Panel C uses the information provided in Panel A to create the *RESTRICT2* calculation for Firm A as of the year 2001.

Panel A: List of Patents Used in Example

Patent #	Application Year	Patent Owner	Patent # Cited	Application Year of Cited	Owner of Cited Patent
1000	2000	Firm A	900	1998	Firm A
			700	1992	Firm A
			850	1997	Firm B
900	1998	Firm A	700	1992	Firm A
			850	1997	Firm B
			450	1990	Firm B
950	1999	Firm B	700	1992	Firm A
850	1997	Firm B	700	1992	Firm A
700	1992	Firm A	N/A		
450	1990	Firm B	N/A		

Panel B: Calculation of Percentage Self-Citations for *RESTRICT1* for year 2001

Firm A's Patents	Application Year	Patent # Cited	Owner of Cited Patent	Self-Citation
1000	2000	900	Firm A	Yes
		700	Firm A	Yes
		850	Firm B	No
900	1998	700	Firm A	Yes
		850	Firm B	No
		450	Firm B	No
			% Self-Citations	**=3/6 or .5**

Panel C: Calculation of Percentage Self-Citations for *RESTRICT2* for year 2001

Patent Citing Firm A	Application Year of Patent	Firm Citing	Patent # Cited		Self-Citation
1000	2000	Firm A	900		Yes
1000	2000	Firm A	700		Yes
900	1998	Firm A	700		Yes
950	1999	Firm B	700		No
850	1997	Firm B	700		No
				% Self-Citations	**=3/5 or .6**

Table I

Descriptive Statistics of Patents granted by the USPTO from 1976 to 2006

The table presents frequency data and descriptive statistics of patent data from the NBER database of United States patents from 1976 to 2006 that have been both applied for and subsequently granted by the United States Patent and Trademark Office (USPTO). Panel A presents frequency data of patent usage. # of firms Applied for patents presents the number of firms in a given year who have applied for a patent by the USPTO who would subsequently be granted. # Patents Applied presents the total number of patents applied for to the USPTO in a given year that would subsequently be granted. # Patents Granted presents the number of patents granted by the USPTO during a given year. # of Patent Citations of Applied presents the total number of citations included on all patents applied for and subsequently granted in a given year. % Self-Citations represents the percentage of all citations in a given year that were cited by their own firm for all patents applied for. Cumulative % Self-Citations represents the percentage of all citations from 1976 to the given year, that were cited by their own firm. Panel B presents data on the usage and workings of United States patents. Patents Held by Firm presents firm-year univariate statistics on the number of patents owned by a firm for a given year where the firm holds at least one patent. Review presents the length of time between application date and date granted of United States patents. Citations per Patent presents the number of citations attached to a patent. YTC presents the minimum time to first citation of a patent. Panel C presents a citation level analysis of how quickly patents are cited by other firms.

Panel A: Patent Frequency and Usage by Year

Year	# Firms Applied for Patent	# Patents Applied	# Patents Granted	# of Patent Citations of Applied	% Self-Citations	Cumulative % Self-Citations
1976	1,470	65,813	1,062	34,066	11.30%	11.30%
1977	1,372	65,998	28,499	61,589	10.69%	10.91%
1978	1,389	65,610	59,033	89,934	9.51%	10.23%
1979	1,318	65,728	47,393	115,073	9.70%	10.03%
1980	1,367	66,505	60,759	140,272	9.28%	9.79%
1981	1,364	63,936	65,390	159,744	8.90%	9.55%
1982	1,371	65,038	57,640	182,495	8.72%	9.36%
1983	1,437	61,585	56,743	192,290	7.74%	9.04%
1984	1,490	67,096	67,147	227,226	7.74%	8.79%
1985	1,599	71,484	71,629	262,375	7.52%	8.57%
1986	1,692	75,122	70,837	305,429	6.89%	8.28%
1987	1,784	81,520	82,917	361,001	6.77%	8.02%
1988	1,805	90,218	77,919	429,247	6.89%	7.83%
1989	1,717	96,188	95,574	482,914	6.92%	7.69%
1990	1,748	99,412	90,355	535,928	6.87%	7.56%
1991	1,843	100,298	96,496	583,216	6.79%	7.46%
1992	1,915	103,949	97,458	671,681	6.63%	7.34%
1993	2,074	108,342	98,357	777,087	6.55%	7.23%
1994	2,242	123,325	101,671	949,798	6.73%	7.16%
1995	2,577	144,523	101,411	1,291,533	6.66%	7.08%
1996	2,597	144,792	109,633	1,291,991	6.59%	7.01%
1997	2,794	169,360	112,009	1,647,305	6.49%	6.93%
1998	2,963	167,826	147,571	1,689,253	6.49%	6.87%
1999	3,059	178,560	153,581	1,926,657	6.35%	6.80%
2000	2,989	189,530	157,580	2,217,668	6.31%	6.73%
2001	2,838	191,722	166,053	2,305,183	6.27%	6.68%
2002	2,501	169,599	167,411	2,130,570	6.48%	6.66%
2003	1,960	119,770	169,114	1,519,454	6.57%	6.65%
2004	1,339	62,396	164,401	799,178	6.98%	6.66%
2005	698	17,177	143,924	224,103	7.10%	6.67%
2006	127	1,039	173,921	13,630	5.02%	6.67%
Total	57,439	3,093,461	3,093,461	23,617,890	6.67%	6.67%

Table I – Continued

Panel B: Descriptive Statistics of NBER USPTO Patent database from 1976 – 2006

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Patents Held by Firm	96,132	191.84	10.000	1,227.08	1.000	46,037
Review	3,093,461	2.137	2.000	1.138	0.000	28.00
Citations per Patent	3,093,461	7.635	4.000	14.147	0.000	785.00
YTC	2,407,511	2.994	2.000	3.209	-89.00	29.00

Panel C: Frequency of Years to Citation of all citations of NBER USPTO Patent data, 1976 – 2006

Years to citation of patent citation	Frequency	% of Total
<0 yrs.	57,832	0.25%
0	340,495	1.46%
1	1,199,485	5.15%
2	1,982,240	8.52%
3	2,282,014	9.81%
4	2,258,721	9.71%
5	2,063,062	8.87%
6	1,814,588	7.80%
7	1,566,470	6.73%
8	1,342,734	5.77%
9	1,151,127	4.95%
10	989,899	4.25%
>10 yrs.	5,537,341	23.79%
Un-cited	685,950	2.95%
Total	23,271,958	100.00%

Table II

Frequency Data of Firm Boundary Choice

The table presents the frequency of boundary changes by alliance type by year from 1986 to 2005 as found in SDC's Strategic Alliance and Joint Venture database. Panel A examines broad boundary definitions while Panel B breaks down the frequency of strategic alliances only. Observations are defined at the firm-pair level with each observation being a single deal.

Panel A: Frequency of boundary changes by year – broad boundary definition

Year	Boundary Changes	Strategic Alliances	Joint Ventures	% of Total
1986	13	2	11	0.42%
1987	14	7	7	0.45%
1988	23	6	17	0.74%
1989	35	21	14	1.12%
1990	117	81	36	3.75%
1991	230	172	58	7.37%
1992	258	232	26	8.27%
1993	237	203	34	7.60%
1994	272	226	46	8.72%
1995	295	234	61	9.46%
1996	229	188	41	7.34%
1997	335	261	74	10.74%
1998	243	204	39	7.79%
1999	284	253	31	9.11%
2000	167	133	34	5.35%
2001	94	86	8	3.01%
2002	58	52	6	1.86%
2003	73	68	5	2.34%
2004	63	56	7	2.02%
2005	79	78	1	2.53%
Total	3,119	2,563	556	100.00%

Panel B: Frequency of Strategic Alliances, 1986 – 2005

Year	Strategic Alliances	Licensing Agreements	Marketing Agreements	Tech., R&D or Manufact.	Un-identified	% of Total
1986	2	0	0	2	0	0.08%
1987	7	0	0	6	1	0.27%
1988	6	0	1	4	1	0.23%
1989	21	0	0	16	5	0.82%
1990	81	2	20	41	18	3.16%
1991	172	0	51	90	31	6.71%
1992	232	0	74	128	30	9.05%
1993	203	1	54	129	19	7.92%
1994	226	0	48	164	14	8.82%
1995	234	0	35	173	26	9.13%
1996	188	0	26	123	39	7.34%
1997	261	3	30	152	76	10.18%
1998	204	7	31	59	107	7.96%
1999	253	4	33	69	147	9.87%
2000	133	2	23	18	90	5.19%
2001	86	0	16	18	52	3.36%
2002	52	0	11	11	30	2.03%
2003	68	1	13	19	35	2.65%
2004	56	1	11	12	32	2.18%
2005	78	1	10	35	32	3.04%
Total	2,563	22	487	1,269	785	100.00%

Table III

Distribution of Firm-Level Boundary Choice and Patent Use by Two-Digit SIC over Sample Period

This table provides the distribution of boundary choice and Patent Use by the two-digit SIC code over the 1986 to 2005 sample period. Boundary choice is determined if a pair of partnering firms decide to enter into either a strategic alliance or joint venture. For each boundary decision, two SIC codes are used, one from each participating firm. *Patents* is the number of patents granted by the United States Patents and Trademark Office to sample firms through 2006. % Using Patents is the percentage of unique sample firms granted at least one patent through 2006.

Panel A: Distribution of boundary choices by industry sorted by Patent usage (Industries with ten or more unique firms in sample)

Two Digit SIC	Industry Description	Sample Firm Years	Unique Firms	Strategic Alliances	Joint Ventures	Patents	% Using Patents
38	Instruments & Related Products	350	142	310	40	127,004	92.25%
37	Transportation Equipment	166	45	107	59	61,152	91.11%
36	Electronic & Other Electric Equipment	693	193	601	92	221,816	90.16%
35	Industry Machinery & Equipment	893	162	829	64	107,236	90.12%
26	Paper & Allied Products	32	20	13	19	9,772	90.00%
30	Rubber & Miscellaneous Plastics Products	15	10	11	4	5,336	90.00%
31	Leather & Leather Products	11	10	10	1	1,652	90.00%
28	Chemical & Allied Products	759	250	628	131	129,008	88.00%
20	Food and Kindred Products	56	22	34	22	5,385	86.36%
23	Apparel and Other Finished Products	33	18	32	1	190	83.33%
33	Primary Metal Industries	17	11	10	7	3,397	81.82%
34	Fabricated Metal Products	17	10	10	7	2,857	80.00%
39	Misc. Manufacturing Industries	35	14	27	8	6,212	78.57%
87	Engineering & Management Services	125	68	100	25	2,296	70.59%
73	Business Services	1,734	406	1,618	116	88,973	64.29%
59	Miscellaneous Retail	30	16	27	3	86	56.25%
13	Oil & Gas Extraction	125	50	41	84	2,399	50.00%
27	Printing & Publishing	78	24	52	26	330	45.83%
51	Wholesale Trade – Nondurable Goods	24	18	19	5	229	42.86%
10	Metal Mining	28	14	3	25	153	40.00%
49	Electric, Gas, & Sanitary Services	152	67	60	92	8,557	38.81%
78	Motion Pictures	60	19	37	23	321	36.84%
79	Amusement & Recreation Services	42	15	25	17	171	33.33%
80	Health Services	44	27	33	11	148	33.33%
48	Communications	322	87	229	93	27,027	32.18%
50	Wholesale Trade – Durable Goods	91	45	84	7	38,322	31.11%
58	Eating & Drinking Places	24	14	10	14	125	28.57%
70	Hotels & Other Lodging Places	19	14	9	10	3,788	28.57%

57	Furniture & Home Furnishings Stores	20	10	17	3	83	20.00%
45	Transportation by Air	32	10	28	4	9	20.00%

Panel B: Distribution of boundary choices by industry sorted by Two-digit SIC code (Industries with less than ten unique firms in sample)

Two Digit SIC	Industry Description	Sample Firm Years	Unique Firms	Strategic Alliances	Joint Ventures	Patents	% Using Patents
01	Agriculture Production – Crops	7	3	4	3	139	100.00%
07	Agricultural Services	2	1	1	1	217	100.00%
12	Coal Mining	6	5	2	4	5	40.00%
15	Building Construction	10	8	2	8	71	37.50%
16	Heavy Construction, Except Building	8	2	4	4	3	50.00%
17	Special Trade Contractors	5	4	2	3	23	50.00%
22	Textile Mills Products	5	5	3	2	257	100.00%
24	Lumber & Wood Products, Except Furniture	8	5	4	4	711	80.00%
25	Furniture and Fixtures	2	2	1	1	385	50.00%
29	Petroleum & Coal Products	44	8	12	32	3,134	100.00%
32	Stone, Clay, & Glass Products	19	3	13	6	8,732	100.00%
40	Railroad Transportation	12	5	7	5	46	40.00%
42	Trucking & Warehousing	11	4	10	1	184	25.00%
43	U.S. Postal Service	1	1	1	0	40	100.00%
44	Water Transportation	3	3	0	3	24	33.33%
46	Pipelines, Except Natural Gas	2	1	0	2	3,729	100.00%
47	Transportation Services	9	7	6	3	42	28.57%
52	Building Materials & Gardening Supplies	4	3	4	0	1	33.33%
53	General Merchandise Stores	15	6	11	4	106	50.00%
54	Food Stores	12	7	8	4	31	57.14%
55	Automotive Dealers & Service Stations	2	1	2	0	0	0.00%
56	Apparel & Accessory Stores	5	4	4	1	1	25.00%
72	Personal Services	2	2	0	2	0	0.00%
75	Auto Repair, Services, & Parking	10	4	7	3	201	50.00%
76	Miscellaneous Repair Services	1	1	1	0	10	100.00%
81	Legal Services	1	1	1	0	0	0.00%
82	Educational Services	3	2	1	2	2	100.00%
83	Social Services	1	1	1	0	2	100.00%
89	Services, Other	1	1	0	1	0	0.00%
Total (Panel A & B)		6,238	1,908	5,126	1,112	872,810	69.48%

Table IV

Descriptive Statistics of Firm-Level Data

Table IV presents descriptive statistics of COMPUSTAT, SDC/Compustat merged, and matched firms to the SDC/Compustat datasets from years 1986 through 2005. All data are at the firm level. Panel A presents descriptive statistics from COMPUSTAT firms regardless if they enter the sample. Panel B presents descriptive statistics of firms matched to SDC's strategic alliance or joint venture firms based on conditional matching done by Industry, Year, and Size (Assets, $mil). Panel C presents descriptive statistics of sample firms who enter into either a strategic alliance or joint venture during a given year. Panel D and E further breakdown these firms into those firms entering into a strategic alliance and those firms entering into a joint venture. Firms with an SIC in the 6000's are excluded from all panels. Results shown are winsorized at the 2% level.

Panel A: Descriptive Statistics of COMPUSTAT firms

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	44,424	0.067	0.024	0.104	0.000	1.000
RESTRICT2	50,008	0.073	0.016	0.124	0.000	1.000
YTC	51,667	2.371	2.196	1.654	0.000	26.000
Patent	167,197	0.393	0.000	0.488	0.000	1.000
Size	167,197	1,020.41	77.069	2,829.12	0.291	15,779.00
R&D	167,197	0.051	0.000	0.114	0.000	0.566
Q	138,860	2.429	1.439	2.916	0.600	16.933
ROA	164,917	-0.031	0.095	0.418	-2.028	0.355
Segments	167,197	1.274	1.000	0.756	1.000	10.000

Panel B: Descriptive Statistics of COMPUSTAT Matched Firms

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	3,428	0.072	0.041	0.096	0.000	1.000
RESTRICT2	3,583	0.079	0.049	0.104	0.000	1.000
YTC	3,554	2.020	1.778	1.330	0.000	15.000
Patent	6,256	0.678	1.000	0.467	0.000	1.000
Size	6,256	3,406.01	1,005.62	4,918.92	0.291	15,779.00
R&D	6,256	0.071	0.036	0.095	0.000	0.566
Q	5,530	2.532	1.702	2.469	0.600	16.933
ROA	6,125	0.101	0.126	0.207	-2.028	0.355
Segments	6,256	1.159	1.000	0.614	1.000	7.000

Panel C: Descriptive Statistics of firms entering into a strategic alliance or joint venture

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	4,718	0.092	0.061	0.096	0.000	1.000
RESTRICT2	4,852	0.097	0.071	0.103	0.000	1.000
YTC	4,869	2.010	1.980	1.150	0.000	10.000
Patent	6,238	0.846	1.000	0.361	0.000	1.000
Size	6,238	5,366.72	1,752.17	6,326.18	0.291	15,779.00
R&D	6,238	0.091	0.067	0.104	0.000	0.566
Q	6,129	3.103	1.947	3.050	0.600	16.933
ROA	6,202	0.093	0.134	0.222	-2.028	0.355
Segments	6,238	1.302	1.000	0.913	1.000	10.000

Table IV – Continued

Panel D: Descriptive Statistics of firms entering into a strategic alliance

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	4,044	0.088	0.057	0.094	0.000	1.000
RESTERIC2	4,148	0.096	0.067	0.103	0.000	1.000
YTC	4,170	1.896	1.795	1.108	0.000	10.000
Patent	5,126	0.869	1.000	0.337	0.000	1.000
Size	5,126	5,060.93	1,414.49	6,229.98	0.291	15,779.00
R&D	5,126	0.103	0.083	0.106	0.000	0.566
Q	5,040	3.302	2.112	3.175	0.600	16.933
ROA	5,097	0.089	0.136	0.232	-2.028	0.355
Segments	5,126	1.224	1.000	0.782	1.000	9.000

Panel E: Descriptive Statistics of firms entering into a joint venture

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	674	0.116	0.088	0.106	0.000	0.512
RESTRICT2	320	0.100	0.076	0.102	0.000	0.589
YTC	532	2.756	2.909	1.167	0.000	8.000
Patent	1,112	0.737	1.000	0.440	0.000	1.000
Size	1,112	6,776.34	4,115.05	6,573.33	0.516	15,779.00
R&D	1,112	0.039	0.006	0.071	0.000	0.566
Q	1,089	2.181	1.508	2.155	0.600	16.933
ROA	1,105	0.109	0.126	0.170	-2.028	0.355
Segments	1,112	1.663	1.000	1.303	1.000	10.000

Table V

Correlation Matrix of Main Variables

Table V presents univariate Pearson pair-wise correlation coefficients of the NBER/Compustat/SDC merged sample between 1986 and 2005. All observations are at the firm level. Variable descriptions can be found in Appendix A. Due to RESTRICT1, RESTRICT2, and YTC requiring patents to create the respective variables, correlations between these variables and Patent Usage are not applicable. Variables are winsorized at the 2% level.

Variable	Structure	RESTRICT1	RESTRICT2	YTC	Patent	Size	R&D	Q	ROA
Structure									
RESTRICT1	0.091								
RESTRICT2	0.064	0.739							
YTC	0.069	0.428	0.145						
Patent	0.090	N/A	N/A	N/A					
Size	0.125	0.418	0.287	0.259	0.198				
R&D	-0.003	-0.132	0.002	-0.327	0.229	-0.247			
Q	0.007	-0.134	-0.060	-0.335	0.111	-0.124	0.251		
ROA	0.002	0.022	-0.024	0.076	0.117	0.213	-0.423	-0.061	

Table VI

Univariate Subset Analysis of Main Variables at Firm Level

Table VI presents descriptive statistics of the main firm-level variables of the paper broken down into various sub-samples. The sample is composed of COMPUSTAT/SDC merged samples of strategic alliances and joint ventures from 1986 through 2005 as well as conditionally matched firms. Panel A presents descriptive statistics of sample firms that engaged in either a strategic alliance or joint venture and was granted a patent by the United States Patent and Trademark Office (USPTO) at any time between 1976 and 2006. Panel B presents descriptive statistics of firms that engaged in either a strategic alliance or joint venture and was never granted a patent between 1976 and 2006. Panel C presents descriptive statistics of conditionally matched firms from COMPUSTAT, matched by Year, Industry and Size (assets, $mil) that were granted a patent by the USPTO from 1976 and 2006. Panel D presents conditionally matched firms that were not granted a patent between 1976 and 2006. Variable definitions can be references in Appendix A. Variables are winsorized at 2%.

Panel A: Firms with boundary change and use patents

Variable	Obs	Mean	Med.	Std. Dev.	Min	Max
RESTRICT1	4,718	0.092	0.061	0.096	0.000	1.000
RESTRICT2	4,852	0.097	0.071	0.103	0.000	1.000
YTC	4,869	2.010	1.981	1.150	0.000	10.000
Size	5,276	5,815.00	2,206.62	6,465.89	0.291	15,779.00
R&D	5,276	0.101	0.080	0.103	0.000	0.566
Q	5,198	3.222	2.057	3.090	0.600	16.933
ROA	5,245	0.102	0.144	0.214	-2.028	0.355
Segments	5,276	1.320	1.000	0.948	1.000	10.000

Panel B: Firms with boundary change and do not use patents

Variable	Obs	Mean	Med.	Std. Dev.	Min	Max
RESTRICT1						
RESTRICT2						
YTC						
Size	962	2,908.16	465.65	4,806.09	0.291	15,779.00
R&D	962	0.038	0.000	0.093	0.000	0.566
Q	931	2.440	1.545	2.719	0.600	16.933
ROA	957	0.040	0.106	0.258	-2.028	0.355
Segments	962	1.206	1.000	0.676	1.000	6.000

Panel C: Firms without boundary change and use patents

Variable	Obs	Mean	Med.	Std. Dev.	Min	Max
RESTRICT1	3,428	0.072	0.041	0.096	0.000	1.000
RESTRICT2	3,583	0.079	0.049	0.104	0.000	1.000
YTC	3,554	2.020	1.778	1.330	0.000	15.000
Size	4,242	4,063.21	1,454.85	5,268.13	0.424	15,779.00
R&D	4,242	0.087	0.059	0.093	0.000	0.566
Q	3,904	2.707	1.858	2.608	0.600	16.933
ROA	4,236	0.117	0.140	0.198	-2.028	0.355
Segments	4,242	1.182	1.000	0.656	1.000	7.000

Panel D: Firms without boundary change and do not use patents

Variable	Obs	Mean	Med.	Std. Dev.	Min	Max
RESTRICT1						
RESTRICT2						
YTC						
Size	2,014	2,021.78	436.20	3,726.36	0.291	15,779.00
R&D	2,014	0.038	0.000	0.090	0.000	0.566
Q	1,626	2.111	1.433	2.041	0.600	16.933
ROA	1,889	0.063	0.104	0.222	-2.028	0.355
Segments	2,014	1.111	1.000	0.510	1.000	7.000

Table VII

Univariate Analysis of Differences in Main Variables at Firm Level

This table reports the differences in univariate statistics among different data sub-samples. The sample is composed of COMPUSTAT/SDC merged observations of strategic alliances and joint ventures, along with matching COMPUSTAT firms, from 1986 through 2005. The sub-samples are determined by 'Patent Usage' for which a firm is designated 'Yes' if the firm has been granted a patent by the United States Patent and Trademark Office (USPTO) at any time from 1976 and 2006 and 'No' otherwise. Sub-samples are also determined by if the firm engaged in a boundary change as indicated by entering the SDC strategic alliance and joint venture dataset. 'Yes' indicated firms who have entered into either a strategic alliance or joint ventures and 'No' indicates matched COMPUSTAT firms not entering into a strategic alliance or joint venture. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2%. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Variable	Patent Usage=Yes vs. No Boundary Change=Yes	Patent Usage=Yes vs. No Boundary Change=No	Patent Usage=Yes Boundary Change=Yes vs. No	Patent Usage=No Boundary Change=Yes vs. No	Boundary Change=Yes vs. No	Patent Usage=Yes vs. No
RESTRICT1			0.020***		0.020***	
			(9.28)		(9.28)	
RESTRICT2			0.018***		0.018***	
			(7.89)		(7.89)	
YTC			-0.010		-0.010	
			(0.36)		(0.36)	
Size	2,906.84***	2,041.43***	1,751.79***	886.38***	1,960.71***	2,725.96***
	(16.27)	(17.61)	(14.56)	(5.04)	(19.34)	(27.92)
R&D	0.063***	0.049***	0.014***	0.000	0.020***	0.057***
	(18.99)	(19.90)	(6.96)	(0.00)	(11.22)	(29.19)
Q	0.782***	0.596***	0.515***	0.329***	0.571***	0.770***
	(7.91)	(9.08)	(8.61)	(3.21)	(11.16)	(14.00)
ROA	-0.004	0.054***	-0.015***	0.043***	-0.008**	0.053***
	(0.45)	(9.08)	(3.54)	(4.40)	(2.07)	(10.84)
Segments	0.114***	0.071***	0.138***	0.095***	0.143***	0.116***
	(4.49)	(4.68)	(8.37)	(3.86)	(10.27)	(8.59)

Table VIII

The Propensity to Form Strategic Alliances/Joint Ventures

This table reports the probability of entering into either a strategic alliance or joint venture in a multivariate framework. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures, with matching observations from COMPUSTAT, from 1986 through 2005. Columns (A) through (C) are binary probit models with the dependent variable defined as the choice to enter a strategic alliance or joint venture (dependent variable set to '1') or not (dependent variable set to '0'). Columns (D) through (F) model the choice to enter a strategic alliance or joint venture using a linear probability model with fixed effects. Industry fixed effects are at the 2-digit SIC level. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2%. Standard errors are clustered at the 2-digit SIC code. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	Boundary	*Boundary*	*Boundary*	*Boundary*	*Boundary*	*Boundary*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
RESTRICT1	1.226***			0.534***		
	(7.70)			(8.54)		
RESTRICT2		0.830***			0.383***	
		(5.86)			(6.82)	
YTC			0.033***			0.008*
			(2.61)			(1.93)
Log(Size)	0.040***	0.041***	0.045***	0.015***	0.016***	0.019***
	(4.56)	(4.88)	(5.45)	(4.42)	(4.85)	(5.84)
R&D	1.171***	1.141***	1.237***	0.419***	0.429***	0.443***
	(6.33)	(6.30)	(6.69)	(5.89)	(6.10)	(6.22)
Q	0.051***	0.048***	0.052***	0.016***	0.016***	0.018***
	(9.35)	(8.95)	(9.43)	(7.56)	(7.47)	(8.29)
ROA	-0.373***	-0.322***	-0.326***	-0.146***	-0.122***	-0.136***
	(3.95)	(3.53)	(3.58)	(3.99)	(3.43)	(3.82)
Log(Segments)	0.270***	0.274***	0.266***	0.080***	0.081***	0.076***
	(6.67)	(6.94)	(6.67)	(5.12)	(5.29)	(4.95)
Intercept	-0.430***	-0.407***	-0.436***	0.665***	0.712***	0.466***
	(6.06)	(5.98)	(5.91)	(3.61)	(3.85)	(9.33)
Industry F.E.	No	No	No	Yes	Yes	Yes
Year F.E.	No	No	No	Yes	Yes	Yes
Pseudo R^2 / R^2	0.023	0.023	0.020	0.043	0.038	0.033
Obs	7,902	8,168	8,157	7,902	8,168	8,157

Table IX

The Propensity to Form Strategic Alliances and Joint Ventures

This table reports the probability of entering into strategic alliances or joint ventures in a multivariate framework. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures, with matching observations from COMPUSTAT, from 1986 through 2005. All models employ a binary probit regression. Columns (A) through (C) use the sub-sample of firms that choice to enter a strategic alliance and their subsequent COMPUSTAT matched firms. Columns (D) through (F) use the sub-sample of joint ventures and their subsequent COMPUSTAT matched firms. The dependent variable is set to '0' if the firm did not enter a strategic alliance or joint venture and '1' if they did. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2%. Standard errors are clustered at the 2-digit SIC code. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	Boundary	*Boundary*	*Boundary*	*Boundary*	*Boundary*	*Boundary*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
RESTRICT1	1.256***			1.236***		
	(7.04)			(3.57)		
RESTRICT2		0.748***			1.129***	
		(4.91)			(3.24)	
YTC			0.020*			0.096***
			(1.87)			(3.13)
Log(Size)	0.033***	0.035***	0.037***	0.107***	0.107***	0.111***
	(3.52)	(3.94)	(4.22)	(4.51)	(4.68)	(5.02)
R&D	1.252***	1.204***	1.242***	0.558	0.603	1.002*
	(6.38)	(6.28)	(6.40)	(0.94)	(1.02)	(1.69)
Q	0.050***	0.048***	0.051***	0.033*	0.028	0.042**
	(8.98)	(8.60)	(8.91)	(1.76)	(1.52)	(2.22)
ROA	-0.319***	-0.298***	-0.293***	-0.972***	-0.682**	-0.669**
	(3.20)	(3.11)	(3.05)	(3.37)	(2.39)	(2.38)
Log(Segments)	0.303***	0.303***	0.299***	0.234***	0.241***	0.224***
	(6.03)	(6.20)	(6.02)	(3.30)	(3.49)	(3.22)
Intercept	-0.406***	-0.378***	-0.374***	-0.871***	-0.894***	-1.118***
	(5.36)	(5.23)	(4.94)	(4.50)	(4.73)	(5.51)
Industry F.E.	No	No	No	No	No	No
Year F.E.	No	No	No	No	No	No
Pseudo R^2	0.027	0.026	0.020	0.041	0.035	0.034
Obs	6,814	7,019	7,021	1,187	1,250	1,242

Table X

Ordered Analysis on the Formation of Strategic Alliances/Joint Ventures

This table reports the probability of entering into strategic alliances or joint ventures in a multivariate framework. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures, with matching observations from COMPUSTAT, from 1986 through 2005. All models employ a probit regression. Columns (A) through (C) utilize a binary probit regression; setting the dependent variable to '1' for if a firm and enters into a joint venture and '0' for a strategic alliance. Columns (D) through (F) utilize an ordered probit regression; setting the dependent variable to '0' for no alliance, '1' for strategic alliance and '2' for joint venture. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2%. Standard errors are clustered at the 2-digit SIC code. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	JVSA	*JVSA*	*JVSA*	*Structure*	*Structure*	*Structure*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
RESTRICT1	0.769***			1.242***		
	(2.99)			(8.83)		
RESTRICT2		0.780***			0.768***	
		(4.00)			(6.09)	
YTC			0.217***			0.088***
			(9.70)			(7.68)
Log(Size)	0.047***	0.054***	0.049***	0.051***	0.055***	0.056***
	(3.10)	(3.81)	(3.57)	(6.38)	(7.24)	(7.58)
R&D	-4.062***	-4.381***	-3.168***	0.038	0.037	0.338**
	(11.20)	(11.72)	(8.69)	(0.024)	(0.23)	(2.08)
Q	-0.031***	-0.032***	-0.006	0.027***	0.025***	0.035***
	(3.25)	(3.38)	(0.60)	(5.99)	(5.50)	(7.41)
ROA	-0.824***	-0.711***	-0.717***	-0.461***	-0.412***	-0.381***
	(4.88)	(4.11)	(4.37)	(5.70)	(5.26)	(4.87)
Intercept	-0.970***	-1.037***	-1.560***	0.284***	0.284***	0.451***
	(7.92)	(8.76)	(12.08)	(4.42)	(4.62)	(6.73)
Intercept 2				1.913***	1.892***	2.075***
				(17.78)	(29.34)	(29.73)
Industry F.E.	No	No	No	No	No	No
Year F.E.	No	No	No	No	No	No
Pseudo R^2	0.079	0.082	0.100	0.014	0.010	0.011
Obs	4,647	4,769	4,800	7,902	8,168	8,157

Table XI

Selection Model for the Determinants of Forming Strategic Alliance verses Joint Venture

This table reports the probability of entering into either a strategic alliance or joint venture in a multivariate framework once the decision has been made to form an alliance. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures, with matching observations from COMPUSTAT, from 1986 through 2005. The first stage selections predicting the probability of forming an alliance are from Columns (A) through (C) of Table VIII. All models in this table use a linear probability model as the second stage. Columns (D) through (F) use fixed-effects while Columns (A) through (C) do not. Industry fixed effects are at the 2-digit SIC level. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2% and standard errors are clustered at the 2-digit SIC industry code. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	JVSA	*JVSA*	*JVSA*	*JVSA*	*JVSA*	*JVSA*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
RESTRICT1	0.118**			0.104*		
	(2.02)			(1.77)		
RESTRICT2		0.121***			0.108***	
		(2.85)			(2.60)	
YTC			0.052***			0.033***
			(10.77)			(6.47)
Log(Size)	0.009***	0.011***	0.008***	0.008***	0.012***	0.008***
	(2.79)	(3.58)	(2.76)	(2.61)	(4.12)	(2.80)
R&D	-0.724***	-0.738***	-0.552***	-0.737***	-0.772***	-0.499***
	(11.54)	(11.82)	(8.82)	(11.69)	(12.50)	(7.94)
Q	-0.008***	-0.009***	-0.003	-0.009***	-0.007***	-0.001
	(4.87)	(5.02)	(1.60)	(5.15)	(4.12)	(0.65)
ROA	-0.167***	-0.156***	-0.130***	-0.163***	-0.196***	-0.108***
	(5.41)	(5.15)	(4.37)	(5.27)	(6.38)	(3.58)
Inverse Mills	-0.212***	-0.205***	-0.186***	-0.267***	-0.275***	-0.142**
	(4.42)	(4.33)	(3.67)	(5.95)	(6.28)	(2.25)
Intercept	0.236***	0.217***	0.101***	0.256***	0.069*	0.026
	(7.70)	(7.38)	(3.21)	(8.44)	(1.67)	(0.52)
Industry F.E.	No	No	No	Yes	Yes	Yes
Year F.E.	No	No	No	Yes	Yes	Yes
Obs	4,647	4,769	4,800	4,647	4,769	4,800

Table XII

Robustness Checks on the Propensity to enter Strategic Alliances/Joint Ventures

This table reports the probability of entering into strategic alliances or joint ventures. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures, with matching observations from COMPUSTAT, from 1986 through 2005. Model A and B employ a multinomial logistic model with firms not entering into an alliance as the base case. Sub-model 1 (A1 and B1) analyze the choice of forming a strategic alliance against the base case while sub-model 2 (A2 and B2) analyze the choice of forming a joint venture. Columns (C) and (D) employ a linear probability model; with the dependent variable set to '0' for no alliance, '1' for strategic alliance and '2' for joint venture. Columns (E) and (F) also employ a linear probability model with the sample restricted to firms in the 1-digit SIC code in the 2000 or 3000. Industry fixed effects are at the 2-digit SIC level. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2%. Standard errors are clustered at the 2-digit SIC. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	Structure	*Structure*	*Structure*	*Structure*	*Structure*	*Structure*	*Structure*	*Structure*
Variable	(A1)	(A2)	(B1)	(B2)	(C)	(D)	(E)	(F)
RESTRICT1	2.072***	3.137***			0.640***		0.495***	
	(7.36)	(7.38)			(8.13)		(5.20)	
YTC			0.037**	0.205***		0.030***		0.057***
			(2.03)	(8.27)		(4.64)		(6.82)
Log(Size)	0.051***	0.180***	0.061***	0.188***	0.030***	0.033***	0.032***	0.029***
	(3.47)	(6.37)	(4.47)	(7.04)	(6.80)	(8.11)	(5.90)	(5.77)
R&D	2.418***	-6.332***	2.423***	-4.727***	0.056	0.198**	0.416***	0.698***
	(7.80)	(8.09)	(7.83)	(6.13)	(0.63)	(2.20)	(3.46)	(5.67)
Q	0.088***	0.026	0.087***	0.050**	0.015***	0.019***	0.015***	0.020***
	(9.37)	(1.29)	(9.13)	(2.50)	(5.55)	(6.89)	(3.48)	(4.63)
ROA	-0.465***	-2.022***	-0.421***	-1.548***	-0.269***	-0.227***	-0.158***	-0.051
	(2.80)	(5.81)	(2.62)	(4.61)	(5.86)	(5.08)	(2.64)	(0.87)
Intercept	-0.794***	-2.640***	-0.739***	-3.223***	0.828***	0.897***	0.304***	0.197***
	(6.69)	(11.18)	(6.22)	(13.64)	(3.57)	(3.85)	(7.11)	(4.37)
Industry F.E.	No		No		Yes	Yes	Yes	Yes
Year F.E.	No		No		Yes	Yes	Yes	Yes
Pseudo R^2 / R^2	0.040		0.037		0.041	0.035	0.021	0.023
Obs	7,902		8,157		7,902	8,157	5,017	5,138

Table XIII

Determinants of Boundary Selection at the Firm-Pair Level: Degree of Restriction

This table reports a series of probit models estimating the probability of firm pairs entering into either a strategic alliance or joint venture. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures from 1986 through 2005 along with COMPUSTAT firms as their matched counterparts. Columns (A) through (C) present binary probit models; taking the value of '1' for joint ventures and '0' for strategic alliances. Columns (D) through (F) present ordered probit models; taking the values of 2, 1, or 0 for joint venture, strategic alliance and no alliance respectively. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2%. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	JVSA	*JVSA*	*JVSA*	*Structure*	*Structure*	*Structure*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
AVG(RESTRICT1)	1.745***			1.326***		
	(2.77)			(4.27)		
AVG(RESTRICT2)		2.015***			0.632**	
		(4.51)			(2.35)	
AVG(YTC)			0.317***			0.116***
			(5.97)			(4.81)
VRC	-0.050	0.034	-0.020	-0.021	-0.018	-0.007
	(0.55)	(0.45)	(0.23)	(0.51)	(0.45)	(0.18)
Log(Hor)	0.018	-0.022	-0.036	-0.066**	-0.065**	-0.067**
	(0.28)	(0.33)	(0.55)	(2.20)	(2.21)	(2.28)
Log(Distance)	0.021	0.029	0.014	-0.031***	-0.033***	-0.039***
	(0.84)	(1.13)	(0.57)	(2.87)	(3.05)	(3.54)
Log[REL(Size)]	-0.077***	-0.076***	-0.103***	0.093***	0.098***	0.096***
	(3.08)	(3.05)	(4.16)	(7.04)	(7.76)	(7.59)
Log[AVG(Size)]	0.031	0.033	0.038	0.098***	0.100***	0.098***
	(0.86)	(0.95)	(1.16)	(5.96)	(6.47)	(6.53)
AVG(R&D)	-5.026***	-5.877***	-3.231***	0.391	0.366	0.816**
	(6.46)	(7.22)	(4.16)	(1.20)	(1.16)	(2.49)
AVG(Q)	-0.020	-0.031	0.009	0.018**	0.012	0.024***
	(1.04)	(1.55)	(0.46)	(2.07)	(1.45)	(2.74)
AVG(ROA)	-1.269***	-0.914**	-0.987***	-0.433***	-0.449***	-0.401**
	(3.42)	(2.41)	(2.80)	(2.64)	(2.83)	(2.54)
Intercept1	-0.933***	-1.068***	-1.686***	0.960***	0.909***	1.079***
	(2.72)	(3.13)	(4.79)	(6.316)	(6.18)	(6.87)
Intercept2				2.549***	2.484***	2.693***
				(16.34)	(16.44)	(16.62)
Pseudo R^2	0.088	0.108	0.111	0.032	0.030	0.032
Obs	1,703	1,773	1,799	3,723	3,889	3,873

Table XIV

Analysis of Boundary Sub-Categories and Strategic Alliance Choice: Firm-Level

This table reports a series of probit models estimating the probability of firm pairs entering into various alliance sub-categories. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures from 1986 through 2005. Columns (A) and (C) use an ordered probit model using the full sample of identified sub-alliance definitions, joint ventures, and their matched counterparts. The dependent variable *Structure2* takes on the values of 4, 3, 2, 1 and 0 for joint venture, R&D/Technology/Manufacturing alliance, Marketing Agreement, Licensing Agreement, and no alliance respectively. Columns (B) and (D) limit the sample to only identified strategic alliance (no matched firms) with the dependent variable taking the values of 0, 1, and 2 for the alliance types. Columns (E) and (F) model a binary probit model with a limited sample of R&D/Technology/Manufacturing alliances and joint ventures with the dependent variable set to 0 and 1 respectively. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2% and standard errors are clustered at the 2-digit SIC industry code. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	Structure2	*Structure2^*	*Structure2*	*Structure2^*	*Structure2^*	*Structure2^*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
RESTRICT1	1.507***	0.901***			0.693*	
	(10.33)	(3.05)			(1.84)	
YTC			0.118***	0.051*		0.188***
			(9.64)	(1.79)		(6.68)
Log(Size)	0.037***	-0.033**	0.046***	-0.009	0.091***	0.074***
	(4.41)	(2.19)	(5.85)	(0.64)	(5.59)	(4.60)
R&D	0.430**	1.541***	0.842***	1.756***	-5.744***	-4.733***
	(2.49)	(4.80)	(4.85)	(5.52)	(13.53)	(11.23)
Q	0.018***	-0.002	0.029***	-0.001	-0.006	0.013
	(3.48)	(0.24)	(5.39)	(0.14)	(0.56)	(1.09)
ROA	-0.252***	0.407**	-0.177**	0.330**	-1.412***	-1.286***
	(2.85)	(2.55)	(2.08)	(2.13)	(7.38)	(6.89)
Intercept					-0.733***	-1.162***
					(5.48)	(7.86)
Industry F.E.	No	No	No	No	No	No
Year F.E.	No	No	No	No	No	No
Pseudo R^2 / R^2	0.011	0.011	0.010	0.010	0.122	0.132
Obs	6,785	2,867	6,986	2,943	2,861	2,878

^Indicates the dependent variable is modified to fit the sample used such that the lowest level of the dependent variable is ‘0’.

Table XV

Analysis of Boundary Sub-Categories and Strategic Alliance Choice: Firm-Pair Level

This table reports a series of probit and linear probability models estimating the probability of firm pairs entering into various alliance sub-categories. The sample is composed of SDC/COMPUSTAT merged observations of strategic alliances and joint ventures from 1986 through 2005. Columns (A) and (C) use an ordered probit model using the full sample of identified sub-alliance definitions, joint ventures, and their matched counterparts. The dependent variable *Structure2* takes on the values of 4, 3, 2, 1 and 0 for joint venture, R&D/Technology/Manufacturing alliance, Marketing Agreement, Licensing Agreement, and no alliance respectively. Columns (B) and (D) limit the sample to only identified strategic alliance (no matched firms) with the dependent variable taking the values of 0, 1, and 2 for the alliance types. Columns (E) and (F) model a binary probit model with a limited sample of R&D/Technology/Manufacturing alliances and joint ventures with the dependent variable set to 0 and 1 respectively. Industry fixed effects are at the 2-digit SIC level. Variables definitions can be referenced in Appendix A. Variables are winsorized at 2% and standard errors are clustered at the 2-digit SIC industry code. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	Structure2	*Structure2^*	*Structure2*	*Structure2^*	*Structure2^*	*Structure2^*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
AVG(RESTRICT1)	1.952***	1.486**			1.262**	
	(5.97)	(2.14)			(2.40)	
AVG(YTC)			0.175***	0.129**		0.299***
			(6.73)	(1.98)		(4.47)
VRC	-0.021	0.123	0.001	0.088	0.011	-0.058
	(0.49)	(1.37)	(0.02)	(1.03)	(0.10)	(0.57)
Log(Hor)	-0.085***	-0.042	-0.090***	-0.037	0.028	0.010
	(2.65)	(0.65)	(2.85)	(0.60)	(0.36)	(0.13)
Log(Distance)	-0.025**	0.015	-0.033***	0.004	0.020	0.001
	(2.12)	(0.68)	(2.79)	(0.18)	(0.67)	(0.04)
Log[REL(Size)]	0.105***	-0.010	0.107	-0.012	-0.106***	-0.130***
	(7.45)	(0.39)	(7.86)	(0.50)	(3.69)	(4.61)
Log[AVG(Size)]	0.074***	-0.073**	0.081***	-0.008	0.074*	0.061*
	(4.17)	(1.97)	(5.07)	(0.24)	(1.92)	(1.66)
AVG(R&D)	1.182***	2.794***	1.792***	2.711***	-7.855***	-5.490***
	(3.40)	(3.93)	(5.08)	(3.93)	(8.46)	(6.06)
AVG(Q)	-0.004	0.000	0.008	-0.008	0.012	0.046*
	(0.36)	(0.02)	(0.75)	(0.39)	(0.47)	(1.80)
AVG(ROA)	-0.004	0.768**	-0.003	0.500	-1.766***	-1.741***
	(0.02)	(2.06)	(0.02)	(1.49)	(4.19)	(4.29)
Intercept					-0.700*	-1.180***
					(1.85)	(3.03)
Pseudo R^2 / R^2	0.029	0.022	0.030	0.017	0.147	0.149
Obs	3,323	1,115	3,442	1,175	1,080	1,095

^Indicates the dependent variable is modified to fit the sample used such that the lowest level of the dependent variable is '0'.

Table XVI

Pre/Post Announcement Date Descriptive Statistics

This table reports descriptive statistics and differences of the firm-pair level variables two years prior to two years after the boundary change. The sample is composed of COMPUSTAT/SDC merged samples of strategic alliances and joint ventures from 1986 through 2000 and includes matched observations taken from the Primary Pool and Secondary Pool of firm-pairs. Panels A and B report univariate firm-pair descriptions of the matched COMPUSTAT and SDC matched observations. Panels C and D report univariate firm-pair descriptions of strategic alliances and joint ventures respectively. Variables are constructed using winsorized firm characteristics at 2%. Variables definitions can be referenced in Appendix A.

Panel A: Descriptive Statistics of COMPUSTAT Matched Firm-Pairs +/- 2 years from Announcement Date

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Δ%Cross Patents	2,047	0.066	0.000	0.366	-1.472	10.000
ΔSize	3,585	2,330.58	952.77	3,502.17	-8,931.59	23,730.76
ΔR&D	3,585	-0.000	0.000	0.066	-0.820	0.766
ΔQ	2,831	0.658	0.212	3.147	-30.798	28.934
ΔROA	3,498	0.008	0.002	0.173	-1.364	4.367
Distance	2,868	1,908.38	1,597.44	1,439.49	0.000	7,902.07
Hor	3,585	1.362	1.000	1.583	0.000	4.000
VRC	3,585	0.350	0.000	0.477	0.000	1.000

Panel B: Descriptive Statistics of SDC Matched Firm-Pairs +/- 2 years from Announcement Date

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Δ%Cross Patents	2,354	0.101	0.000	0.946	-1.941	24.983
ΔSize	3,741	2,105.63	867.95	3,334.87	-5,801.00	22,687.26
ΔR&D	3,741	0.001	0.000	0.070	-1.116	1.001
ΔQ	3,154	0.770	0.278	3.191	-27.500	35.741
ΔROA	3,670	0.015	0.005	0.150	-0.995	1.397
Distance	3,341	1,993.86	1,750.31	1,474.57	0.000	6,084.12
Hor	3,741	1.356	1.000	1.588	0.000	4.000
VRC	3,741	0.366	0.000	0.482	0.000	1.000

Panel C: Descriptive Statistics of Strategic Alliance Firm-Pairs +/- 2 years from Announcement Date

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Δ%Cross Patents	1,337	0.122	0.000	0.460	-1.942	10.583
ΔSize	1,688	2,454.05	1,107.04	3,571.05	-9,055.00	21,408.74
ΔR&D	1,688	0.002	0.001	0.076	-1.627	0.584
ΔQ	1,449	1.122	0.468	3.758	-26.964	36.857
ΔROA	1,661	0.022	0.015	0.182	-1.038	2.239
Distance	1,566	1,876.55	1,557.06	1,525.08	0.000	4,335.52
Hor	1,688	1.376	1.000	1.609	0.000	4.000
VRC	1,688	0.352	0.000	0.477	0.000	1.000

Panel D: Descriptive Statistics of Joint Ventures +/- 2 years from Announcement Date

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Δ%Cross Patents	231	0.185	0.000	0.905	-1.801	10.583
ΔSize	415	1,863.72	736.77	3,291.72	-7,034.10	21,536.72
ΔR&D	415	0.003	0.000	0.048	-0.469	0.383
ΔQ	364	1.205	0.243	4.070	-7.767	26.846
ΔROA	408	0.034	0.008	0.169	-0.867	1.004
Distance	348	1,588.68	1,209.19	1,317.30	0.000	6,267.10
Hor	415	1.279	1.000	1.479	0.000	4.000
VRC	415	0.335	0.000	0.473	0.000	1.000

Table XVII

Analysis of Change in Knowledge Flow Pre/Post Alliance Announcement

This table reports the effect of boundary choice on the change in knowledge flow between firms. The sample is composed of COMPUSTAT/SDC merged samples of strategic alliances and joint ventures from 1986 through 2000. Columns (A) through (C) use matched firms from the Primary Pool of firms from COMPUSTAT. Columns (D) through (E) use matched firms from the Secondary Pool of firms from SDC's Strategic Alliance and Joint Venture database. Year fixed effects are included. Variables definitions can be referenced in Appendix A. Variables are constructed using winsorized firm characteristics at 2%. ***, **, and * indicate significance at the 1, 5, and 10% levels respectively.

	Δ*Cross Patents*	Δ*Cross Patents*	Δ*Cross Patents*	Δ*Cross Patents*	Δ*Cross Patents*
Variable	(A)	(B)	(C)	(D)	(E)
Boundary	0.064***			0.065***	
	(3.24)			(3.81)	
Structure		0.065***			0.065***
		(4.01)			(4.62)
JVSA			0.115**		
			(2.29)		
VRC	0.076***	0.077***	0.112***	0.072***	0.073***
	(3.68)	(3.72)	(3.16)	(4.11)	(4.16)
Log(Hor)	0.037**	0.037**	0.057**	0.030**	0.030**
	(2.42)	(2.43)	(2.27)	(2.32)	(2.32)
Log(Distance)	0.010*	0.010*	0.024***	0.011**	0.011**
	(1.76)	(1.73)	(2.61)	(2.33)	(2.32)
$\Delta Size$	0.000	0.000	-0.000	0.000	0.000
	(0.63)	(0.69)	(0.33)	(0.98)	(1.00)
$\Delta R\&D$	0.020	0.020	-0.056	0.047	0.048
	(0.12)	(0.13)	(0.19)	(0.33)	(0.33)
ΔQ	0.001	0.000	-0.002	0.000	0.000
	(0.16)	(0.11)	(0.37)	(0.16)	(0.14)
ΔROA	0.119*	0.120*	0.201	0.100	0.101
	(1.65)	(1.67)	(1.64)	(1.56)	(1.58)
Intercept	-0.047	-0.050	-0.110	-0.052	-0.055
	(1.06)	(1.15)	(1.56)	(1.37)	(1.47)
Year F.E.	Yes	Yes	Yes	Yes	Yes
R^2	0.015	0.017	0.021	0.014	0.016
Obs	2,659	2,659	1,247	3,066	3,066

Table XVIII

Target and Acquirer Descriptive Statistics for Mergers/Acquisitions

This table reports descriptive statistics of Target and Acquirer firms with completed mergers between 1986 and 2005 as well as firms matched to Target firms from COMPUSTAT. The sample is composed of completed deals from SDC's Mergers & Acquisitions database. Panel A reports descriptive statistics of firms matched to Target firms taken from COMPUSTAT. Panel B and C report descriptive statistics of Target and Acquirer firms respectively. Variables are winsorized at 2%. Variable definitions can be referenced in Appendix A.

Panel A: Descriptive Statistics of COMPUSTAT firms matched to Target firms from 1986 through 2005

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	465	0.063	0.020	0.107	0.000	1.000
RESTRICT2	499	0.073	0.018	0.134	0.000	1.000
YTC	518	1.852	1.600	1.519	0.000	12.000
Size	1,332	525.716	99.210	1,589.53	0.658	15,779.00
R&D	1,332	0.071	0.004	0.118	0.000	0.566
Q	1,182	2.358	1.488	2.567	0.600	16.933
ROA	1,315	0.017	0.094	0.236	-2.028	0.355

Panel B: Descriptive Statistics of Target firms from 1986 through 2005

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	507	0.062	0.026	0.092	0.000	0.667
RESTRICT2	556	0.070	0.019	0.119	0.000	1.000
YTC	585	2.224	2.000	1.615	0.000	13.000
Size	1,349	565.044	102.940	1,649.91	0.686	15,779.00
R&D	1,349	0.078	0.010	0.127	0.000	0.566
Q	1,290	2.224	2.317	2.317	0.600	16.933
ROA	1,328	0.017	0.101	0.298	-2.028	0.355

Panel C: Descriptive Statistics of Acquirer firms from 1986 through 2005

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	760	0.078	0.043	0.091	0.000	0.429
RESTRICT2	792	0.081	0.052	0.096	0.000	1.000
YTC	816	2.260	2.243	1.337	0.000	9.333
Size	1,349	3,442.50	915.38	5,036.71	2.167	15,779.00
R&D	1,349	0.051	0.014	0.084	0.000	0.566
Q	1,288	2.645	1.853	2.505	0.600	16.933
ROA	1,338	0.116	0.141	0.174	-2.028	0.355

Table XIX

Relative Firm-Pair Measures of Strategic Alliances, Joint Ventures, and Mergers/Acquisitions

This table reports descriptive statistics of the relative values between firms in a firm pair across boundary types. The sample is composed of strategic alliances, joint ventures and mergers/acquisitions from 1986 through 2005. Strategic alliances and joint ventures are obtained through SDC's Strategic Alliance and Joint Venture database while mergers/acquisitions are obtained from SDC's Mergers/Acquisitions database. Panel A reports firm-pair specific statistics for strategic alliances. Panel B reports statistics for joint ventures and Panel C reports statistics for mergers/acquisitions. The variables *RESTRICT1*, *Size*, and *Q* are calculated as relative measures. The maximum value of the firm-pair is divided by the minimum value. Variables *R&D* and *ROA* are also relative measures, but calculated using the difference between the maximum and minimum value. The variables *VRC* and *HOR* are already defined at the firm-pair level. Relative measures are winsorized at the 2% level. Variable definitions can be referenced in Appendix A.

Panel A: Relative Values between Firms in Strategic Alliances

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	1,134	4.119	2.657	3.435	1.000	12.390
Size	2,563	39.506	5.655	80.622	1.000	293.465
R&D	2,563	0.086	0.056	0.098	0.000	0.566
Q	2,477	2.208	1.690	1.272	1.000	5.295
ROA	2,534	0.180	0.111	0.235	0.000	2.384
VRC	2,563	0.372	0.000	0.483	0.000	1.000
HOR	2,563	1.465	1.000	1.633	0.000	4.000

Panel B: Relative Values between Firms in Joint Ventures

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	173	3.317	2.132	2.943	1.000	12.390
Size	556	33.448	3.962	71.099	1.000	293.465
R&D	556	0.038	0.014	0.064	0.000	0.541
Q	531	1.734	1.313	1.029	1.002	5.295
ROA	547	0.118	0.064	0.192	0.000	2.215
VRC	556	0.356	0.000	0.479	0.000	1.000
HOR	556	1.390	1.000	1.550	0.000	4.000

Panel C: Relative Values between Firms in Mergers/Acquisitions

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
RESTRICT1	230	4.242	2.938	3.477	1.000	12.458
Size	1,349	29.890	6.283	62.053	1.000	293.504
R&D	1,349	0.054	0.013	0.097	0.000	0.566
Q	1,235	1.766	1.443	0.917	1.000	5.295
ROA	1,317	0.170	0.086	0.256	0.000	2.195
VRC	1,349	0.410	0.000	0.492	0.000	1.000
HOR	1,349	2.314	3.000	1.601	0.000	4.000

Table XX

Analysis of Likelihood of Becoming Target Firm

This table reports a series of linear probability models estimating the likelihood of a firm being a target firm in a merger/acquisition. The sample is composed of firms from SDC Mergers & Acquisitions database from 1986 through 2005. Columns (A) through (C) also contain firms matched to the target firm from COMPUSTAT. For Columns (A) through (C), the dependent variable takes the value of '1' if the firm is a target firm and '0' if the firm is a matched firm. For Columns (D) through (F), the dependent variable takes the value of '1' for a target firm and '0' for an acquirer firm. Industry fixed-effects are at the 2-digit SIC level. Variable definitions can be referenced in Appendix A. Variables are winsorized at 2% and standard errors are clustered at the 2-digit SIC industry code. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	Target	*Target*	*Target*	*Target*	*Target*	*Target*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
RESTRICT1	0.015			0.336**		
	(0.10)			(2.27)		
RESTRICT2		0.142			0.214*	
		(0.91)			(1.86)	
YTC			0.048***			0.016*
			(4.03)			(1.75)
Log(Size)	0.013	0.007	0.008	-0.142***	-0.141***	-0.140***
	(1.01)	(0.61)	(0.68)	(18.84)	(20.23)	(21.09)
R&D	0.572***	0.426**	0.477**	-0.181	-0.258	-0.145
	(2.90)	(2.18)	(2.55)	(1.11)	(1.63)	(0.96)
Q	-0.016***	-0.012*	-0.012**	-0.023***	-0.021***	-0.021***
	(2.65)	(1.96)	(2.00)	(4.72)	(4.50)	(4.50)
ROA	0.060	0.063	0.037	-0.036	-0.051	-0.025
	(0.78)	(0.84)	(0.51)	(0.53)	(0.79)	(0.40)
Intercept	-0.171	-0.073	-0.215	1.111***	0.739*	0.741*
	(0.33)	(0.14)	(0.42)	(2.64)	(1.78)	(1.79)
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.053	0.039	0.052	0.310	0.319	0.328
Obs	922	1,004	1,047	1,220	1,300	1,351

Table XXI

Descriptive Statistics of Announcement Date Effects for Strategic Alliances, Joint Ventures and Mergers/Acquisitions

This table reports descriptive statistics of the 1, 2, and 5 day abnormal returns around the announcement dates of strategic alliance, joint ventures and mergers/acquisitions. The sample is composed of deals found in SDC's Strategic Alliance and Joint Venture database as well as SDC's Mergers & Acquisitions database from 1986 through 2005. Announcement dates come from SDC and are verified by Lexis-Nexis and online corporate announcements. Abnormal returns are calculated as the difference between the actual return and the market return using the CRSP value-weighted index over the time window. Panel A and B report the abnormal return of each firm for strategic alliances and joint ventures respectively. Panel C reports the abnormal return of the acquirer firm of a merger/acquisition. Returns are winsorized at 2%.

Panel A: Descriptive statistics of firm level abnormal returns for strategic alliances

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
1 Day Return	4,766	0.007	0.001	0.060	-0.148	0.242
2 Day Return	4,766	0.007	0.001	0.084	-0.554	0.323
5 Day Return	4,766	0.011	0.002	0.117	-0.326	0.446

Panel B: Descriptive statistics of firm level abnormal returns for joint ventures

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
1 Day Return	998	0.004	0.001	0.047	-0.148	0.242
2 Day Return	998	0.004	0.001	0.071	-0.554	0.323
5 Day Return	998	0.002	-0.001	0.089	-0.326	0.446

Panel C: Descriptive statistics of deal cumulative abnormal returns for mergers/acquisitions

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
1 Day Return	758	-0.012	-0.007	0.072	-0.272	0.189
2 Day Return	758	-0.010	-0.006	0.082	-0.264	0.260
5 Day Return	758	-0.009	-0.007	0.109	-0.409	0.302

Table XXII

Announcement Date Effects of Strategic Alliances, Joint Ventures, and Mergers/Acquisitions

This table reports the effect of knowledge flow restrictions on the 1, 2, and 5 day abnormal returns around the announcement dates of strategic alliances, joint ventures and mergers/acquisitions. The sample is composed of deals found in SDC's Strategic Alliance and Joint Venture database as well as SDC's Mergers & Acquisitions database from 1986 through 2005. Announcement dates come from SDC and are verified by Lexis-Nexis and online corporate announcements. Abnormal returns are calculated as the difference between the actual return and the market return using the CRSP value-weighted index over the t-1/t+1, t-2/t+2, and t-5/t+5 day windows where t=0 is the announcement date. *Diff* is the difference between the predicted choice of a strategic alliance versus a joint venture and the actual choice from the probit model found in Table XI, Column (A). Standard errors are clustered at the 2-digit SIC industry code and variables are winsorized at 2%. Variable definitions can be referenced in Appendix A. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

	MRet1	*MRet2*	*MRet5*	*MRet1*	*MRet2*	*MRet5*
Variable	(A)	(B)	(C)	(D)	(E)	(F)
JVSA	0.005	0.005	0.001			
	(0.76)	(0.55)	(0.20)			
RESTRICT1	0.033***	0.053***	0.084***	0.014	0.014	0.017
	(3.26)	(3.83)	(4.30)	(0.38)	(0.33)	(0.29)
JVSA x RESTRICT1	0.011	0.022	0.011			
	(0.37)	(0.56)	(0.20)			
Log(Size)	-0.004***	-0.004***	-0.005***	-0.004	-0.006*	-0.002
	(7.44)	(5.30)	(4.47)	(1.27)	(1.89)	(0.52)
R&D	-0.014	-0.037**	-0.022	-0.098	0.069	0.175
	(1.11)	(2.12)	(0.87)	(1.37)	(0.86)	(1.58)
Q	0.001**	0.002***	0.004***	0.003	-0.001	-0.001
	(2.41)	(3.03)	(5.36)	(1.20)	(0.46)	(0.29)
ROA	-0.002	-0.005	-0.012	-0.021	0.037	-0.042
	(0.33)	(0.57)	(1.00)	(0.70)	(1.09)	(0.91)
Diff	-0.010	-0.000	-0.003			
	(1.10)	(0.01)	(0.17)			
Intercept	0.003	0.003	0.028	0.064	0.099	0.063
	(0.05)	(0.04)	(0.26)	(0.85)	(1.18)	(0.54)
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.046	0.029	0.040	0.159	0.157	0.105
Obs	3,756	3,756	3,756	304	304	304