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Liberty in Law? Intellectual Property Rights and Global Alliance Networks

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Abstract

Do formal legal institutions complement or substitute social network mechanisms of knowledge protection? We explore how the composition and structure of firms' international alliance networks changes in response to the passage of intellectual property rights (IPR) laws in their home countries. We find that, when IPR laws are strengthened, firms form more international alliances, particularly if they operate in IP intensive industries, and do so with partners from a greater diversity of countries. The significance of status (centrality) as a predictor of international alliance formation decreased after the passage of IPR laws, in line with a substitution effect that 'democratized' access to the global network by increasing the participation of firms that were peripheral before the legal changes. In contrast, the closure of firms' alliance networks increased with stronger IPR laws, in line with a complementarity effect that increased the use of social control. The increase in closure was strongest in the networks of the low status entrants into the global network. Using a difference-in-difference empirical design, we found that these changes coincided exactly with the timing of the passage of the laws across thirteen countries between 1988 and 2005. This study addresses issues of great theoretical and practical importance to the literatures on institutions, networks, and IPR.

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Abstract: Do formal legal institutions complement or substitute social network mechanisms of knowledge protection? We explore how the composition and structure of firms' international alliance networks changes in response to the passage of intellectual property rights (IPR) laws in their home countries. We find that, when IPR laws are strengthened, firms form more international alliances, particularly if they operate in IP intensive industries, and do so with partners from a greater diversity of countries. The significance of status (centrality) as a predictor of international alliance formation decreased after the passage of IPR laws, in line with a substitution effect that 'democratized' access to the global network by increasing the participation of firms that were peripheral before the legal changes. In contrast, the closure of firms' alliance networks increased with stronger IPR laws, in line with a complementarity effect that increased the use of social control. The increase in closure was strongest in the networks of the low status entrants into the global network. Using a difference-in-difference empirical design, we found that these changes coincided exactly with the timing of the passage of the laws across thirteen countries between 1988 and 2005. This study addresses issues of great theoretical and practical importance to the literatures on institutions, networks, and IPR.

In an increasingly knowledge-based economy, interfirm collaborations are essential for many firms and industries. These collaborations are often globally dispersed because knowledge and resources are widely distributed across countries (Rosenkopf and Almeida 2003). But capturing the value created by these global partnerships is a major concern for the firms involved. One of the most pressing issues in this regard is the lack of uniformity in intellectual property rights (IPR) across markets. Because IPR affects the amount of value appropriated by firms involved in global partnerships, firms in places with weak IPR struggle to attract foreign partners, who may be wary of losing their valuable knowledge without proper compensation (Zhao, 2006).

To address these concerns, researchers and practitioners have focused on two types of institutional mechanisms. One the one hand, formal regulation that protects IPR induces firms to invest and combine their resources by alleviating concerns related to expropriation by defining property rights, enabling contracts, and providing legal recourse in the case of contractual breaches (Zucker 1986; Teece 1986; North 1990). On the other hand, informal mechanisms of protection can play a functionally similar role. Scholars from many disciplines have shown that mechanisms rooted in social norms and relationships can also be effective means to protect firms' intellectual property and other resources from expropriation (Granovetter 1985; Zucker 1986; Greif 1993). Yet a fundamental but unsettled question is how formal and informal mechanisms of knowledge protection affect one another.

In this paper we focus on how firms' use of informal, socially rooted mechanisms of IP protection changes when formal IPR protection is legally strengthened. While the passage of IPR laws is typically beyond the control of firms, the frequency with which firms participate in external collaborations and how they structure the network created by those collaborations in response to threats to their knowledge resources is more strategic in nature (Gulati 1999; Hernandez, Sanders, and Tuschke 2015). We take advantage of a series of changes in the law that strengthened IPR protection across several countries to examine how the composition and structure of firms' global alliance networks responds to those laws. We address two outcomes of

theoretical interest. First, we examine whether strengthening IPR laws facilitates greater access to international alliance partners, by allegedly reducing the perceived risk of expropriation. We expect that formal IPR will not only allow firms to have a greater number of international partners, but that the composition of the firm's network will become more diverse in terms of the nationalities represented.

Second, we assess whether IPR laws substitute or complement the use of informal network mechanisms associated with knowledge protection. Research has considered two means by which firms can rely on networks to protect their resources. One mechanism is to partner with others of high status or reputation—usually reflected in the centrality of the partner in the network (e.g. Podolny 2001). Status serves as a signal of the trustworthiness of the partner, and also acts as insurance against malfeasance because of the loss of reputation that high status actors would suffer in the event of opportunistic behavior. Another mechanism is to embed the tie with the partner in question within a dense network—usually reflected in the closure of the focal actor's network (Coleman, 1988). Closure can be effective as a device to protect IP because it limits the flow of information outside of the dense cluster of ties, fosters common norms of behavior, and thus facilitates social monitoring (Lin 2001).

We argue that the strengthening of formal IPR in a country diminishes the use of status as a mechanism to facilitate tie formation and enhances the incidence of closure as a knowledge protection structure. In the absence of IPR laws, firms can only rely on informal means to protect their IP when participating in international alliance networks. The network status of a firm from a country with weak IPR is a particularly useful, albeit noisy, signal of reliability for foreign partners. High status firms thus disproportionately accrue the few foreign partnership opportunities available for firms from IPR regimes. When IPR laws are strengthened, foreign firms are significantly more willing to partner with a wider set firms from the reforming country because they can rely on formal means to protect their assets. This 'democratization' effectively opens up the global alliance network to a greater number of firms, especially those that were

previously peripheral or of low status, and results in a post-reform decrease in the significance of centrality as a driver of tie formation.

At the same time, the increased participation of many new, low status firms in the global network after IPR reforms results in the increased use of closure as a means of knowledge protection. Though foreign firms may now consider entering alliances with firms that are relatively lower in status, the absence of a reputation-based means of assurance requires firms to rely on an alternative informal mechanism. While the law provides some protection, it does not cover all the day-to-day issues that may arise in a partnership (North 1990). Research has demonstrated that a closed network can be a useful complement to formal protection because it provides the ability to monitor partners and fosters an agreed upon a set of norms that can be socially enforced in routine interactions (Hernandez et al. 2015; Hallen et al. 2014). We therefore expect that network closure will increase following the strengthening of formal IPR protection, and that the increase will be most pronounced in the networks of firms that were of low status before the IPR reforms.

We tested these ideas examining the networks of firms from thirteen countries that passed meaningful patent protection reforms (Branstetter, Fisman, and Foley 2006). The sample covers 11,035 firms during 1988-2005 and their alliance networks composed of partners from all over the world. An attractive feature of the setting is that we can make strong statistical inferences by taking advantage of the exogenous timing of the passage of IPR laws across the different countries. Using a multiple event difference-in-difference design, we find support for our hypotheses. The strengthening of IPR laws significantly increased the number of international alliances formed by firms from the reforming countries, particularly in IP-intensive industries, and enhanced the cross-national diversity of firms' alliance partners. These changes coincided exactly with the timing of the passage of the laws in each market. The significance of centrality (high status) as a predictor of international alliance formation decreased after the passage of IPR laws, in line with a substitution effect. In contrast, stronger IPR laws increased the closure of

firms' alliance networks, especially those that were of low status during the weak IPR regime, in line with a complementarity effect.

These results are important because they address a fundamental question in the dilemma faced by firms in markets with weak formal institutions seeking to attract international collaborators. While research on formal and informal mechanisms to protect knowledge and resources has generally developed along parallel paths—especially work on "macro" institutions and research on interfirm networks—we integrate the two. We show that formal IPR strengthening has nuanced effects on firms' use of informal network governance. Status based mechanisms of assurance become less relevant to tie formation, suggesting that the law 'democratizes' access to alliance partners by allowing less central firms to enter the global network. To accommodate this entry, informal means based on network embeddedness become more prevalent, suggesting that the law increases demand for this mechanism. This demonstrates the institutional origins of network composition and structure, bringing together two literatures that have been "oddly disconnected" (Powell et al. 2005). Another valuable contribution is the strength of the empirical design, which allows us to approach causality in making these claims. Finally, the phenomenon is of great managerial and policy importance because it provides relevant facts about the efficacy of efforts to strengthen IPR laws.

BACKGROUND

Institutions and networks exist because cooperation can be beneficial for value creation but problematic for value appropriation. While cooperation can take many forms, here we are interested in that between firms engaged in joint work through cross-border alliances. These international collaborations have increased dramatically over the last few decades as globalization has made opportunities for value creation through resource sharing across geographies a highly attractive proposition (Gomes-Casseres 1996), particularly when it comes to knowledge-related activities (Zaheer and Hernandez 2011). Indeed, much academic and managerial writing has been dedicated to the value creation aspects of such alliances (Lavie 2006 provides a good review). But as firms from various national jurisdictions come in contact with

one another, issues of value appropriation due to uneven intellectual property rights (IPR) protection have become one of the most (if not the most) important concerns reported by managers (Teece 1986; Ginarte and Park 1997; Zhao 2006).

The issue of operating in markets with weak IPR has been addressed in prior literature. For example, Zhao (2006) asked how MNEs overcome the appropriability concerns of conducting R&D in countries with weak IPR. She proposed an institutional arbitrage framework by which the complexity and complementarity of internal linkages between technologies within the firm serve as a barrier to imitation. Alcacer and Zhao (2012) further show how that such strong internal linkages allow firms to protect their IP from spillover in industry clusters where knowledge spillovers are likely. Other research focuses on different actions or strategies firms can follow to safeguard their knowledge in weak IPR regimes (e.g. Singh 2008; Agarwarl, Ganco, and Ziedonis 2009; Schotter and Teagarden 2014). But the emphasis has been primarily on protections for IP-related activities that firms conduct internally. Yet a significant portion of firms' knowledge related activities, as just mentioned, are done in collaboration with other firms.

Firms originating from countries with weak IPR regimes are at a marked disadvantage in attracting partners from the global alliance network. If firms from these countries lag technologically, foreign partnerships have the promise of providing needed know-how to upgrade firms' capabilities. But potential foreign partners will be wary of losing their IP and having no legal recourse to adjudicate disputes. And even if firms from weak IPR countries have strong technological capabilities, foreign partnerships are valuable in providing access to new markets or complementary technologies. But, once again, foreign firms will have concerns of unwanted knowledge spillovers into the weak IPR location. Hence firms from weak IPR countries have both strong incentives and major constraints to establish international alliances. For collaborations to arise in these situations, firms need to be able to trust that their partners will not expropriate them. Zucker (1986) identifies three different mechanisms by which trust may be generated: process-based, characteristic-based, and institution-based. Institution-based mechanisms are rooted in formal laws, codes, standards and other formal means. The hallmark of

these is that they are impersonal, arms-lengths means of securing exchange between counterparties. In our setting, these formal institutions correspond to laws protecting IPR within countries. Process- and characteristic-based mechanisms are both informal in nature and rooted in social, personal processes. But they operate in different ways. Characteristic-based trust is rooted in reliance on the identity of the other party, such as co-ethnicity or membership in a common organization (e.g. alumni group) (Greif 1993). This kind of informal institution corresponds to reliance on the network status of an actor (Podolny 1992), as we elaborate below. Process-based trust is rooted in prior interactions or repeated exchange with others, and corresponds to the concepts of embeddedness and closure in the networks literature (Granovetter 1985; Coleman 1988). Our study examines the interplay between each of these three institutional mechanisms of governance.

An issue that will permeate much of this paper is the fundamental question of whether formal and informal institutions substitute or complement one another. Strong arguments have been made in favor of both propositions (see Poppo and Zenger 2002). As we discuss more below, North's (1990) work is ambivalent about this issue. While he tends to assume that even in the most advanced societies informal constraints play an important role in ongoing economic exchange, he also makes a strong case that economic progress is frequently predicated on replacing socially based exchange with formal, arms-length transacting (see also Zucker 1986). Perhaps the fairest characterization of North's research is that the interplay of the two types of institutions depends on historical circumstances.

Granovetter's (1985) celebrated work puts forward the view that relational norms can govern collaborative exchange even in the absence of explicit formal contracts and institutions that support their enforcement. This has frequently been inferred as support for the notion that formal and informal governance mechanisms are functional substitutes, a view that has been expanded on by subsequent research (Hill 1990; Dyer 1997; Adler 2001). Rangan (2000:1), building on Granovetter's (1985) work concludes that "when actors need to but cannot, independently or via market mechanisms, cost-effectively ascertain the identity and reliability of

potential exchange partners, then scope exists for social networks to appreciably and systematically influence efficiency"; otherwise, formal incentives dominate socially based exchange. However, some scholars have also argued that informal governance continues to play an important role even in the presence of formal protections. Poppo and Zenger (2002), focusing on "micro" institutions (i.e. organizational forms rather than laws), argue that formal contracts and relational governance are complements. They propose that contracts create incentives for partners to invest in relational routines through repeated exchange, while relational governance allows firms to develop more customized contractual solutions. Helmke and Levitsky (2004) attempt to resolve the contradictory arguments by suggesting that complementarity or substitution between types of institutions depends on whether they have compatible objectives and whether informal institutions are effective in accomplishing their objectives.

Our purpose here is not to fully summarize the literature on this debate, but to point out that the issue is not settled. In what follows, we distinguish between informal institutions that resolve exchange concerns through signaling—based on network status—and those that ameliorate concerns by constraining information and norms of behavior—based on network closure. We will argue that this distinction is important because formal institutions (IPR laws, in our case) will substitute for one but complement the other. We posit that complementarity and substitution are not necessarily driven by the functional attributes of formal vs. informal institutions, as prior research argues. Instead, they can be explained by the fact that status-based mechanisms are limited in supply while closure-based mechanisms are more broadly accessible as participation in the network increases after the strengthening of formal institutions. We elaborate on this in the hypothesis development.

HYPOTHESES

Network Tie Formation

We start with a pair of baseline hypotheses that, while theoretically straightforward, are practically of great importance. While scholars and policy makers expect that the passage or strengthening of IPR laws "works" by reducing appropriability concerns, the effects of these

laws on firms' ability to attract foreign alliance partners has not been empirically verified. Since international partnerships are frequently the most important vehicle by which firms from weak IPR countries gain access to new technologies, capabilities, and markets (Siegel 2007; Palepu, Khanna, and Vargas 2006), this outcome is highly important for managers and policy makers. We expect that the passage (or significant strengthening) of IPR laws will have such an effect. Further, the effect should be particularly strong for firms in industries that are IP intensive because those firms stand to benefit the most from the reforms. Hence,

> *Hypothesis 1a: Firms in countries that strengthen IPR laws form more international alliances after the passage of the laws.*

> *Hypothesis 1b: Firms from IP intensive industries in countries that strengthen IPR laws form more international alliances after the passage of the laws than firms from low technology industries.*

From a networks perspective, the preceding hypotheses establish that IPR laws increase tie formation activity. But the composition and structure of a firm's network are key to determining how much and in what way it will benefit from participating in the network (Gulati and Gargiulo 1999; Ahuja 2000; Rosenkopf and Schillin 2007). By composition we refer to the attributes of a focal firm's network partners, whereas by structure we refer to the position the firm occupies in terms of how ties are distributed between the focal firm and others. The remaining hypotheses focus on these issues.

Network Composition

We focus first on how IPR laws affect network composition. If the strengthening of formal institutions affects tie formation by reducing the appropriability concerns of foreign partners, this should allow firms to not only attract more foreign partners, but partners from a greater variety of countries than the firm was able to before the strengthening of IPR. There is a difference between a firm from, say, Argentina that engaged in alliances with Spanish firms before IPR was strengthened and now increases the frequency and intensity of its alliances with Spanish partners and the same firm now having access to new partners from Japan, the U.S., and Brazil. In both cases we would observe an increase in the rate of international tie formation (per

H1a and H1b), but only in the latter would we observe that the global diversity of ties also increases. If firms only formed more ties with firms from foreign countries to which they already had ties, then legal changes would simply be reinforcing previous linkages among countries that already exchanged with one another because of specific bilateral factors (such as prior colonial ties or immigration patterns).

In contrast, if firms diversify the countries from which they find alliance partners, the legal change is creating opportunities for firms to access new ideas through access to novel parts of the global knowledge network. Exposure to partners from distinct national jurisdictions is a source of resource and knowledge diversity. The persistent differences across countries across many dimensions—institutional, cultural, or economic (Ghemawat, 2001)—create pockets of idiosyncratic knowledge, technologies, practices, and other resources. Of relevance to the domain of IP-related issues is research demonstrating that countries have unique national innovation systems (Nelson 1993), and that firms with networks that span various innovation systems derive innovation and other performance benefits (Lavie and Miller 2008; Vasudeva, Zaheer, and Hernandez 2013). If the passage of laws that strengthen IPR works as intended, the laws should lower expropriation concerns for foreign firms from all other countries rather than just from the ones with whom firms in the reforming country had pre-existing ties. Hence,

> *Hypothesis 2: Firms in countries that strengthen IPR laws form international alliances to partners from a more diverse set of countries after the passage of the laws.*

Network Structure

We now consider how IPR laws affect the structural properties of firm's networks. These effects are important because network structure is often viewed as playing a role similar to that of formal institutions such as IPR laws. Like formal institutions, network structure can serve as a means of reducing concerns of exchange hazards between partners engaged in economic transactions (Granovetter 1985). Hence, whether and in what ways network mechanisms of IP protection substitute or complement formal institutional means is a fundamental question.

We explore two distinct attributes of networks that have been viewed as means of informal protection against opportunistic behavior. High status in a network functions as a signal of unobservable quality (Podolny 1993) and plays a prominent role in trust generation because it functions like the characteristic-based mechanisms discussed by Zucker (1986). Under conditions of uncertainty, high status firms tend to disproportionately attract resources and network ties because others use status as a proxy for desirability as an exchange partner (Podolny 2001). Status is a prized resource that the possessor does not want to compromise through opportunistic behavior and the reputational fallout such behavior could elicit (Jensen and Roy 2008). Another view proposes that organizations with networks that are closed, dense, or tightly knit (we will use closure from now on) are able to safeguard valuable resources (Coleman, 1988), particularly sensitive knowledge-based ones (Hernandez et al. 2015). When network participants must protect a prized resource, closure is valuable for a few reasons. First, a dense web of ties allows firms to more easily obtain information about the actions of others, in essence lowering the costs of monitoring—one of the fundamental roles of institutions (North 1990). Second, closed networks tend to be composed of actors who share similar norms of behavior and increase the odds that norms will be socially enforced when deviations occur (Coleman 1988), akin to the process-based means of trust production discussed by Zucker (1986). Notice that status and closure operate through different means—the former through signaling, the latter through informational and normative constraints. We will argue that the strengthening of IPR laws diminishes the use of status-based mechanisms and heightens the use of closure-based mechanisms.

Status Substitution. In a series of papers, Podolny shows that status has economic value because it serves as a signal of firm quality and reliability (1993, 2001). One of the main empirical approaches to show this is to demonstrate that the returns to status increase with the level of 'altercentric uncertainty' (Podolny 2001). Altercentric uncertainty refers to the inability of external parties (or network alters) to ascertain the quality and trustworthiness the focal firm

(the ego) as an exchange partner.[1] Status in the network (usually measured as eigenvector centrality, as we discuss later) reduces altercentric uncertainty by signaling that a potential exchange partner is reliable. Empirical work thus shows that status is most valuable to firms as a means of attracting partners when altercentric uncertainty is high (Podolny 1992, 2001).

The function of status can be likened to that of formal institutional constraints, which serve as a means to reduce concerns of hazardous behavior between actors. In the absence of formal institutional solutions to the problem of partner screening, status becomes a crucial enabler of tie formation. In our context, foreign partners are more willing to form alliances with the most central (high status) firms in countries with weak IPR. For example, high status firms such as those in business groups disproportionately attract foreign partners in these countries (e.g. Palepu, Khanna, and Vargas 2006; Siegel 2007). But when IPR laws are meaningfully strengthened, a more credible and formalized means of reducing appropriability concerns exists for foreign firms establishing ties with firms from the reforming country (Rangan 2000). This should lead foreign firms to be more willing to ally with firms that were less prominent in the pre-reform regime. One reason may be that formal laws decrease altercentric uncertainty. But this does not necessarily mean that the threat of reputation loss as a mechanism to protect against opportunistic behavior is less desirable for foreign partners after the passage of the laws. Rather, the introduction of formal institutions broadens the consideration set of viable partners from the reforming country, and thus status plays a less determining role in tie formation.

North (1990:46) discusses how "the shift from status to contract has been amply discussed" in historical accounts of economic development. As economic actors seek to engage in complex exchanges—and IP-related exchanges across firms are highly complex—formal institutions tend to replace some socially based mechanisms of governance based on the identity of the exchange partner (e.g. status, clientilization, cronyism) (Zucker 1986; North 1990; Greif 1993). This should result in a 'democratization' of participation in economic exchange when

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[1] This contrasts with 'egocentric uncertainty, or the uncertainty that the focal firm itself faces when going about its usual activities.

formal institutions are strengthened. From a networks perspective, this means that new ties will accrue disproportionately less than before to highly central firms. This should be reflected in a broader set of firms being able to attract international alliance partners instead of those that had high status in the network before the passage of IPR laws. Thus:

> *Hypothesis 3: The effect of network centrality on the number of international alliances formed by a firm declines when IPR laws become stronger in the country of the focal firm.*

Closure Complementarity. Despite the preceding hypothesis, it would be premature to conclude that formal protection can replace all types of informal institutions (Poppo and Zenger 2002). As just mentioned, the increase participation in the network is driven by firms that were previously less able to attract foreign partners because of their low status. They were peripheral in the network and thus deemed risky in the absence of formal institutional assurances. IPR laws may increase the willingness to partner with low status firms, but laws are never fully effective on their own. North (1990) makes this point forcefully. For example: "The difference between informal and formal constraints is one of degree" (1990:46) "[Formal regulation through coercive power] is never ideal, never perfect, and the parties to the exchange still devote immense resources to attempting to clientize exchange relationships. But neither self-enforcement by parties not trust can be completely successful… Indeed, effective third-party enforcement is best realized by creating a set of rules that then make a variety of informal constraints effective" (1990:35) Further, "Formal rules can complement and increase the effectiveness of informal constraints. They may lower information, monitoring, and enforcement costs and hence make informal constraints possible solutions to more complex exchange" (1990:46-47).

If laws are complemented by informal constraints, the issue is that the majority of the new participants in the network are not of high status. Indeed, status is by definition a rare commodity. Hence foreign firms partnering with those in the reforming country must rely on an alternative informal mechanism to complement the law. Closure can play this role. Granovetter (1985) suggested that economic actors frequently embed transactions in social relationships.

Subsequent research explored this idea from a networks perspective, suggesting that firms can structurally embed resource exchanges in social relations by forming ties to others with whom both parties have a common contact (Gulati 1998). This tie formation behavior results in networks rich in closed triads (high closure or density), which, as argued previously, allow firms to control the flow of information and increase the likelihood of developing and enforcing an agreed upon set of norms (social control). As Lin (2001:27) argues, "the root of preferring a dense or closed network lies in certain outcomes of interest. For *preserving or maintaining resources…* denser networks may have a relative advantage… On the other hand, for *searching for and obtaining resources* not presently possessed… accessing an extending bridges in the network should be more useful." (Lin, 2001: 27). Recent work has empirically validated this proposition by showing that when a firm's sensitive knowledge is exposed to unwanted leakage to rivals firms tend to increase network closure (Hernandez et al. 2015).

Network closure is thus useful after the passage of IPR laws because it can help address many of the day-to-day interactions between partners that are not explicitly covered by the legal framework. Indeed, trying to rely only on the formal constraints would be inefficient when minor disputes or unexpected situations arise. Reliance on a dense network to monitor situations and appeal to a socially accepted set of values and norms is likely to be more effective and "fill in" the gaps in formal legal frameworks (Uzzi 1997). The functioning of formal institutions ultimately depends on a series of underlying values and agreed upon norms of behavior, or "moral constraints on behavior" (North 1990:60), that are consistent with the objectives of the institutional structure. In network-based exchange such as the international alliances of this study, being able to trust that partners share certain values consistent with the intent of IPR laws is crucial. Network closure, which facilitates shared norms of behavior and their social enforcement, accomplishes this.

Because of its value as a complement to formal constraints, the demand for closure will increase after the passage of IPR laws. To be clear, we are not saying that closure was ineffective before the reforms; only that it was less prevalent. Since closure is not a dyadic property, it

requires the participation of third parties to whom the firm from the focal country and the foreign partner are tied. But pre-reform, the network was relatively sparse, thus limiting the availability of common third parties to provide social control. The significant increase in network participation (per H1a and H2) increases the odds of finding third parties linked to firms from the reforming country. Further, because the increase in participation is greatest among firms that lack network status (H3), the demand for closure will be greatest among for partnerships involving these low status firms. Thus,

> *Hypothesis 4: The alliance networks of firms in countries that strengthen IPR laws become more closed after the passage of the laws.*

> *Hypothesis 5: The increase in closure in the alliance networks of firms in countries that strengthen IPR laws is stronger the lower the network centrality of the firm before the IPR laws are strengthened.*

While each hypothesis is interesting by itself, the overall story told by the set of hypotheses is important because it provides a fairly comprehensive understanding of how firms' use of informal network mechanisms responds to the availability of formal legal institutions. The passage of IPR laws increases the supply of international alliances partners for firms from the countries that pass those laws (per H1a, H1b). This supply of partners is not just greater in quantity, but in the diversity of locations from which partners are available (H2). The democratization of access to the global network is reflected in a decline in the importance of status as a driver of international tie formation (H3). Because the supply of high status firms is limited, it cannot meet the heightened demand for informal institutional assurances. At the same time, the broader participation of firms from the reforming country in the global network increases opportunities to use closure as an informal institution (H4), particularly in the networks of the new, low status entrants into the network (H5).

DATA AND METHODS

Our sampling frame consists of firms from thirteen countries that passed substantial laws to strengthen patent protection during the 1990's. We drew information about these IPR changes and their timing from Branstetter, Fisman, and Foley (2006). They define an improvement in IPR

as a governmental intervention that leads to expansions of eligible inventions, patent scope or patent length as well as improvements in patent enforcement and administration. We refer the reader to the appendix of Branstetter et al. (2006) for a very detailed explanation of the reforms in each country. The basic research design of our study is similar to theirs (and subsequent studies such as Branstetter et al. 2010, 2011) in that we take advantage of differences in the timing of IPR changes across markets to assess the pre vs. post change in outcomes of interest (i.e. a difference-in-difference design).

Our primary firm and network data source is the SDC Platinum database from which we drew information on interfirm alliances. This is the most comprehensive source of global interfirm alliances across multiple industries (Schilling 2009).[2] Alliance data of a reasonable quality in SDC Platinum is only available starting in 1988. We were thus forced to drop firms from some of the original sixteen countries making significant law changes identified by Branstetter et al. (2006) because they occurred prior to 1988. These include Japan (1983), South Korea (1987), Spain (1986) and Taiwan (1986). In addition to the remaining twelve countries in the original study, our sample also included India, which was identified by Branstetter et al. (2006) as passing a significant IPR reform but not included in their analysis as 1999 was the last year in their sample. The thirteen countries in our sample are listed in Table 1 along with the years in which the legal changes occurred. We note that there is disagreement as to the actual effectiveness of IPR changes in China and Argentina, but our results remain generally robust if we exclude firms from those countries. The findings are also robust to excluding any one country at a time from the analysis.

INSERT TABLE 1 HERE

Our sample includes 11,035 firms from the thirteen IPR-changing countries that participated in an alliance between 1988-2005 as indicated by SDC Platinum. Though our focal firms are only from the countries in which we observe the legal changes, their alliances could be

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[2] The only other source with fairly global coverage, the MERIT-CATI database, was discontinued in 2013 because SDC Platinum contained superior information.

with firms from anywhere in the world. We consider alliance ties to be active for a period of three years, consistent with similar standard assumptions in alliance research (e.g. Gulati 1995). For example, a firm's network in 1991 consists of all ties formed between 1989-1992, inclusive.

Dependent Variables

To test H1a/b, we capture the number of *new international ties* as a logged count of the number of new alliances that the focal firm establishes in a given year with partners that are based in a different country to its own, as classified by SDC's alliance participant location data. To test H2, we capture the international dispersion of a firm's partners, *partner national diversity*, as $1 - \sum_i S_i^2$ where S_i is the fraction of the firm's partners that are from country i.

Because we want to ensure that the results for H4 are not driven by one particular way of measuring closure, we use a variety of measures expecting to find similar results across them. We calculate the *network constraint* for the focal firm's ego-network, following Burt (1992), as $\sum_j (p_{ij} + \sum_q p_{iq} p_{qj})^2$. Higher values of constraint indicate networks with more closure. As a simpler measure of this same concept we count the number of ties (common third parties) that exist between a firm's partners. Since this measure is likely to be influenced by the number of partners the firm has, we use a measure of *normalized bridging ties*, which is the logged ratio of the count of common third parties among the focal firm's partners to the total number of partners the firm has (i.e. its degree). We also use a measure of *network density*, captured as the ratio of the number of ties between the firm's partners to the maximum possible number of ties that could exist between them (i.e. Bridging ties$_i$ /$^nC_2$, where n is the number of partners firm i has in the year in question.

Independent Variables

Our principal independent variables of interest are the aforementioned *post reform* and the various indicator variables capturing a series of years before and after the year preceding the reform. To test H3, also in the spirit of not relying on one particular network variable, we use three different measures of the firm's network centrality: *degree* is a simple logged count of the

number of partners the firm possesses in a given year, *eigenvector centrality* (Bonacich 1987) is a measure that weights each of the firm's ties by the centrality of the actor to which it is associated (and is the measure most frequently associated with status (e.g. Podolny, 2001)), and *component size* is the number of other firms to which the focal firm can connect through its network (regardless of distance), i.e. the number of other firms present in the same network component as the focal firm.

The variable *patent intensive* indicates whether the industry to which the firm belongs (based on the firm's primary 4 digit SIC code) is classified as being patent intensive. We use two different classifications to ensure robustness. The primary classification we use was generated by the US Patent Office (USPTO 2012) based on a multi-year analysis of patenting behavior across all industries in the economy. The other classification was independently created by the European Patent Office (EPO and OHIM, 2013) in a similar study, and results in substantially similar results.

Control Variables

Countries that pass IPR strengthening reform are likely to simultaneously be undergoing other changes that could influence alliance activity. The fact that our empirical design identifies effects by comparing only across similar countries using multiple events over a relatively short space of time allows us to be more precise in pinning the observed effects to our causes of interest. In addition we also control for various other events that could be occurring in these countries. Primarily, many of these countries are also likely to have been undergoing broader economic liberalization and opening up their markets to external influences (Henisz, Zelner and Guillen 2005). We identify significant liberalizing regulatory changes in the countries of interest from Wacziarg and Welch (2003). To control for these we include a *liberalization* dummy variable to indicate the year in which such a change occurred in the home country of the firm. Further, we also control for the extent to which the countries in our sample are open to capital flows based on Quinn and Toyoda (2008). This variable (*cap flows openness*) is on a 0-100 scale with 100 representing an economy that is fully open to capital flows. In addition, the passage of

IPR reform in a proximate country may affect the alliance activity of the firms in the focal country. To account for this we include a variable – *reformed neighbors* – which is a running count of the number of other countries in the same continent as the focal country which have passed meaningful patent reform based on our data.

We control for the number of *new domestic ties* that a firm generates in a particular year, measured as a logged count. While our interest is on the formation of international alliances, the investment made in domestic alliances can enable or constrain firms in establishing foreign ties. We also include a yearly measure of political constraint (*polcon*) in the focal country, which reflects the number of veto players present in the country's governing structure (Henisz 2000). This could influence the timing and nature of the laws passed as well as the degree to which firms are able to influence the government. We also control for the *FDI inflows* into the country and total *exports* of goods and services out of the country, as well as the country's *hi-tech exports*, measured as the dollar value of the country's exports in products with high R&D intensity as defined by the World Bank.

Quality of infrastructure could be an important facilitator of international alliances that may vary concurrently with the passage of IPR laws. To control for this we include the number of *cellphone connections* per 100 people as well as the *Internet connectivity* of the country measured as the number of Internet users per 100 people. We also control for the total number of commercial *flight takeoffs* during the year from the country's airports, which may proxy for the accessibility of the focal country to international markets. The relative wealth of the local population may also be a consideration for foreign firms interested in local markets, therefore we control for the country's *GNI per capita*. Finally, we include the proportion of the country's population living in urban areas (*urban population fraction*) as a proxy for ease of access to labor, which may influence the interest of foreign firms in forming alliances with local firms.

Since the timing of IPR changes across markets is a central part of the identification strategy (as explained next), the need for many control variables is not as strong as in a cross-

sectional or fixed-effects design. This is because many firm-specific factors that may impact tie formation or network structure are unlikely to coincide exactly with the timing of laws.

Design and Estimation

We consider each IPR law change to be a 'treatment' event and use a multiple event difference-in-difference design in which firms from countries in which the law change has not occurred act as controls for the firms in countries that have experienced a law change. As is typical for this research design, our primary independent variable, *post reform,* is an indicator equal to 1 for a particular firm in all the years following the passage of the law in its home country and 0 otherwise. The coefficient of this variable gives us the difference-in-difference estimate. In addition, some of the hypotheses are tested using a triple difference (difference-in-difference-in-difference) design by interacting *post reform* with a further indicator. For instance, in H1b we interact *post reform* with *patent intensive* and for H3 we interact *post reform* with *centrality*. The coefficient of these interactions reflects the additional 'difference' in how different types of firms react after IPR changes, further strengthening statistical inference.

This empirical design allows us to approach causality in our empirical claims. We are examining the pre- vs. post-treatment difference (the first difference) between the treated and control firms (the second difference). For our estimates to be biased we would require a violation of the parallel trends assumption, i.e. in the absence of treatment, the treated and control groups would have to display systematically different variation in outcomes (i.e. they would need to be trending differently) at the time of treatment (Angrist and Pischke, 2008). In other words, following the treatment year in question the firms from the treated countries would have to a display a systematically different change in their alliance behavior compared to the firms from the untreated countries *in the absence of treatment*. Furthermore, since our identification relies on multiple events rather than just one, this systematic difference would have to be consistent across all the events to bias our results.

The empirical identification assumes that the timing of the various law changes is exogenous across markets. To validate the parallel trends assumption and the exogeneity across

event timing, we break down the analysis by year using dummy variables to capture a series of years before and after the passage of the law. If the cause of our expected changes is the timing of the law, we should expect effects to happen after the year before the law is passed but not before then. That is, the pre-trend should be distinct from the post-trend. We thus generate a series of indicators in which *reform (t-4)* is equal to one for all firm year observations that are four or more years before the passage of the law in the focal country and zero otherwise. *Reform (t-3)* equals one for observations that are exactly three years prior to the passage of the law, and *reform (t-2)* is one for observations that are two years prior to passage. *Reform (t)* indicates the year of passage of the law while re*form (t+1), reform (t+2), reform (t+3)* and *reform (t+4)* analogously indicate one, two, three and four or more years following the passage of the law. The omitted year is the year before the passage of the law so that all the coefficients for these indicators show the effect (or the "difference") relative to that baseline year (see Branstetter et al. 2006).

Our estimates are rather conservative because the sample consists only of firms from countries that experience the 'treatment' at some point. Similar studies relying on multiple events often include firms from countries that never experience the treatment as additional 'controls', usually because the number of treated observations is too low to generate sufficient statistical power. The inclusion of non-treated observations is not technically incorrect, but it does introduce the possibility that the treated and never-treated groups suffer from unobserved heterogeneity that may violate the parallel trends or other identification assumptions. By including only firms from treated countries, the comparison sets are more homogenous, reducing concerns of unobserved variation and relying strictly on the exogeneity of timing across events. The combination of these considerations allows us to draw relatively strong inferences. In addition, all our models include firm fixed effects, eliminating time invariant unobserved heterogeneity between firms. We also include year fixed effects to control for macroeconomic effects that may cause fluctuations in global alliance activity.

RESULTS

Table 2 shows the summary statistics and correlations for our variables of interest. Table 3 shows the results for the models in which we examine the effect of the passage of the laws on new international alliance formation and the composition of firms' alliance networks. The positive and significant coefficient of *post reform* in model 1 is supportive of Hypothesis 1a ($p <$ 0.01), which suggested that the number of international ties that a firm has access to would rise with the strengthening of formal IPR protection in its home country. In model 2 we break down the effects by year using a set of dummy variables to indicate the time in relation to the year before the passage of the law.

INSERT FIGURE 1 HERE

Figure 1 shows the coefficients from model 2 plotted (with vertical lines indicating the 95% confidence interval). There is a significant rise in the number of international alliances corresponding exactly with the passage of the law (*reform (t)*). This spike is sustained at a significant level for one more year (*reform (t+1)*), following which the change becomes less evident.

INSERT TABLES 2 AND 3 HERE

Next, we examine the difference in the strength of this effect between firms from patent intensive and non-patent intensive industries. These results are shown in models 3 and 4. Hypothesis 1b suggested that firms from patent intensive industries would display a more pronounced increase in the number of international ties than those from non-patent intensive industries. The positive and significant coefficient of the triple difference term in model 3 lends support to this hypothesis ($p < 0.05$). In model 4 we break down this triple difference by year and observe that the statistical distinction between these groups spikes exactly coincident with the passage of the law (*patent intensity x teform (t)*). Further, the statistically significant distinction between them is sustained for at least three years following the passage of the law. These results offer some confidence that the mechanisms driving the changes are specifically related to IPR protection and not simply other factors correlated to IPR law changes.

Hypothesis 2 suggested that the passage of the law would facilitate access to a greater diversity of cross-national partners for firms in the focal country. This is tested in models 5 and 6. Now the dependent variable is *partner national diversity*. The positive coefficient of *post reform* in model 5 is in line with our expectation, though it is only marginally significant (p < 0.1). The timing effects in model 6 however demonstrate a clear spike in the national diversity of alliance partners following reform. Note that the spike in partner diversity appears to arrive in the year following the passage of the law but is sustained for longer than the changes observed in model 2 for the number of international partners. We explore this in more detail in the discussion section.

Table 4 displays how the effect of network centrality on the propensity to garner international ties changes following the passage of IPR laws. To do this we interact *post reform* with various measures of centrality. We do not use the centrality for years after the law was passed because post reform centrality itself is affected by the passage of the law, making it subject to the "bad control" problem that creates biased estimates (Angrist and Pischke, 2008). Instead, we interact *post reform* with centrality from the year prior to the passage of the law— this gets at our interest in whether the law "democratizes" tie formation by accruing fewer new ties to firms that were of high status in the network before the law was passed. As we observe from the negative and significant coefficients in models 7, 9 and 11, hypothesis 3 receives strong support (p < 0.001). The timing effects are shown in models 8, 10 and 12. They demonstrate that centrality plays an important role before the passage of the laws but a relatively insignificant role subsequent to law changes.

<div align="center">INSERT FIGURE 2 HERE</div>

Figure 2 charts the coefficients from model 10, clearly displaying this decline. The drop in the relevance of centrality as a determinant of tie formation appears to commence in the year prior to the passage of the law, after which it remains stable or continues to decline. We consider this further in the discussion.

<div align="center">INSERT TABLES 4 AND 5 HERE</div>

Table 5 shows the results for models using various measures of closure as the dependent variable. The positive and significant coefficients of the *post reform* variable in models 13, 15 and 17 lend support to Hypothesis 4 (p < 0.01 in all models), which suggested that firms would tend to adopt more closed networks following the passage of the law.

INSERT FIGURE 3 HERE

Models 14, 16, and 18 show that the increase in closure corresponded exactly with the passage of the laws, and Figure 3 displays these coefficients for network density (model 16). The spike in closure coincided exactly with the passage of the laws and the increase was sustained over time. We observed nearly identical effects across the different measures of closure.

INSERT TABLE 6 HERE

Table 6 contains the results from models in which we examine how centrality affects the change in closure post reform. All the models in table 6 use constraint as the measure of closure, though the results are practically unchanged when we use density or bridging ties as the DV. The results from table 5 demonstrated that on average closure clearly increases across all firms following the institution of reforms, in line with hypothesis 4. Models 19, 21 and 23 in table 6 interact the post reform dummy with different measures of centrality. We find a negative and significant coefficient on each of these interaction terms (p < 0.01 or lower) indicating that the increase in network closure following reform is significantly lower the higher the centrality of the firm in question. Models 20, 22 and 24 show the breakdown of these effects by year which further demonstrate how this change unfolds over time. We see the difference in levels of closure between firms that differ in centrality gets stronger and more negative immediately following the passage of the reforms. These results are strongly supportive of hypothesis 5. Figure 4 graphs the coefficients by year from the interactions terms in model 22.

INSERT FIGURE 4 HERE

Robustness Checks

We examine our results in a variety of alternative specifications and subsamples. We measure partner diversity as a logged count of the number of countries in which firms have

partners rather than as the Herfindahl based measure shown in models 5 and 6 and the results are robust. We also run the models in table 5 using a non-normalized count of bridging ties as the dependent variable and the results are practically unaltered. We use the European classification of patent intensive industries in place of the American one and find the results in models 3 and 4 to be qualitatively unchanged. Further, we include quite stringent county-year fixed effects rather than year fixed effects and find our results to be robust[3]. We replicate all our analyses after dropping firms from China and India, respectively, and find them all to be qualitatively unaltered. The only significant difference we observe is that the coefficient on the triple difference in model 3 is no longer statistically significant at the 0.05 level when the firms from China are dropped, though it is still positive and of a comparable magnitude. Further, for the models in table 4 that use centrality measures, we replicate the results using the centrality from 2 and 3 years before the passage of the law rather than the year before and find the results to be robust.

Despite these robust results our approach has limitations. An important concern would be that the observed effects could be driven by something unrelated to IPR protection. These regulatory changes do not occur in isolation: they are often accompanied by other events that could make the climate in the country more favorable for foreign firms or increase exposure to global competition. Though this concern is substantially alleviated by the fact that we base our identification on a range of events across different countries and the fact that the timing of the observed effects coincides precisely with treatment, it is not altogether eliminated. Further, almost all the countries in our sample are emerging or underdeveloped economies. This casts doubt over whether the results we observe may be generalizable institutional changes in more developed markets. What we observe can be best understood as local average treatment effects for the set of countries in our sample. Furthermore, our sample only consists of firms that have entered at least one alliance over the course of the study period. While this is not a particularly

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[3] Country-Year fixed effects are only feasible in models with triple differences as in all the other models they are collinear with the post reform variable.

stringent restriction in many industries, some industries do not engage in much alliance activity and may respond in other ways to IPR strengthening. Yet these non-network responses are beyond the scope of the study to begin with.

DISCUSSION

We examined the effect of the strengthening of laws protecting IPR on firms' alliance network structure and composition. Our findings suggest that stronger formal IPR protection does provide a significant boost to international alliance formation for firms from the country that passes the reforms. Further, we find that it also facilitates access to partners from a wider variety of countries. IPR protection also levels the playing field substantially in terms of access to international partners—under weaker formal protection centrality (as an alleged status signal) plays a critical role in determining the choice of partner. The strengthening of legal IPR protection however facilitates improved access to the global alliance network for more peripheral firms. We also find that network closure based security mechanisms take on increased importance following the strengthening of formal protection. This effect is more pronounced for firms that are of lower status. Following the reforms, a wide range of less prominent actors become active in the network. The absence of the threat of reputation loss as a disciplining mechanisms means that an alternative mechanism of protection needs to be employed by partners of these firms. Our results suggest that as a consequence they form more dense networks, thus drawing on the social monitoring and disciplining qualities of closed networks (Coleman 1988).

The examination of alliance formation using a natural experiment based diff-in-diff design is an important contribution of this study. While the "micro" transaction cost drivers of alliance formation are theoretically well understood (Hennart 1988; Williamson 1995), there have been few empirical studies attempting to establish a clear causal relationship between the "macro" regulatory environment (North 1990) and firms' propensities to collaborate. In this paper we are able to leverage a series of legal changes that happened in close succession to identify a spike in alliance activity corresponding precisely to the timing of formal IPR protection. This is an

important empirical validation of the macro-institutional theory of alliance formation as well as a solid foundation on which we build an examination of questions relating to network structure and the complementary or substitutable nature of macro institutions and informal network structures.

Scholars have highlighted the lack of empirical research examining the institutional origins of networks (Powell et al. 2005). This study is an important step towards the goal of understanding how institutional influences shape the way firms associate with each other.

The spike in the number of international alliances to which a firm has access is not sustained indefinitely. The number of new ties rises significantly for a couple of years and then returns to pre-IPR change levels. However, the breadth of countries from which the firm has partners is sustained for a longer period. These two results in combination would suggest that what is being observed is effectively a re-working of the firms' alliance networks following the environmental shift. There is most likely a certain baseline rate at which firms tend to form new relationships. While this rate is exceeded in the years immediately following the passage of the IPR strengthening law changes, firms cannot keep this up indefinitely due to simple resource and value-creation limits. However, these new ties lend a different complexion to the alliance network in terms of partner nationality, which is more sustainable than having a larger network.

An important theoretical contribution is to emphasize the distinction between different informal institutional mechanisms (signal- vs. information/norm-based) and how they respond to form institutions. Signal-based mechanisms of new tie formation have been well explored by organizational scholars (e.g. Podolny 1993; Gulati 1995). Firms tend to use status or reputation as a signal for trustworthiness. These signals take on greater importance with increasing altercentric uncertainty (Podolny 2001). As this uncertainty is mitigated by the passage of IPR laws, the signaling benefits of status in generating new ties declines, indicating a substation effect. Importantly, this results in a more egalitarian distribution in the new ties generated following the passage of the laws. We also observe that this effect starts to become observable in the year just prior to the passage of the law, which may be driven by anticipation on behalf of the firms in relation to the imminent law. An interesting direction in which to take this research

would be to examine if other uncertainty-lowering mechanisms have similar effects in diminishing the importance of status in new tie formation.

The other informal mechanism of IPR protection we explore is related to network closure, which constrains knowledge circulation and increases the odds of social norm enforcement. The perception in the literature has typically been that informal and formal mechanisms serve essentially the same purpose, despite notable exceptions (e.g. Poppo and Zenger 2002). Our study represents an important contribution to this literature in offering empirical support for the arguments that these mechanisms are in fact complementary. While formal legal protections are an important inducement for firms to collaborate, they do not appear to be sufficient in and of themselves to mitigate all security related concerns. It is likely that certain types of concerns are best addressed through formal protection whereas others require social mechanisms to be invoked. While contracts and courts are a valid deterrent to opportunistic behavior, scholars have shown that these are in reality rarely invoked explicitly (Eccles 1981; Mayer and Argyres 2004). Being embedded within a network of closely connected partners facilitates the process of making and enforcing these adjustments as well as creating a valid threat of social ostracism to ward off unilateral opportunistic behavior. Our results suggest that these mechanisms become more important as firms engage in more extensive and wide ranging collaborative activity, with strengthening of formal IPR protection serving as a means to increase the supply of such opportunities, particularly to peripheral firms which may be younger.

From a policy perspective, our results suggest that the introduction of formal IPR protections is beneficial for home country firms, particularly those in high technology industries, because it allows them to increase the odds of collaborations with foreign partners. Further, it also facilitates a leveling of the playing field in terms of which firms are able to obtain these collaborations. However, since network development is endogenously driven (firms display a tendency to form ties to others from within their own pre-existing networks), facilitating an entry point into valuable networks for local firms may help seed the process of generating international ties that may bring valuable technology and other resources to firms in locations with weak IPR.

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Figure 1: Effects of law change on number of new international ties by year (Model 2)
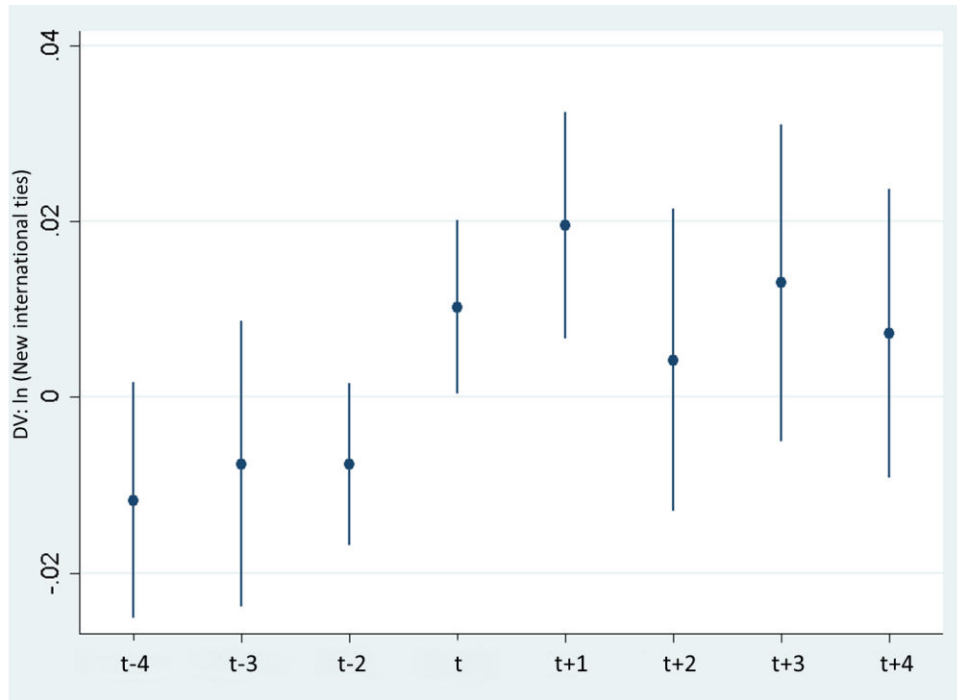
Figure 2: Effect of law change on the importance of centrality for future tie generation (Model 10)
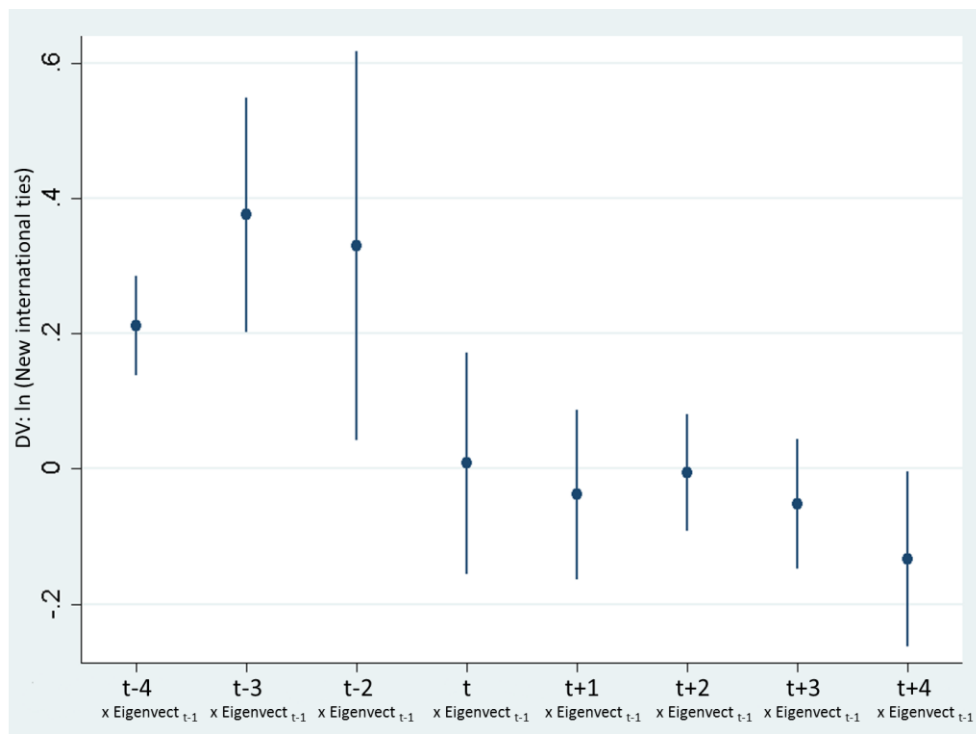
Figure 3: Effect of law change on ego network density by year (Model 18)
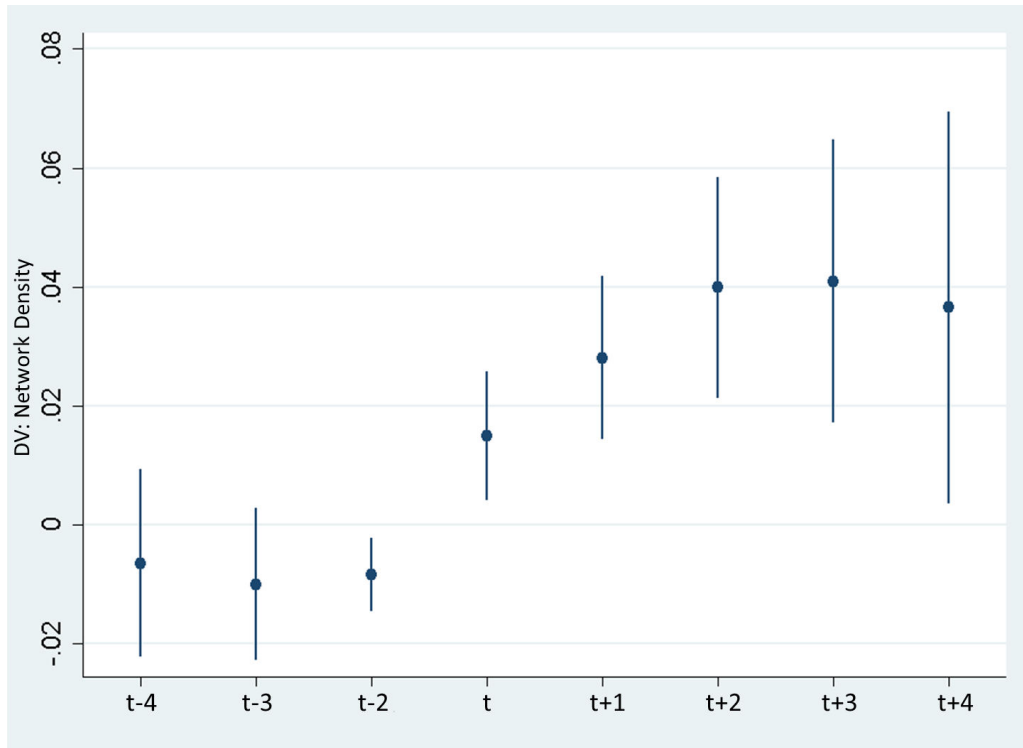
Figure 4: Moderating effect of centrality on closure following law change (Model 22)
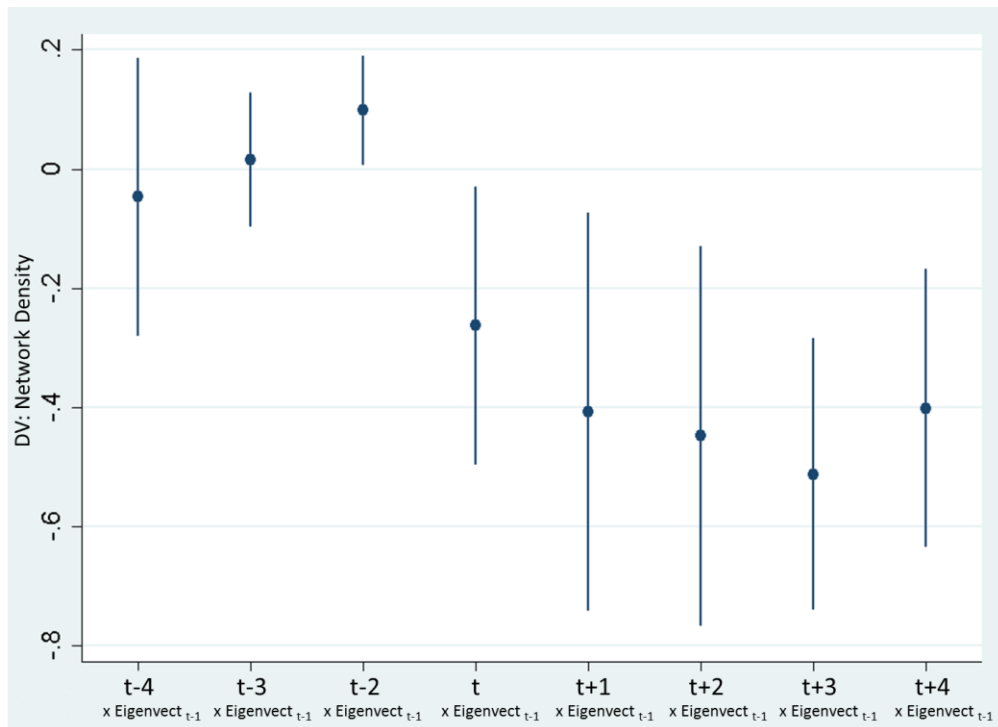
Table 1: Countries in sample and year of reform

Country	Year of reform
Argentina	1996
Brazil	1997
Chile	1991
China	1993
Colombia	1994
India	1999
Indonesia	1991
Mexico	1991
Philippines	1997
Portugal	1992
Thailand	1992
Turkey	1995
Venezuela	1994

Table 2: Summary Stats and Correlations

Sl No	Variable	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	New international ties b	0.046	0.203	0.000	3.401	1.000																					
2	Partner National Diversity	0.027	0.119	0.000	0.925	0.444	1.000																				
3	Network Constraint	0.159	0.352	0.000	1.125	0.392	0.307	1.000																			
4	Normalized bridging ties b	0.024	0.134	0.000	4.220	0.192	0.597	0.246	1.000																		
5	Network density	0.049	0.210	0.000	1.000	0.300	0.658	0.424	0.652	1.000																	
6	Degree	0.168	0.403	0.000	4.234	0.094	0.530	0.494	0.570	0.434	1.000																
7	Eigenvector Centrality	0.009	0.080	0.000	3.828	0.083	0.242	0.099	0.213	0.138	0.348	1.000															
8	Component Size	0.856	2.480	0.000	9.512	0.078	0.410	0.410	0.424	0.327	0.781	0.374	1.000														
9	Patent Intensive	0.197	0.398	0.000	1.000	0.021	0.004	0.049	-0.008	0.003	0.028	0.040	0.044	1.000													
10	New domestic ties b	0.022	0.145	0.000	2.565	0.328	0.324	0.256	0.173	0.336	0.055	0.039	0.043	-0.003	1.000												
11	Liberalization dummy	0.347	0.476	0.000	1.000	0.018	0.019	0.030	0.033	0.022	0.048	-0.002	0.034	-0.138	0.015	1.000											
12	Cap Flows openness	50.206	14.261	25.000	100.000	0.033	0.026	0.064	0.036	0.026	0.067	0.009	0.050	-0.093	0.035	0.577	1.000										
13	Reformed Neighbors	5.132	1.969	0.000	7.000	-0.008	0.032	0.037	0.018	0.022	0.071	0.029	0.051	0.071	0.022	-0.417	-0.164	1.000									
14	PolCon	0.316	0.342	0.000	0.890	0.009	0.010	0.022	0.010	-0.011	0.034	-0.008	0.026	-0.080	0.017	0.465	0.319	-0.173	1.000								
15	FDI Inflows	0.187	0.195	-0.046	0.621	0.001	0.013	0.056	0.014	0.030	0.057	0.027	0.045	0.082	0.004	-0.494	-0.232	0.386	-0.670	1.000							
16	Hi-Tech Exports	0.353	0.640	0.000	2.731	-0.035	-0.026	-0.016	-0.021	-0.027	-0.007	0.014	-0.021	0.050	-0.014	-0.313	-0.029	0.407	-0.434	0.754	1.000						
17	Cellphone Connections b	1.146	1.211	0.000	4.624	-0.056	-0.045	-0.006	-0.019	-0.038	0.033	0.007	-0.003	-0.029	-0.021	0.229	0.294	0.256	-0.013	0.397	0.591	1.000					
18	Exports b	2.977	0.493	1.887	4.258	0.004	0.031	0.037	0.048	0.046	0.078	0.020	0.051	-0.060	0.024	0.456	0.250	0.192	-0.124	0.077	0.244	0.462	1.000				
19	GNI per capita b	-0.025	0.879	-1.109	2.780	0.002	-0.007	0.048	0.021	0.005	0.063	-0.001	0.039	-0.107	0.003	0.716	0.588	-0.441	0.336	-0.015	0.099	0.566	0.317	1.000			
20	Internet connectivity b	0.748	0.876	0.000	3.569	-0.056	-0.046	-0.014	-0.028	-0.049	0.024	0.004	-0.011	-0.045	-0.023	0.313	0.360	0.223	0.157	0.163	0.451	0.919	0.430	0.515	1.000		
21	Flight takeoffs b	0.928	0.825	-1.005	2.493	-0.015	-0.006	0.029	-0.011	-0.001	0.027	0.019	0.019	0.093	-0.012	-0.521	-0.269	0.337	-0.581	0.862	0.680	0.342	-0.166	-0.065	0.161	1.000	
22	Urban Pop. Fraction b	1.328	0.364	0.938	2.196	-0.007	-0.028	0.020	-0.006	-0.018	0.023	-0.005	0.011	-0.106	-0.015	0.643	0.489	-0.515	0.277	-0.051	0.025	0.436	0.103	0.852	0.458	-0.021	1.000

N = 166080. All correlations of absolute magnitude >0.02 are significant at the p<0.05 level

b: Logged Variable

Table 3: Effect of IPR Law Change on International Tie Formation

	DV: New international ties [b]		DV: New international ties [b]		DV: Partner National Diversity [c]	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Post Reform	**0.0169****		**0.0159****		**0.0083+**	
	(0.0046)		**(0.0045)**		**(0.0046)**	
Patent Intensity x Post Reform			**0.0061***			
			(0.0026)			
Reform (t-4)		-0.0078		-0.0084		-0.0037
		(0.0072)		(0.0072)		(0.0038)
Reform (t-3)		-0.0060		-0.0073		-0.0021
		(0.0086)		(0.0082)		(0.0029)
Reform (t-2)		-0.0064		-0.0067		-0.0022
		(0.0052)		(0.0052)		(0.0024)
Reform (t)		**0.0104***		0.0081		0.0036
		(0.0045)		(0.0049)		(0.0035)
Reform (t+1)		**0.0203****		0.0159*		**0.0090+**
		(0.0059)		(0.0057)		**(0.0043)**
Reform (t+2)		0.0052		0.0015		**0.0137****
		(0.0080)		(0.0085)		**(0.0043)**
Reform (t+3)		0.0136		0.0121		**0.0160***
		(0.0081)		(0.0080)		**(0.0063)**
Reform (t+4)		0.0082		0.0083		0.0146
		(0.0068)		(0.0068)		(0.0085)
Patent Intensity x Reform (t-4)				0.0025		
				(0.0040)		
Patent Intensity x Reform (t-3)				0.0082		
				(0.0091)		
Patent Intensity x Reform (t-2)				0.0023		
				(0.0050)		
Patent Intensity x Reform (t)				**0.0139***		
				(0.0049)		
Patent Intensity x Reform (t+1)				**0.0263*****		
				(0.0051)		
Patent Intensity x Reform (t+2)				**0.0229*****		
				(0.0048)		
Patent Intensity x Reform (t+3)				**0.0126+**		
				(0.0066)		
Patent Intensity x Reform (t+4)				0.0015		
				(0.0038)		
Controls	Y	Y	Y	Y	Y	Y
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Number of Observations	166080	166080	166080	166080	166080	166080
Number of firms	11072	11072	11072	11072	11072	11072

b: Logged Variable; c: Partner National Diversity is a Herfindahl type measure of the spread of a firm's partners across countries; Standard errors reported in parentheses are Heteroscedasticity robust and clustered by country

Table 4: Effect of centrality on new international tie formation post reform

DV: New international ties $_b$	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Post Reform	0.0431***		0.0208***		0.0358***	
	(0.0052)		(0.0046)		(0.0050)	
Degree ^c_b x Post Reform	-0.1202***					
	(0.0104)					
Eigenvector ^{c} x Post Reform			-0.2899***			
			(0.0435)			
Component Size ^c_b x Post Reform					-0.0149***	
					(0.0016)	
Reform (t-4)		-0.0275**		-0.0113		-0.0222**
		(0.0077)		(0.0070)		(0.0070)
Reform (t-3)		-0.0399**		-0.0113		-0.0298*
		(0.0097)		(0.0088)		(0.0100)
Reform (t-2)		-0.0394***		-0.0102		-0.0288**
		(0.0074)		(0.0058)		(0.0068)
Reform (t)		0.0172**		0.0112*		0.0161**
		(0.0054)		(0.0048)		(0.0051)
Reform (t+1)		0.0326***		0.0221**		0.0302***
		(0.0070)		(0.0060)		(0.0061)
Reform (t+2)		0.0195*		0.0070		0.0155+
		(0.0071)		(0.0075)		(0.0072)
Reform (t+3)		0.0308**		0.0161+		0.0262**
		(0.0086)		(0.0079)		(0.0085)
Reform (t+4)		0.0272*		0.0112		0.0221*
		(0.0100)		(0.0068)		(0.0087)
Centrality Measure [1] x Reform (t-4)		0.0772**		0.2112***		0.0091**
		(0.0202)		(0.0339)		(0.0026)
Centrality Measure [1] x Reform (t-3)		0.1401***		0.3751***		0.0166***
		(0.0186)		(0.0796)		(0.0028)
Centrality Measure [1] x Reform (t-2)		0.1837***		0.3293*		0.0209**
		(0.0415)		(0.1317)		(0.0059)
Centrality Measure [1] x Reform (t)		0.0009		0.0083		-0.0011
		(0.0156)		(0.0751)		(0.0018)
Centrality Measure [1] x Reform (t+1)		-0.0121		-0.0379		-0.0032+
		(0.0122)		(0.0574)		(0.0015)
Centrality Measure [1] x Reform (t+2)		-0.0193		-0.0061		-0.0026
		(0.0130)		(0.0394)		(0.0018)
Centrality Measure [1] x Reform (t+3)		-0.0285**		-0.0521		-0.0040*
		(0.0086)		(0.0442)		(0.0014)
Centrality Measure [1] x Reform (t+4)		-0.0548**		-0.1338*		-0.0072**
		(0.0147)		(0.0594)		(0.0022)
Controls	Y	Y	Y	Y	Y	Y
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Number of Observations	166080	166080	166080	166080	166080	166080
Number of firms	11072	11072	11072	11072	11072	11072

b: Logged Variable   c: Variable is measured in the year before the passage of the regulation

1: The 'Centrality Measure' is different for Models 18, 20 and 22. In Model 18 it is degree, in Model 20 it is Eigenvector and in Model 22 it is Component size, all of which are measured in the year prior to the passage of the law

Standard errors reported in parantheses are heteroscedasticity robust and clustered by country

Table 5: Effect of IPR Law Change on Network Closure

	DV: Network Constraint		DV: Normalized Bridging Ties b c		DV: Network Density	
	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
Post Reform	**0.0602****		**0.0196****		**0.0253****	
	(0.0166)		**(0.0047)**		**(0.0068)**	
Reform (t-4)		-0.0398+		-0.0073		-0.0113
		(0.0193)		(0.0063)		(0.0084)
Reform (t-3)		-0.0097		-0.0075		**-0.0112+**
		(0.0156)		(0.0043)		**(0.0063)**
Reform (t-2)		0.0012		**-0.0071****		**-0.0089***
		(0.0119)		**(0.0022)**		**(0.0034)**
Reform (t)		**0.0294***		0.0100+		**0.0122***
		(0.0104)		(0.0048)		**(0.0055)**
Reform (t+1)		**0.0645*****		**0.0179****		**0.0250****
		(0.0118)		**(0.0052)**		**(0.0063)**
Reform (t+2)		**0.0997*****		**0.0275*****		**0.0375*****
		(0.0122)		**(0.0057)**		**(0.0064)**
Reform (t+3)		**0.0968*****		**0.0326****		**0.0392*****
		(0.0182)		**(0.0092)**		**(0.0088)**
Reform (t+4)		**0.0777****		**0.0266***		**0.0378***
		(0.0222)		**(0.0118)**		**(0.0137)**
New domestic ties b	0.5674***	0.5672***	0.0816***	0.0817***	0.4196***	0.4197***
	(0.0349)	(0.0352)	(0.0188)	(0.0185)	(0.0365)	(0.0367)
Liberalization dummy	0.0059	-0.0099	0.0064	0.0062	0.0109	0.0106
	(0.0137)	(0.0141)	(0.0071)	(0.0067)	(0.0087)	(0.0071)
Cap Flows openness	0.0001	0.0001	0.0000	0.0001	-0.0000	0.0000
	(0.0003)	(0.0004)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Reformed Neighbors	-0.0033	-0.0054	-0.0023	-0.0027	-0.0022	-0.0032
	(0.0056)	(0.0076)	(0.0020)	(0.0021)	(0.0035)	(0.0034)
PolCon	0.0586	0.0494	0.0275	0.0279*	0.0219	0.0232
	(0.0384)	(0.0299)	(0.0173)	(0.0116)	(0.0236)	(0.0153)
FDI Inflows	0.1465	0.1275	0.0052	-0.0063	0.0515	0.0386
	(0.1327)	(0.1171)	(0.0453)	(0.0470)	(0.0507)	(0.0559)
Hi-Tech Exports	0.0091	0.0194	-0.0009	0.0057	-0.0129+	-0.0030
	(0.0174)	(0.0126)	(0.0063)	(0.0074)	(0.0073)	(0.0094)
Cellphone Connections b	-0.0307	-0.0201	-0.0010	-0.0012	-0.0055	-0.0063
	(0.0230)	(0.0248)	(0.0097)	(0.0097)	(0.0117)	(0.0118)
Exports b	0.0394	0.0227	0.0227*	0.0132+	0.0388*	0.0225+
	(0.0295)	(0.0232)	(0.0098)	(0.0074)	(0.0139)	(0.0121)
GNI per capita b	0.0341	0.0085	0.0295	0.0173	0.0372	0.0182
	(0.0566)	(0.0380)	(0.0197)	(0.0149)	(0.0238)	(0.0165)
Internet connectivity b	0.0185	0.0201	0.0071	0.0088	0.0133	0.0158
	(0.0275)	(0.0288)	(0.0113)	(0.0110)	(0.0139)	(0.0141)
Flight takeoffs b	0.0295	0.0252	-0.0049	-0.0051	-0.0002	-0.0003
	(0.0257)	(0.0238)	(0.0083)	(0.0083)	(0.0105)	(0.0096)
Urban Pop. Fraction b	-0.3521*	-0.2444+	-0.0401	-0.0292	-0.0462	-0.0341
	(0.1456)	(0.1279)	(0.0463)	(0.0392)	(0.0581)	(0.0480)
Constant	0.3172+	0.2536+	-0.0009	0.0118	-0.0289	0.0007
	(0.1734)	(0.1362)	(0.0644)	(0.0518)	(0.0830)	(0.0692)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Number of Observations	166080	166080	166080	166080	166080	166080
Number of firms	11072	11072	11072	11072	11072	11072

b: Logged Variable; c: Normalized bridging ties are calculated as count of bridging ties / degree; Standard errors reported in parentheses are heteroscedasticity robust and clustered by country

Table 5: Effect of centrality on change in network closure post reform

DV: Constraint	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24
Post Reform	0.1248***		0.0654**		0.1097***	
	(0.0134)		(0.0167)		(0.0149)	
Degree ^c_b x Post Reform	-0.2959***					
	(0.0251)					
Eigenvector ^{c} x Post Reform			-0.3897**			
			(0.0978)			
Component Size ^c_b x Post Reform					-0.0390***	
					(0.0037)	
Reform (t-4)		-0.0294		-0.0412*		-0.0353+
		(0.0213)		(0.0184)		(0.0196)
Reform (t-3)		-0.0488*		-0.0115		-0.0434*
		(0.0163)		(0.0156)		(0.0150)
Reform (t-2)		-0.0336**		-0.0006		-0.0295*
		(0.0095)		(0.0119)		(0.0099)
Reform (t)		0.0695***		0.0327**		0.0605***
		(0.0092)		(0.0105)		(0.0102)
Reform (t+1)		0.1411***		0.0696***		0.1213***
		(0.0117)		(0.0122)		(0.0143)
Reform (t+2)		0.1871***		0.1056***		0.1643***
		(0.0115)		(0.0125)		(0.0141)
Reform (t+3)		0.1935***		0.1036***		0.1681***
		(0.0163)		(0.0177)		(0.0160)
Reform (t+4)		0.1665***		0.0835**		0.1446***
		(0.0227)		(0.0217)		(0.0199)
Centrality Measure [1] x Reform (t-4)		-0.1405*		-0.0471		-0.0159+
		(0.0501)		(0.1073)		(0.0087)
Centrality Measure [1] x Reform (t-3)		0.0599		0.0160		0.0107
		(0.0931)		(0.0517)		(0.0116)
Centrality Measure [1] x Reform (t-2)		0.1234*		0.0981*		0.0202**
		(0.0477)		(0.0419)		(0.0049)
Centrality Measure [1] x Reform (t)		-0.1646***		-0.2626*		-0.0221***
		(0.0320)		(0.1068)		(0.0047)
Centrality Measure [1] x Reform (t+1)		-0.3565***		-0.4071*		-0.0449**
		(0.0616)		(0.1535)		(0.0104)
Centrality Measure [1] x Reform (t+2)		-0.4005***		-0.4481**		-0.0497***
		(0.0645)		(0.1459)		(0.0106)
Centrality Measure [1] x Reform (t+3)		-0.4107***		-0.5122***		-0.0507***
		(0.0577)		(0.1044)		(0.0097)
Centrality Measure [1] x Reform (t+4)		-0.3683***		-0.4018**		-0.0470***
		(0.0524)		(0.1070)		(0.0093)
Controls	Y	Y	Y	Y	Y	Y
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Number of Observations	166080	166080	166080	166080	166080	166080
Number of firms	11072	11072	11072	11072	11072	11072

b: Logged Variable   c: Variable is measured in the year before the passage of the regulation

1: The 'Centrality Measure' is different for Models 18, 20 and 22. In Model 18 it is degree, in Model 20 it is Eigenvector and in Model 22 it is Component size, all of which are measured in the year prior to the passage of the law

Standard Errors reported in parentheses are heteroscedasticity robust and clustered by country