Helpful Thirds and the Durability of Collaborative Ties*

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May 18, 2017

Abstract

Collaboration is increasingly the norm in many creative domains. Among collaborative ties, repeated ones are especially beneficial as they entail fewer frictions, facilitate greater amounts of information transfer, and engender more trust – all contributing to more creative outputs. Prior studies have found that dyads embedded in triads have considerably longer lasting collaborations, but the mechanisms remain unclear. We elaborate on triadic closure: a social configuration where all individuals in a group are strongly linked to each other. We build on the work of **?** as well as others and theorize that two forms of closure exist, *weak* and *strong*. We argue that weak closure keeps triads intact because of the active relational efforts of third parties, whereas strong closure incorporates norms of helpfulness and generalized exchange, thereby facilitating durable group solidarity. Using a novel research design that considers the unexpected death of a third party as an exogenous event that takes away the active relational efforts of a third party, we find in accordance with our arguments that 1) working with a helpful actor is likely to increase ego's own helpfulness and 2) dyads that lose helpful third parties have significantly more durable collaborations compared to dyads that lose non-helpful third parties. The results of our work extend the growing literature on the relationship between norms and networks.

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The authors would like to thank Pierre Azoulay, Waverly Ding, Emily Erikson, Frank Flynn, Ozgecan Kocak, David Krackhardt, James Lincoln, Olav Sorenson, David Waguespack, and workshop and seminar audiences at Stanford GSB, INSEAD, National University of Singapore, and Brigham Young University.

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Introduction

Sociologists have long recognized the importance of social networks in influencing individual, organizational, and market behaviors. For example, network mechanisms shape social and economic processes in industrial clusters (e.g., ??), scientific innovation (e.g., ??), career advancement (e.g., ??), and creative production (e.g., ??). Although the specific mechanisms have varied across studies and contexts, prior research has primarily treated the causal forces driving network effects as structural, with network configurations placing constraints on or enabling social action (???). However, growing awareness exists in the literature that *how* networks enable or constrain depends on prevailing cultural norms within specific contexts (e.g., ???). Thus, a key challenge for social theory is understanding how different norms are established in structurally similar networks, and how these differences shape social dynamics.

Although scholars have posited that norms shape how individuals understand and use their networks (e.g., ???), compelling theoretical accounts of how particular norms take hold and shape network processes are largely missing in the literature (?). In most research, scholars assume that normative variation emanates from pre-existing differences in role expectations (e.g., ?), organizational culture (e.g., ?), or national culture (e.g., ???). The focus on these larger cultural environments has lead to a relative neglect of pertinent differences across subgroups and network clusters (?????).

Contributing to these efforts to understand the relationship between networks and norms, we consider how normative variation in networks shapes an important social process: the long-term persistence of social ties (???). Given that persistent, repeated interaction has been understood as a sign of a strong relationship and has also been linked to trust, altruism, joint problem solving, and exchange of goods and information (??????) it is important to understand the structural and normative antecedents of tie persistence. Specifically, we examine how network processes shape variation in norms of helpfulness across clusters of research scientists and how these differences in turn shape long-term patterns of collaboration. We take as our theoretical starting point the argument of **?** that *third parties* play an important role in the creation and persistence of social ties. While there exists a large literature building on Simmel's insights about third parties, much of the literature has focused on the role of the third party as a *broker* who benefits by keeping individuals apart (e.g., **??**). However, **?** also suggests that third parties facilitate *closure* by bringing and keeping people together (**?**). We build on Simmel's insight that the *triad*—a social form where three individuals are tied to each other—establishes a micro environment conducive to long-term relational endurance (e.g., **???**).

We argue that the third party creates closure and thus stability in two ways. First, third parties keep others together by actively mediating their conflicts and reconciling opposing perspectives (**????**). Second, third parties facilitate the development of shared identities, culture, and norms in the triad (**??**). These shared understandings can shape behavior even without active third party involvement and shift the interests and incentives of individuals away from themselves to the larger group (**?**).

Hence, we theorize that dyads embedded in a triad develop norms conducive to collaboration and relational endurance if the third party can facilitate the emergence of cooperative norms in that triad. Specifically, we propose that actors are likely to become more helpful if they are tied to other helpful actors, relative to non-helpful ones (**???????**). Further, we argue that dyads tied to helpful third parties are thus more likely to develop helpful norms and hence are likely to be better able to withstand the disintegrating effects of conflict, inequity, and misaligned incentives on their relationships even if active intervention by the third party is absent (**??**). Consequently, variation in third party helpfulness leads to two different predictions about the long-term durability of social groups that we argue correspond to two different types of closure, *weak* and *strong*. Under *weak closure*—where third parties actively monitor, but cooperative norms do not exist—the dyad will dissolve if the third party is not actively involved. Conversely, under *strong closure*—where cooperative norms also shape behavior—the dyad will continue to act as one social unit and the social tie will endure even without the active third.

However, strong and weak closure are difficult to separate in intact triads since active relational efforts and established cooperative norms may be concurrently operating. Thus, to distinguish between the weak and strong versions of closure, we analyze a special social situation: triads that transition into dyads due to the loss of a member. In this situation, active relational efforts by the third party are effectively "shut off." We argue that, absent an effortful third party, dyads that have adopted cooperative norms will have more durable collaborations (**???**). However, testing this claim is difficult due to considerable empirical challenges. First, to facilitate causal inference, the transition of a triad to a dyad must be an exogenous event (**??**), that is, uncorrelated with preexisting characteristics of the third party, the dyad, and the social environment. Second, variation in cooperative norms is often difficult to observe in field settings since cooperative norms are often subtle or invisible to the researcher. Indeed, most rigorous work on cooperative norms has been conducted in laboratory settings or with "lab-in-the-field" designs (e.g., **??**). Finally, a valid test of the effect of cooperative norms on network dynamics would require linking differences in the helpfulness of third parties to long-term dynamics in social interaction for the focal dyad. Consequently, data must be be available about whether members of a dyad continue their interaction (**?**).

We use a novel research design to asses the relationship between helpful third parties and the durability of social ties. Our context is scientific collaboration in the university setting, a rich context for studying helpfulness and collaboration. Suitably, scientific collaboration displays different degrees of helpful behaviors and levels of collaboration (**?**). We employ a unique dataset comprising the scientific collaborations—published articles in peer-reviewed journals—between 11,084 pairs of research immunologists who lost a third collaborator due to an unexpected death. We argue that these deaths are exogenous and essentially random (e.g., **??**). Our results strongly indicate that dyads whose departed third was helpful—as indicated by acknowledgements in journal articles—continue to collaborate after the third party's passing. On the other hand, dyads whose departed third was non-helpful, experienced a substantial drop in their probability of repeat collaboration. Our results provide evidence that variation in the helpful behavior of third parties produces different types of closure, which in turn produces different long-term social dynamics.

Theory and Hypotheses

Sociologists have recently begun to consider the role that culture plays in network processes (**??**). One strand of this work has focused on understanding how culture and norms—often national or organizational—shape how individuals build, sustain, and use their networks (e.g., **???**). Another strand of this literature has viewed networks as incubators of culture, wherein norms, expectations, and beliefs are shaped through processes of social interaction (e.g., **?**). At a theoretical level, many scholars agree that culture and networks shape each other and then jointly shape individual behavior and outcomes (**??**).

As far back as **?**, closed triads have been viewed as loci for both cultural and network processes and are qualitatively different from dyads. Whereas in a dyad each member is a participant in every interaction, in a closed triad each member can observe the interactions of the other two and every interaction of hers with one of the other two can be observed by the remaining third member. Interactions in dyads embedded in triads have thus been found to conform more strongly to norms than interactions in dyads without such embedding (**???**). Hence, we focus our theorizing of the relationship between cooperative norms and networks on *closed triads*. We thus emphasize Simmel's insights on the stability of triads and the role of the third party as someone who brings others together, facilitates closure, and mediates conflicts (**?**, pp. 135-153; see also **?**) rather than separates others (**?**, pp. 154-169; see also **?**).

Third Parties, Closure, and Relational Stability

Third parties as Active Facilitators — Network structures are often unstable (**???**). The diverging interests of actors in the network, conflict over scarce resources, and the costliness of coordinating the activities of diverse individuals all create opportunities for network ties to decay (**?**). Yet, despite these built-in sources of instability, sociologists have found many instances where network ties and social groups appear to endure even the most destabilizing forces (**??????**). What leads to such stability? One important mechanism promoting endurance is an actor who actively mediates conflicts between others and facilities collaboration (**??**). These actors purposefully encourage certain behaviors while curtailing others. Thus, **?** argues a triad is potentially more stable than a dyad for three reasons: the limiting of individualism, bargaining power, and the mitigation of conflict.

First, third parties limit individuality by creating situations where any one individual's preferences are not valued over the triad's. In most contexts, individuals are motivated to act in ways that optimize their own outcomes. This latter situation arises because of both innate preferences (e.g. **??**) but also larger incentive systems in organizations and societies (e.g., **?**). For example, researchers may prefer to keep results secret, not provide advice, or limit the sharing of their data (**?**). In organizations characterized by tournaments for status, wages, or power, individuals maximize their outcomes over that of the collective by strategically claiming credit or limiting the help they provide to their colleagues (**?**). Even more subtle behaviors such as the allocation of time on individual versus group activities may result from incentives that encourage self-interest. In all these cases, third parties can constrain this tendency by forming coalitions with others to exert pressure on the individual to behave according to group interests (?).

Second, third parties limit bargaining power by making the threats of any one individual hollow in the face of joint opposition from others in the group. For instance, individual demands such as those for resources, credit, or other preferences are less compelling in a triad. Third parties, because they can align with other group members (giving them greater strength in numbers), can effectively neutralize the effectiveness of an individual alters' demands (?). Further, any threats by an individual to leave the group over such demands are made weaker because of the resulting isolation she will face from the third party and the other member of the triad. Thus, one individual holds little sway over how the group behaves.

Finally and most importantly for us, third parties can limit conflict by resolving disputes and realigning interests towards the triad (?, pp.145-153). Because the third party is viewed as impartial, she can help the disagreeing parties arrive at solutions in the interest of the group (??). A third party does this by presenting conflicting positions in a rational way, stripped of their affective qualities. Doing so allows the disputing parties to see each others' positions with more clarity, thereby increasing the likelihood that group members remain aligned and conflict is resolved (??). Furthermore, a trusted third can herself unilaterally impose a decision that resolves a conflict. Her distance from the conflict allows her to impartially weigh the merits of each position and each individual's interests. Finally, the mere presence of another party can lead to more conformist behavior (?), preemptively reducing the likelihood of conflict.

Through these three activities, a third party can facilitate collaboration by constraining the self-interested tendencies of individuals and reorienting behavior towards group interests and group cohesion.

Third Parties and Norms — The sociological literature defines norms in several ways, but most scholars agree that norms "specify appropriate and inappropriate behavior" and that they "govern conduct in social situations" (?). In practice, norms are the rules that members of a social group use to guide their behavior (**??????**). While there are broader social norms, each group also develops norms particular to itself, emerging out of the actual behavior within the group (**?**) where habitualized patterns of action come to be seen as the natural ways of doing things (**?**). When new members join a group, they learn the group norms through interaction, observation, and active socialization (**??**).

However, while all groups develop some kinds of norms, not all group norms are conducive to collaboration (**?**). **?**, for instance, notes that cooperative norms are unevenly distributed, with some contexts exhibiting more of them than others. This variation in cooperative norms has been found even in isolated hunter-gatherer communities (**?**). Or, as **?**, p. 41 wrote: "Hence, cooperation compels changes in the motives of individuals which otherwise would not take place. So far as these changes are in a direction favorable to the cooperative system they are resources to it. So far as they are in a direction unfavorable to cooperation, they are detriments to it or limitations of it."

A third party who mediates conflicts within the group thus has the potential to shape the norms of collaboration within the group through her behavior and example, but not all third parties are likely to shape the norms in the same way. For instance, some third parties may establish norms more consistent with self-interest and others may establish more helpful norms, shifting the behavior of group members to behaviors more aligned with group interests. Hence, in some groups, only *weak closure* exists; the group is held together by the active efforts of the third party. Absent the third party's active involvement in a relationship, self-interest reemerges and begins to create divergences in interests and unmitigated conflict. On the other hand, the presence of cooperative norms offers an alternative prediction. If norms are referenced independently of active third party reinforcement, then they should affect dyadic interaction and collaboration even after a third party is no longer present (**??**). Consequently, norms can continue to serve as mechanisms for resolving conflict or coordinating activity. Thus, *strong closure* shapes interaction and may cause interactions to persist even if third parties are not actively facilitating. Accordingly, two opposing predictions emerge regarding the fate of a dyad in the presence of weak versus strong closure:

Hypothesis 1a: *Under weak closure, when the persistence of collaboration relies on active faciliation, the probability of a collaboration between A and B declines after active third party facilitation is shut off.*

Hypothesis 1b: *Under strong closure, when the persistence of collaboration relies on the presence of collaborative norms, the probability of a collaboration between A and B does not decline after active third party facilitation is shut off.*

It is important to note two points, one empirical and the other theoretical. First, an intact triad is not a useful empirical unit for distinguishing between these two types of closure. Within intact triads, active facilitation and norms are indistinguishable to an outside observer. Second, from a theoretical perspective, the *third party* is not any specific individual in a triad, but it is a role played by each member of any triad in relation to the other two members of the triad.

Third parties, Helpfulness, and Social Learning

A key challenge in separating the two forms of closure is theorizing about third party behaviors that engender strong closure in triads. We will theorize this in two steps. First, based on recent empirical evidence, we argue that the process of working with a helpful alter increases ego's own helpfulness and thus diffuses helpfulness in the local network. Second, we argue that a group that has evolved norms of helpfulness will exhibit greater collaborative durability.

At the level of the individual person, research has found that although individuals vary in their tendency toward collaborative behavior partly because of innate personality differences, features of their environments strongly affect this tendency (?). Early work by social psychologists found that cooperative norms are learned or emerge through social processes (e.g., ???). More recently, evidence is emerging that cooperative behaviors, such as helping, spread within groups and networks in two ways: through generalized reciprocity and third-party influence.

Recent research suggests that people are more generous to others if they themselves are beneficiaries of someone else's generosity (???????). This process is known as generalized reciprocity, or pay-it-forward behavior where A's helping of B makes B more likely to help C, and is present in a variety of settings (e.g., ???).

A second body of research has found that the public behaviors of social referents can cause individuals to perceive and adopt behaviors they view as norm-based (??????). ?, for example, argues that individuals regularly use social cues—through others' words and actions—to make judgments about what is appropriate or not. In the context of cooperative behavior, C seeing A helping B makes C more likely to help D (??). These inferences of "normal behavior" shape not only short-term behavior by causing individuals to align their own actions to those of their reference groups (e.g., ?), but they also shape long-term cooperative norms (e.g., ?).

In the context of scientific production, helpfulness often takes the form of material or intellectual support to others without an expectation of direct reciprocity (??). Such helpfulness can take several forms and can vary in how costly the behavior is to the helpful scientist. At one extreme, the helpful scientist neither expects nor receives something in return from the receiver (??). For example, a fellow scientist could benefit her colleagues by providing comments and feedback on research ideas, grants, and drafts, but without the assignment of credit. Critiques of this sort serve as intellectual inputs into the production of knowledge. Helpful scientists could also provide more costly forms of support such as rare specimens, cell lines, data, or knowledge of a test or procedure that she shares with others without expecting co-authorship (?). Based on the above, being a recipient of such helpfulness or a close observer of it is thus likely to increase ego's own helpfulness towards others. We thus hypothesize:

Hypothesis 2: *An ego who collaborates with a helpful alter is likely to become more helpful.*

In closed groups, chains of generalized reciprocity can lead to the emergence of norms emphasizing generalized exchange over direct exchange (e.g., **?**). Individuals help others even if they have not received help from these others before *or* expect to be helped by them soon. As more group members exhibit helpful behavior, that behavior is reinforced in others (**?**), potentially becoming an emergent norm.

What is then needed is for someone to initiate helpful behavior (**?**). While unconditional helpfulness by an individual is likely to be taken advantage of in isolated dyads (**??**), in a closed group unconditionally helpful actors are more likely to induce others to help and to create cooperation (**?**), potentially leading to norms of helpful behavior becoming established (**?**). Thus, a group can develop helpful norms if a member exhibits public displays of helpful behavior and members of the group are recipients of this behavior, and pay it forward, or perceive such behavior as normative. Conversely, a group without an individual initiating helpful behavior is less likely to engage in collaborative generalized exchange.

In a closed group, a shared normative understanding regarding helpfulness can eventually lead to solidarity, a shared identity, and continued cooperation within the group (**????**). Group members then increasingly view and interpret their relationships, not as consisting of individuals and the connections between them, but rather as a distinct collective entity (**?**). Homans witnessed the unifying effect of this general helpfulness in the bank wiring room (**?**, p.118):

> There were few occasions when helping another man was required by the

> necessities of the work – indeed it was forbidden by the company; yet it took place just the same, and many of the men testified that helping and being helped made them feel better. Everyone took part in helping; it was not confined, as were some other activities, to the soldering units. In fact it was one of the activities that united the whole group instead of dividing it into cliques...

When relationships are not seen in isolation but rather as constituent parts of a durable group, they can more readily tolerate imbalance, inequity and conflict. This strengthened emphasis on the group leads to greater positive affect toward the group, reduced differentiation between one's own outcomes and the group's outcomes, and greater levels of exchange within the group even if better outside alternatives exist (**???**).

Such shifts in how individuals perceive a relationship should also change the nature and strength of dyadic ties (**?**). Helpful norms are likely to make a tie both stronger as well as multiplex (**?**). Individuals in strong and multiplex relationships will interact intensely in both professional and social capacities. Further, individuals will have greater affection for each other, independent of instrumental reasons for interaction (e.g., **?**) and the resulting ties are likely to be characterized by greater motivation to help, support, and resolve any problems that might arise in the relationship (e.g., **?**). These behavioral changes to the interaction will not only strengthen each dyadic tie, but also strengthen the commitment to the overall group (**?**). Such solidarity will lead social ties to endure even if third parties do not actively manage and regulate members' behaviors to conform to group interests.

Conversely, non-helpful third parties are less likely to introduce norms of helpfulness and hence the triads are less likely to develop them. Absent norms of helpfulness, individuals in the triad are likely to view each collaboration as an isolated event that requires repeated renegotiating and often active management by other group members

(?). Thus, the dyad with a non-helpful third party is likely to be more fragile if the third party mediation is removed. When both helpful norms and active facilitation are absent, self-interested behaviors rather than group-oriented ones can dominate interaction (?). As a result, the remaining dyad is more likely to dissolve. Thus, we are able to more concretely separate weak and strong closure and hypothesize:

Hypothesis 3: *Dyads that lose a helpful third party will have a higher likelihood of future collaboration (strong closure) than dyads that lose a non-helpful third party (weak closure).*

Methods

Data and Sample

A desirable empirical context in which to study collaboration patterns should be one in which 1) collaboration is a common characteristic, 2) a proxy for helpful behavior is readily available in a systematic fashion, and 3) the field is large enough to identify unexpected deaths of third parties. One such setting is the field of academic immunology. In terms of research, immunology is a large and important discipline. Its organization is very similar to other medical and biological sciences, and most of the funding also comes from the National Institutes of Health, specifically the National Institute of Allergy and Infectious Diseases (NIAID).

We construct our sample dataset from multiple data sources. We measure collaboration activity, tie formation, scientist productivity, and scientist location using data from the ISI Web of Science. For this we collect bibliometric data on the 639,439 articles published in the 136 ISI Journal Citation Reports-defined immunology journals between the years 1910 and 2010.

We construct helpfulness data using acknowledgment counts from *The Journal of*

Immunology (JI) (the preeminent journal within the field of immunology), as in **?**. We examine the 50,541 articles published in JI between 1950 and 2007 and apply name-matching algorithms to identify the authors acknowledged in each article. There are on average 3.04 acknowledgments per article.

We collect data on immunologist deaths from two sources: 1) the titles of articles within the set of 639,439 immunology articles (such as: "Berenice Kindred 1928–1985") and 2) the "In Memoriam" column of the bi-monthly American Association of Immunology newsletter. While we identify 360 immunologists who died between 1978 and 2008, we restrict the sample to scientists with uncommon names (to avoid Type II errors) and who had a career age of less than 50 at the time of death (were still research active). While we do make efforts to exclude authors who likely died of natural causes, there is still a chance that some coauthors may have anticipated some of the deaths. However, any remaining anticipated deaths are likely to bias our results towards zero. After these considerations, we are left with 138 immunologists who passed away during our sample period. We call these the treatment group or the treated k's, and the year of death we call the treatment year.

We construct a set of control immunologists to match these treated immunologists. An ideal control immunologist would match a treated immunologists in terms of the relevant criteria, such as productivity, helpfulness, and age, but differ in terms of the death year. For each of the treated immunologists, we look for similar immunologists in terms of the following: year of first publication, number of coauthors by the treatment year, number of publications by the treatment year, number of citations received by 2010 for papers written prior to the treatment year, and the number of acknowledgements received by the treatment year. For each treated immunologists, we then randomly select a control immunologist who is similar along these characteristics and did not die in the same year.

Identifying Authors

Since our study relies on collaboration patterns, we must be able to directly identify which immunologists are collaborating with each other. One limitation of the ISI Web of Science data is that during our period of study, the data on authors lists only the first initial, a middle initial (if present), and the last name for each author of a paper. Since our empirical objective is to identify rates of collaboration, it is first necessary to disambiguate authors (that is, to distinguish B Jones from BL Jones). We rely on heuristics developed by **?** to disambiguate between authors who share the same name. The heuristic considers backward citations of two focal papers. If two papers reference similar papers (inversely weighted by how many times the paper has been cited, i.e., how obscure or popular it is), then the likelihood of the papers belonging to the same author increases, and we link the two papers to the same author. We repeat this process for all papers with authors who have the same first initial and last name and we exclude scientists who do not have more than two publications linked to their names.

Identifying Triads and Dyads

We construct a set of triadic collaborations using the focal 138 authors who died in our sample and find all sets of three authors appearing on the same paper where one of the focal authors was a member. That is, we find all pairs of i's and j's where i and j appear together on the same paper with focal author k. We call this pair of i and j the dyad l and follow its subsequent level of collaboration conditional on what happens to k and characteristics of k. We keep all dyads l in the sample until either i or j has gone three years without publishing a paper, even if that scientist later publishes a paper. We consider these dyads to be at risk of collaborating. Keeping dyads that are not at risk of collaborating in the sample adds a preponderance of zeros and thus downwardly biases our results through attenuation bias. However, we do confirm that our results are robust to relaxing this assumption. We further limit the sample to those dyads that were at risk of collaboration, based on this criteria, at the treatment time, i.e., the time of the death of k for the treated k's. Relaxing this assumption and keeping in the sample dyads that had stopped being at risk of collaboration before the treatment time had very little effect on the results.

Carrying out this procedure results in 11,084 dyads or approximately 80 dyads per k (which is approximately equivalent to 13 co-authors per k who collaborate with each other.[1]

Variables

Collaboration: We created a dummy variable $Collab_{lt}$ to indicate whether a paper was published in the year t that included both members i and j of the dyad l as coauthors. This is our main dependent variable, and we use it to assess the persistence of collaboration in the dyad.

Death of k: To estimate the effect on the dyad caused by the death of k, we code the variable D_{lt} to indicate the years after the passing of k on the dyad l where k was the third party. Thus, for the dyads involved with the treated k's, this variable is zero up to and including the year of k's passing and then one for the subsequent years. For the dyads involved with the control k's, this variable is always zero.

Helpfulness of k: Following **?**, we consider acknowledgments in papers as a sign that the scientist acknowledged for contributing to the paper without receiving formal co-authorship was helpful. Hence, we measure the helpfulness of the treated and control authors by the number of acknowledgements they received by the treatment time. We further classify authors as being helpful if they were above the median on this count and as non-helpful if they were below the median.

[1]The number of dyads from a set of co-authors can be calculated by the formula $\frac{N*N-1}{2}$ so that $\frac{13*12}{2} = 78$.

Productivity of k: We consider the number of papers published by the treated and control authors by the treatment time as a measure of their productivity. We further classify the k's as being productive if they are above the median on this count and as non-productive if they are below the median.

Dyad Fixed Effects: We control for the stable (time-invariant) characteristics of each dyad using dyad fixed effects. These fixed effects capture the stable characteristics of all three parties, i, j, and k, including (but not limited to) their cohorts, age differentials, and k's own productivity and helpfulness.[2]

Calendar Year Fixed Effects: Prior studies have shown general trends in the likelihood of collaboration over time (e.g., **??**). One may be concerned that these trends might be confounded with the effect of the passing of k. Hence, we include as controls a full set of dummy variables for the calendar years. This is the most flexible and conservative way to control for overall trends in collaboration. Including both dyad and calendar year fixed effects means that any additional control variables need to be dyad-specific and time-varying.

Collaboration Age Fixed Effects: Since collaborations have a natural decay over time that might be confounded with the passing of k, we control for the collaboration age with a full set of dummy variables for each year since the first paper on which all of i, j, and k appeared. This is the most flexible and conservative way to control for the age of collaboration.

Colocation of i & j: Since being located at the same institution is likely to increase the propensity to collaborate, we use a dummy variable indicating whether i and j, the members of the dyad l, where at the same institution at the time t. We are unable to

[2] Since we classify k at a single point in time (k's death), k's characteristics do not vary within dyad and thus are captured by the dyad fixed effects.

establish the location of a number of scientists, and hence all dyads where one of these scientists was a member have a missing value for this variable. In our main regressions, we assume that these dyads were not at the same location, but the results are robust both to assuming they were at the same location and to dropping these dyads entirely from the sample.

Papers Published by i & j: Since the passing of a coauthor might affect the productivity of a scientist (**??**), there is a worry that we may confound a drop in overall productivity as reduced collaboration. We control for this possibility using a time-varying count of the total number of papers that i and j, the members of the dyad l, published in the year t.

Helpfulness of i and j: If helpful k's select to work with helpful i's and j's and those collaborations then are likely to last longer, we may confound the causal effect of the helpfulness of k on the dyad with the care with which the helpful k's select their partners. In our data, we find no evidence that dyads with a helpful third party differed in terms of their helpfulness prior to the collaboration with the third party from dyads that had a non-helpful third party, inline with recent evidence suggesting that individuals do not select partners on this basis (e.g., **?**). However, we formally take this potential selection process into account in our estimations to further reduce concerns. First, this possibility is in principle controlled for by the dyad fixed effects. Further, we add as a control the interaction of the number of acknowledgments i and j received prior to the beginning of the triadic collaboration with the passing of k. We use the minimum of the acknowledgments that i and j as individuals had received, but the results are similar if we use the maximum or the average.

Matching

Even though we carefully match the treatment and control k's, there is no reason *a priori* to expect the triads where the k's were members to be fully balanced across the treatment and control groups. We address this concern using the coarsened exact matching (CEM) algorithm (**??**). This allows us to find treated dyads for which a similar control dyad can be found and assign weights to each dyad to obtain a balanced sample. We match dyads at the treatment time, i.e., the time of k's passing for the treatment group and the matched time for the control group, and then apply these weights for the entire life of the dyad. We match dyads on 1) whether the members of the dyad were at the same institution at the treatment time, 2) the rate of their collaboration in the prior three years, 3) the number of papers they individually published in the prior three years, 4) the years since the triadic collaboration began, 5) the treatment year, 6) the dummy indicating whether k was helpful, and 7) the dummy indicating whether k was productive. Table 2 presents the test of balance at the treatment time. The treatment and control groups appear well balanced with no difference statistically significant. Table 3 then presents summary statistics for the matched sample. We also confirm that our results are robust to using the full, unmatched sample.

Estimation

In our main regressions, we estimate the following model:

$$Collab_{lt} = \beta D_{lt} + \sum_{m} \gamma_m X_{ltm} + \phi_l + \eta_t + \theta(CollabAge_{lt}) + \epsilon_{lt}, \tag{1}$$

where $Collab_{lt}$ is a dummy variable indicating whether the dyad l published a paper together in year t, D_{lt} is a dummy indicating whether the third party in the dyad l had passed away by time t, X_{ltm} is a series of control variables, ϕ_l is a vector of dyad l fixed effects, η_t is a vector of fixed effects for the calendar time t, θ is a vector of collaboration age dummies, and ϵ_{lt} is the error term. We also add interactions of the variable D_{lt} with characteristics of the third party k. A statistically significant value for the parameter β indicates that the death of k had an effect on the rate of collaboration in the dyad l. Our preferred estimation method is the linear probability model, i.e., ordinary least squares (OLS), since it allows for a straightforward interpretation of interactions, on which we rely heavily.[3] We confirm that the results are robust to using the logit estimator.[4]

A key issue in regressions dealing with network data is the handling of network dependency (**?**). We use a variant of the **?** model to deal with this concern. Similar models have been used for instance by **?** as well as **?**. **?** clusters separately by each member i and j of each dyad and thus assumes that dyads with a shared member can show correlation but dyads without a shared member are independent. While **?** demonstrates through simulation that this method works very well in large datasets, like ours, **?** expresses concern that the assumption in the Lindgren (2010) model that two dyads are independent if they do not share a member may not always be satisfied in practice.

In our data, we have two potential sources of network dependency through overlap: 1) through the individuals who might be involved in multiple dyads and 2) through the multiple dyads that are linked to the same k. In our data, approximately 10% of individual i's and j's work with more than a single k, but there are no ij-dyads linked to more than one k. Hence, we assume two dyads to be independent only if they do not share a common member and are associated with different k's. To deal with these dependencies, we correct our standard errors by three-way clustering at the i, j, and k

[3] If the model is $z = ax + by + cxy +$ (other variables), the effect of a unit change in x is simply $a + cy$. In particular, this does not depend on the value of the other variables. This allows us to calculate easily the net effect of the passing of a helpful k when that k was productive or non-productive and to test its significance. The main alternative model, the logistic model, is non-linear and hence the derivative with respect to x includes all the variables in the model; thus the effect of a unit change in x depends not only on the value of y but also on the value of x and all of the control variables (**???**). Since our results are consistent with both OLS and logistic regression, we are confident that we are capturing the real underlying effect in the data.

[4] We remodel our main results using a logit estimator in Tables 8 and 9.

levels.[5] Thus, our assumption is much weaker than the assumption **?** makes and hence less susceptible to the criticism by **?**.

Results

Table 4 presents our basic results using the Equation 1. This is a linear probability model estimation of the likelihood of a dyad collaborating on a paper in a given year and includes fixed effects for the dyad itself, the calendar year, and the age of the triadic collaboration. The sample in Model 1 includes all of the third parties in the dataset, and the result suggests a weak negative effect on collaboration within the dyad from the death of the third party. The negative coefficient is consistent with Hypothesis 1a, but the statistical insignificance does not allow us to consider this as strong support.

In Models 2 and 3 we present split-sample regressions estimated using subsamples of dyads with helpful and then non-helpful third parties, respectively. We classify helpful third parties as those with above median acknowledgments and non-helpful third parties as those with below median acknowledgements. The results show a striking difference based on the third party type. The dyads where the third party was non-helpful show a considerable 12% drop in their probability of collaboration following the passing of the third party. In contrast, the dyads where the third party was helpful show an actual increase in the rate of their collaboration, roughly 3.5%, following the passing of the third party. These results are consistent with Hypothesis 3, and thus allow us in these subsamples to find evidence consistent with both Hypotheses 1a and 1b. The finding that collaboration might in fact increase after the passing of a helpful k is quite surprising and theoretically unexpected.

Table 5 adds a consideration for the productivity of the third party, given that productive third parties are also more likely to receive acknowledgements as a function

[5] We implement three-way clustering in Stata through the use of the programs "ivreg2" (**?**) and "clus_nway" (**?**).

of their position in the field. The productive third parties are also more likely to be in a position to offer help to others. We use the same estimation model as in the previous table and add two control variables. First, we include a control for the logarithm of the number of papers i and j, the members of the dyad l, published in total in the given year. This alleviates any concern that the passing of k may have affected the productivity of i and j individually (**??**) and thus the likelihood of collaboration; also alleviates any concern regarding the matching of the dyads on this measure. Second, we add a dummy variable indicating whether i and j, the members of the dyad l, were at the same institution at the time t. This alleviates any concern regarding our matching on this variable and also any potential concern that the dyad's colocation may have been affected by the passing of k and thus indirectly also their collaboration.

Model 1 of Table 5 presents the main effect of the passing of k. The coefficient is negative but not statistically significant, suggesting a potential weak effect. The magnitude of the coefficient is very similar to the result in Table 4 Model 1 and provides support for the exogeneity of k's death (uncorrelated with the newly introduced variables that were previously in the error term). Model 2 then adds an interaction of the passing of k with the dummy indicating whether k was considered helpful. The main effect of the passing of k now turns negative and highly significant with the magnitude of the effect quite close to the effect estimated in Table 4 Model 2. The coefficient of the interaction on the other hand is positive and very significant. The magnitude of the total effect, the main effect plus the interaction, is a 4.2% increase in the probability of collaboration when a helpful k passes away, and thus also quite close to the effect estimated in Table 4 Model 3.

In Models 3 and 4 of Table 5, we consider the interaction of helpfulness and productivity. First, in Model 3, we add the interaction of the passing of k with the dummy of whether k was productive, i.e., above median in the number of papers published at the time. The results indicate that dyads involving productive k's were very likely to persist as well and that a part of the effect of helpful k's is due to the correlation of helpfulness and productivity. In Model 4, we then add the three-way interaction of the passing of k, the dummy for helpful k, and the dummy for productive k. The results suggest a negative interaction between helpfulness and productivity in terms of the durability of ties. That is, helpfulness and productivity seem to be substitutes for each other. For the non-productive k's, the total effect is a 2.9% increase in the probability of collaboration when a helpful k passes away. For the productive k's, the total effect is a 4.0% increase in the probability of collaboration when a helpful k passes away. However, neither of these is statistically significantly different from zero. The effect estimated in Table 4 Model 3, a 3.6% increase, falls in the middle of this narrow range. These results increase our confidence that the data support Hypotheses 1 and 3.

Robustness

A number of alternate explanations may threaten our preferred interpretation of the patterns in the data. First, one may be concerned that the effect of k's helpfulness is really about selection: helpful k's like to work with people who themselves are helpful and whose collaborations tend to persist. In Model 1 of Table 6, we replicate Model 4 of Table 5 with a further control variable: the logarithm of the number of acknowledgements i and j, the members of the dyad l, received prior to the triadic collaboration.[6] The results suggest that collaboration involving helpful people indeed tends to persist, but that does not affect the main results. Second, one might be concerned that the interaction with productivity does not fully capture the effects, and so in Model 2 we replicate Model 1 using only the productive k's as the sample. The interactions involving productive k's now cannot be estimated since all k's are productive in the sample. The main effect of the passing of k weakens considerably

[6] We use the minimum of the two individual values. We also tried the mean and the maximum. The results are similar, with the minimum giving the most conservative test of Hypotheses 1 and 3. Due to zeros, we add1 to the count of acknowledgements prior to taking the logarithm.

and turns insignificant. The interaction with the helpful k dummy also weakens but remains significant. However, the total effect, i.e., the main effect plus the interaction, at a 3.2% increase, is very similar in this regression as in Model 3 of Table 4 as well as Models 2 and 4 of Table 5. Hence, we conclude that helpfulness has an effect even when fully controlling for productivity.

Third, one may be concerned that our sampling strategy is biasing our estimations. Recall that we dropped any dyad from the sample when one member of the dyad had gone three years without publishing a paper. We considered these dropped dyads as having zero or very low risk of collaboration and thus potentially causing attenuation bias in our estimates. In Models 3, 4, and 5 of Table 6, we test this. In Model 3, we keep all dyads until one member has gone five years without publishing a paper. The results are similar to prior results, though overall attenuated. However, the total effect of helpfulness remains at very similar levels as before. In Model 4, we keep all dyads until one member has gone seven years without publishing a paper. The results are again very similar, in particular the total effect of helpfulness. In Model 5, we keep all dyads in the sample until the end of our time period. As in the previous two models, the results are similar, though again all coefficients move towards zero since we are adding a very large number of zero observations, a classic case of attenuation bias. We thus can be confident that our results are not due to the sample selection.

Fourth, there is a concern that the linear probability model, i.e., OLS estimation, may bias the results and that a logit estimation would give a more accurate picture. In Model 6, we repeat the prior models with the main sample but using the logit estimator. The relative magnitudes and significance levels of the coefficients are very similar to the prior results, strongly suggesting that our results are not simply due to our choice of estimator. Hence, we present the linear probability model results since the interpretation of the interactions is more straightforward. Fifth, one might be concerned that the matching employed is driving the results. In Model 7, we present results using the full sample and find that the estimates are very similar, though somewhat attenuated. Again though, the total effect of helpfulness is in line with the prior estimates. Sixth, one may be concerned that the way we imputed locations when we are not sure may bias the results. So in Model 8, we drop all observations that use the impute locations and get results that are again very similar. One further concern may be that the way we dichotomize helpfulness and productivity at the median could lead to a wrong interpretation of the results. To be sure, in Model 9 we use the counts of acknowledgements and papers that k had at the time of death. The results are very consistent with the dichotomized results, which we prefer due to the ease of interpretation.

To summarize, in Table 6 we consider a range of potential concerns and find that the results are robust in all cases. Hence, we are confident that the data support Hypothesis 3, and within the subsample of helpful third parties we find evidence for Hypothesis 1b and in the remaining subsample for Hypothesis 1a.

Let us turn then to Hypothesis 2. In Table 7, we consider how the measure of a scientist's helpfulness changes when she collaborates with a helpful co-author. The observations here are i-k interactions, where we limit ourselves to the k's who passed away. The dependent variable here is the logarithm of the number of acknowledgements i had received by the time of k's death, and we control for a range of factors that may have lead k to start collaborating with i. First, we include full sets of dummies for the number of acknowledgements i received prior to the beginning of the collaboration, for i's career age (i.e., years since first paper) at the time the collaboration began, and for the calendar year in which the collaboration began. Second, we control for the number of papers i published prior to the collaboration, the impact-factor weighted number of papers, as well as the citations i had. We use OLS to estimate and use robust standard errors clustered by i and k, both members of the dyads in question here. Because we control for prior acknowledgements of i, we can interpret the point estimates as changes in helpfulness.

Model 1 shows that working with a helpful co-author is associated with an increase in the focal scientist's measure of helpfulness. Model 2 and 3 then adds a consideration for the duration of the interaction, the exposure of i to k, that is, the time from the first paper published by i and k together to k's passing. This time period is exogenous to the interaction and thus gives us more confidence that the results are causal; in other words, working with a helpful co-author is leading to an increase in the focal scientist's helpfulness. In particular, the results in Model 3 show that the longer i worked with a helpful k, the more helpful i was likely to become. The main effect of exposure of i to k captures the fact that any longer interaction is more to be associated with increased acknowledgements than a shorter interaction. However, there is a real effect coming from being exposed to a helpful co-author.[7] One concern here is that helpful k's simply select more helpful i's for collaboration. While this could be the case, we control for it as much as possible by including a very flexible specification of the helpfulness of i prior to collaborating with k and by considering how the increase in i's measured helpfulness correlates with the exogenously determined period of time of collaboration with k. Hence, these results support Hypothesis 2.

One additional concern is that the helpfulness of k simply reflects a more helpful neighborhood in the global scientific community. With the existing data, we cannot ascertain the earliest source of collaboration in the neighborhood, in particular whether it was created by k or existed prior to k. But the evidence above indicates that the effect works through helpful individuals like k, consistent with our theoretical argument, rather than being simply "in the air."

[7] The results are robust to controlling for the exposure time also with a full set of dummy variables.

Discussion and Conclusion

We examine the interaction between norms and networks in the context of an important social building-block, closed triads. We build on **?** and others' work and theorize two forms of closure —*weak* and *strong*. We argue that weak closure keeps triads intact because of active relational efforts. On the other hand, we argue that with strong closure, norms of helpfulness and generalized exchange emerge and create group solidarity that persists even without third party intervention. Employing a novel research design that uses the unexpected death of a third party, we are effectively able to "shut off" active facilitation in a triad. Consistent with our arguments, we find that 1) helpful third parties in triads introduce cooperative norms and 2) dyads that lose helpful third parties have significantly more durable collaborations. Conversely, we find that dyads that lose non-helpful third parties are less likely to continue collaborating.

Our research design allows us to address many inferential concerns present in the study of social effects (**???**). Because the presence or absence of a third party is credibly exogenous in our setting, arising from unexpected deaths, we are more confident that selection out of a third party situation is not as susceptible to unobserved heterogeneity (**?**). Further, our use of a rich suite of fixed effects allows us to control for important though unobserved fixed characteristics of dyads. Thus, given our design, we are confident that our estimated effects are credible. However, because we use archival data, a key remaining worry is whether our measure of helpfulness captures the ability of the third party to establish helpful norms. We address this concern in three ways. First, we control for several measures of a third's productivity, which may be confounded with helpfulness. Our main effect of helpful third parties persists even when we account for productivity. Further, we find that helpfulness does not vary based on the seniority or status of the third parties—first, middle, and last authors all have comparable levels of helpfulness. Finally, we found to our surprise, a 1-3%-point increase in the rate of collaboration after a dyad loses a helpful third. While this increase is weakly significant (achieving 10% significance in some models), it may suggest that losing a helpful third could cause members of a dyad to further strengthen their collaboration because of the instilled helpful norms. Nevertheless, we think future research can extend our understanding by looking into the specific types of actions and activities of the third party that make them so effective as "social glue."

In demonstrating the existence of these two forms of closure, the results of our work extend the growing literature on the relationship between culture, norms, and networks (**????????**). At a broad level, the notions of weak and strong closure are related to the concepts of *cohesion* and *solidarity*. These are often seen as having an ideational component and a relational component—with mechanisms of cohesion relating to both an individual's identification with the group and the structure of her connections (**??**). Our arguments and results suggest an interaction between the ideational and structural components. Shared norms of helpfulness can unite actors into the triad, but strong ties ease the establishment of such norms. Our arguments and results thus provide micro-level mechanisms for the combined effect of moral order, culture, and structure that **?** found important in creating community. In this sense, helpfulness, and the collaborative norms it supports, are related to what **?**, p. 106 called "social skill" and saw as important in the "emergence, stability, and transformation of many kinds of local orders."

On a more immediate level, we contribute understanding why some ties endure. Persistent, repeated interaction has been understood as a sign of a strong relationship and has also been linked to trust, altruism, joint problem solving, and exchange of goods and information (**??????**). While prior studies have argued that dyads embedded in triads are more likely to endure (e.g., **??**), we find an important contingency. If the third party was helpful and instilled collaborative norms in the triad, then dyadic tie endured even after the departure of the third party. The durability of collaboration thus, at least in part, stems from a combination of norms and structural ties.

In emphasizing the role of the third party in the collaboration of two alters, our work is also related to the notions of *tertius iungens* and *catalyst brokerage* (e.g., **??**).[8] In their typology of brokerage processes, **?** consider three kinds of brokerage processes: the *conduit*, in which a third party transmits, translates, and synthesizes information between two others (see also **?**); the *tertius gaudens*, in which a third party divides or separates two others and benefits from it, potentially at the expense of the other two (see also **??**); and *tertius iungens*, in which a third party brings two others together (see also **?**). A key distinction between the concepts of strong and weak closure on one hand and *tertius iungens* on the other hand is that the *tertius iungens* idea emphasizes the creation of the collaboration while the strong and weak closure arguments are agnostic about who initially brought the triad together and emphasize the stability of collaboration, rather than its formation. In a way, our work could be seen as providing key insights into how the third parties engaging in *tertius iungens* promote durable collaboration in the two alters. A second distinction is that in many examples of *tertius iungens*, the third party withdraws after bringing together the two alters. In the concepts of strong and weak closure, the third party is an active member of the resulting triad or at least strongly engaged with it, as the norms of helpfulness take time to diffuse and establish themselves.

Another avenue for further research is to investigate why some third parties do not help establish collaborative norms. The available data does not allow us to investigate this question fully at present. While we cannot rule out that the triads with collaborative norms represent a generally more helpful corner of the academic world, it does appear that the effect is transferred via interactions with particular third parties rather than being "in the air" as it were. Hence, the question remains as to why these particular individuals are likely to establish collaborative norms. Considering Table 7, we can see that, while the exact magnitude of the effect of the third party might vary

[8]Following **?**, we consider these two concepts similar and will, for brevity, use the first one.

between interactions, the statistical significance of the effect suggests that there is a general tendency towards increased helpfulness in others as a consequence of working with these helpful third parties. Hence, it does not appear that the same third party in some triads promotes helpful norms and in others keeps the alters more distant from each other. One potential answer then is that through their prior interactions with helpful others and memberships in helpful triads elsewhere, these third parties have learned helpful norms that they then transfer to new triads. However, it is also possible that some third parties have learned competitive norms and these are expressed as the absence of collaborative norms. In most settings the emergence of norms is contentious and actors are constantly making efforts to displace existing norms. For example, helpful norms and norms of competition can be variously seen to coexist, displace one or the other, or exist in constant flux (e.g., **?**).

Hence, another important direction for future research comes from a key limitation in our study: we have not theorized about triads who play a negative role in a dyadic relationship. Third parties in our data are either helpful or non-helpful; thus we do not theorize about nor test the negative impact that third parties can have on social groups (**?**).[9] However, negative interactions in closed triads are no less real or impactful, third parties can potentially create distrust and rancor as easily as they can create an environment of helpfulness. Beyond closed triads, in settings where the two structurally equivalent alters monitor each other, a third party engaging in *tertius gaudens* or *divide et impera* processes could potentially establish persistent rivalry or even animosity between the alters that might endure beyond the presence of the third party. Thus, third parties can play a multifaceted role within triads and larger network structures and many avenues for exciting research remain to be investigated to understand more clearly the roles that they play.

At the macro level, we see possibilities for understanding how the norms that we

[9]We thank an anonymous reviewer for this suggestion

observe taking root in small triads spread through larger structures (?). ? argues that a larger group may need a sufficient distribution of *tertius iungens* skill to be able to foster sufficient connectivity and mobilize for collective action. Our findings could be considered to extend that line of thinking suggesting that a sufficient distribution of collaboratively-oriented actors may be necessary for the emergence of large-scale collaboration, in particular collaboration that is *collective* in the sense of being resilient to the possible removal of individual actors, including those same collaboratively-oriented actors. Furthermore, we theorized on the resiliency of collaboration to the removal of an actor, yet one can imagine various other forms of shocks and it remains to be investigated what the limits to resiliency are.

At the empirical level, our work provides evidence that norms have lasting effects on social structure in an important setting: the production of scientific knowledge. Understanding the foundations of durable collaboration becomes increasingly important, as collaboration is increasing in scientific production (?) and the patterns of collaboration may influence the direction of scientific development (?). Furthermore, we are cautiously optimistic that our findings can generalize in at least two ways. First, we think the most natural contexts to which our findings can be generalized are where networks are central to the production of creative goods. These settings, we believe, include the production of culture (e.g., ??), entrepreneurial ecosystems (e.g., ?), and the vast online world where knowledge, journalism and software are created through the collaboration of networked individuals (e.g., ?). For instance, norms related to sharing knowledge, assigning credit, or mobility across groups and organizations can shape informal networks and the quality of the innovations or ideas they produce (??).

A second set of contexts where we think our findings are likely to be generalized to are settings where individuals are collaborative, but outcomes are individual rather than collective. Both classical and recent work in sociology shows how important networks are in settings such as schools (e.g., ??), neighborhoods (e.g., ?), and social movements (e.g., **?**). In these settings as well, norms are likely to co-emerge with networks to shape the outcomes of individuals and the collective. For instance, in classrooms, "open" or "traditional" cultures can modulate friendship patterns and thus student outcomes (**?**). In neighborhoods, cultural and network heterogeneity co-evolve to shape the outcomes of children, families, and the community at large (**?**). In these situations and others, norms of behavior modulate interaction and subsequently shape the functioning and durability of these social systems.

Moving forward, much work must be done in thinking about other norms beyond helpfulness in the exchange of knowledge or materials. At the micro level, fruitful extensions of our work could include better understanding the relationship between network structures, norms, and their effect on conversational dynamics (e.g., **?**), decision-making (e.g., **??**), or tastes and value judgment about the quality of cultural objects (e.g., **?**). In each of the later cases, norms related to deference (**?**), turn-taking (**?**), and individual versus collective goals (**?**), likely interact with patterns of preexisting social relationships to shape outcomes.

Finally, our use of a quasi-experimental approach provides a useful framework for studying the emergence and endurance of norms in social groups. We think that such quasi-experimental designs and the growing field-experimental literature on networks (e.g., **??**) has the potential to further elucidate cultural processes that shape and are shaped by networks. While our research design provides more convincing causal evidence for our theory, we think that there exist exciting possibilities for enriching our understanding by better measuring individuals behavior with the aid of the increasing availability of large scale data on micro-interactions (**?**). Thus the most exciting extension of this research will likely come from a marriage of sharper social theory, rigorous experimental and research design, and detailed micro-behavioral data about individuals.

Table 1: Summary Statistics for Dying Ks

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Year of Death	2000.43	5.38	1983	2008
Career Age	29.30	11.15	5	50
Coauthors	22.91	26.44	1	169
Publications	46.97	44.43	4	256
Impact Factor-Weighted Publications	220.55	286.67	10.59	1913.09
Citations	2050.91	2986.34	35	20923
Acknowledgements	4.04	6.12	0	33
Helpful (0/1)	0.41	N/A	0	1
Productive (0/1)	0.33	N/A	0	1
Helpful & Productive (0/1)	0.23	N/A	0	1
N		138		

Table 2: Balance Test for Matched Dyads at the Time of k's Death

Sample Average	(1) Treated k's	(2) Control k's
i & j at the same institution	0.0736	0.0736
Collaboration (3 yr sum)	0.311	0.311
Papers by i & j (3 yr sum)	4.189	4.700
Collaboration Age	3.424	2.842
Death Year of k	2000.2	2000.3
Helpful k	0.488	0.488
Productive k	0.564	0.564
Observations	11084	9236

No difference is statistically significant.

Table 3: Summary Statistics for Matched Dyads

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Papers by i & j at t	2.572	3.254	0	104
i & j at the same institution at t	0.154	0.361	0	1
Year	2001.158	4.584	1974	2010
Collaboration Age	4.841	4.485	0	36
Helpful k	0.394	0.489	0	1
Productive k	0.505	0.5	0	1
Acknowledgements for k	3.238	5.967	0	55
Papers by k	45.41	34.719	4	256
N		163179		

Table 4: Propensity of i & j to Collaborate

	(1) All k's	(2) Non-helpful k's	(3) Helpful k's
Death of k	-0.0385	-0.122***	0.0348*
	(0.0538)	(0.0345)	(0.0167)
R^2	0.150	0.307	0.065
Observations	163179	98845	64334

Robust standard errors in parentheses, clustered by i, j, and k.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Propensity of i & j to Collaborate - Interaction with Productivity

	(1)	(2)	(3)	(4)
Papers by i & j at t (log)	0.115***	0.115***	0.115***	0.115***
	(0.0117)	(0.0125)	(0.0125)	(0.0125)
i & j at the same insitution at t	0.197***	0.194***	0.194***	0.194***
	(0.0347)	(0.0339)	(0.0340)	(0.0339)
Death of k	-0.0510	-0.141***	-0.165***	-0.171***
	(0.0514)	(0.0327)	(0.0246)	(0.0232)
Death of k x Helpful k		0.183***	0.0794***	0.201***
		(0.0282)	(0.0230)	(0.0287)
Death of k x Productive k			0.130***	0.161***
			(0.0259)	(0.0302)
Death of k x Helpful k x Productive k				-0.151***
				(0.0419)
Death of helpful, non-productive k				0.0298
				(0.0266)
Death of helpful, productive k				0.0404
				(0.0246)
R^2	0.205	0.215	0.217	0.218
Observations	163179	163179	163179	163179

Robust standard errors in parentheses, clustered by i, j, and k.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Propensity of i & j to Collaborate - Robustness Tests

	(1) Selection	(2) Productive k	(3) 5 yrs	(4) 7 yrs	(5) All yrs	(6) Logit	(7) Full sample	(8) Location	(9) Count
main									
Papers by i & j at t (log)	0.115***	0.0814***	0.0855***	0.0766***	0.0614***	2.329***	0.134***	0.0937***	0.116***
	(0.0123)	(0.0107)	(0.00802)	(0.00685)	(0.00428)	(0.0800)	(0.0159)	(0.0112)	(0.0122)
i & j at the same insitution at t	0.194***	0.143***	0.165***	0.153***	0.112***	1.748***	0.240***	0.194***	0.195***
	(0.0340)	(0.0150)	(0.0345)	(0.0332)	(0.0237)	(0.203)	(0.0414)	(0.0361)	(0.0342)
Death of k	-0.178***	-0.0226	-0.113***	-0.0838**	-0.0659**	-2.703***	-0.118***	-0.0890*	-0.667***
	(0.0250)	(0.0228)	(0.0274)	(0.0282)	(0.0245)	(0.507)	(0.0343)	(0.0348)	(0.123)
Death of k x Helpful k	0.202***	0.0549*	0.146***	0.118***	0.0806***	3.438***	0.142***	0.121**	
	(0.0280)	(0.0258)	(0.0232)	(0.0200)	(0.0218)	(0.773)	(0.0260)	(0.0393)	
Death of k x Productive k	0.166***		0.0946***	0.0664**	0.0639**	2.987***	0.107**	0.0995**	
	(0.0310)		(0.0219)	(0.0202)	(0.0200)	(0.694)	(0.0325)	(0.0369)	
Death of k x Helpful k x Productive k	-0.152***		-0.0773*	-0.0496	-0.0458+	-2.959**	-0.0740+	-0.0899+	
	(0.0419)		(0.0339)	(0.0308)	(0.0272)	(0.929)	(0.0434)	(0.0460)	
Death of k x Prior Ack'ments of i & j (log)	0.0642**	-0.0174	0.0498*	0.0394*	0.0295+	0.0498	0.0559*	0.0344*	0.0598*
	(0.0241)	(0.0155)	(0.0202)	(0.0177)	(0.0159)	(0.508)	(0.0283)	(0.0164)	(0.0260)
Death of k x k's Acknowledgements (log)									0.281**
									(0.0938)
Death of k x Papers by k (log)									0.153***
									(0.0303)
Death of k x k's Ack'ments (log) x Papers by k (log)									-0.0590**
									(0.0212)
Death of helpful, non-productive k	0.0248		0.0327+	0.0339+	0.0147		0.0243	0.0324	
	(0.0256)		(0.0171)	(0.0178)	(0.0111)		(0.0270)	(0.0302)	
Death of helpful, productive k	0.0387	0.0323*	0.0501+	0.0507+	0.0327+		0.0570+	0.0419+	
	(0.0251)	(0.0157)	(0.0260)	(0.0264)	(0.0190)		(0.0333)	(0.0229)	
R^2	0.218	0.103	0.168	0.157	0.139		0.208	0.162	0.217
Log-Likelihood						-12797.8			
Observations	163179	82437	269622	341655	600962	78975	192897	116351	163179

Robust standard errors in parentheses, clustered by i, j, and k.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Change in i's helpfulness

	(1)	(2)	(3)
Prior Papers by i (log)	-0.0677	-0.0756^{+}	-0.0738^{+}
	(0.0444)	(0.0434)	(0.0436)
Prior IF-weighted papers by i (log)	0.133***	0.138***	0.134***
	(0.0279)	(0.0271)	(0.0270)
Prior Forward Cites to i (log)	0.0250^{+}	0.0240^{+}	0.0256^{+}
	(0.0144)	(0.0139)	(0.0137)
Acknowledgements of k (log)	0.0948***	0.0820***	0.0179
	(0.0218)	(0.0245)	(0.0278)
Exposure of i to k		0.0165**	0.0104*
		(0.00538)	(0.00513)
Exposure of i to k x Acknowledgements of k (log)			0.00425***
			(0.00123)
Prior Acknowledgements of i Dummies	Yes	Yes	Yes
i Career Age Dummies	Yes	Yes	Yes
Initial Co-Authoring Year Dummies	Yes	Yes	Yes
R^2	0.658	0.664	0.665
Observations	4073	4073	4073

Robust standard errors in parentheses, clustered by i and k.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Propensity of i & j to Collaborate (Logit)

	(1)	(2)	(3)
	All k's	Non-helpful k's	Helpful k's
Death of k	-0.839	-2.253**	0.606*
	(0.677)	(0.733)	(0.299)
Dyad Fixed Effects	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes
Collaboration Age Dummies	Yes	Yes	Yes
Log-Likelihood	-17117.0	-8398.9	-7004.4
Observations	78975	58154	20821

Robust standard errors in parentheses, clustered by i, j, and k.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Propensity of i & j to Collaborate - Interaction with Productivity (Logit)

	(1)	(2)	(3)	(4)
Papers by i & j at t (log)	2.353***	2.341***	2.329***	2.329***
	(0.0811)	(0.0842)	(0.0807)	(0.0801)
i & j at the same insitution at t	1.798***	1.745***	1.739***	1.748***
	(0.196)	(0.197)	(0.202)	(0.203)
Death of k	-0.609	-1.811**	-2.493***	-2.700***
	(0.527)	(0.557)	(0.497)	(0.483)
Death of k x Helpful k		2.574***	0.876+	3.439***
		(0.662)	(0.494)	(0.778)
Death of k x Productive k			2.464***	2.985***
			(0.653)	(0.678)
Death of k x Helpful k x Productive k				-2.959**
				(0.930)
Dyad Fixed Effects	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
Collaboration Age Dummies	Yes	Yes	Yes	Yes
Log-Likelihood	-13250.2	-12934.9	-12824.6	-12797.9
Observations	78975	78975	78975	78975

Robust standard errors in parentheses, clustered by i, j, and k.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Propensity of i & j to Collaborate

	(1)	(2)	(3)	(4)	(5)
Death of k	-0.032	-0.110^{*}	-0.099	-0.010	-0.054
	(0.048)	(0.053)	(0.062)	(0.119)	(0.130)
Death of k x Helpful k		0.140^{**}	0.138^{**}	0.074^{**}	0.043^{*}
		(0.044)	(0.047)	(0.023)	(0.019)
Death of k x i & j at Same Institution			-0.060	-0.102^{***}	0.002
			(0.043)	(0.029)	(0.021)
Death of k x k, i & j at Same Institution			-0.008	0.007	-0.009
			(0.029)	(0.029)	(0.029)
Death of k x Productive k				0.046^{+}	0.019
				(0.024)	(0.018)
Death of k x k Editor at JI				-0.035	-0.027
				(0.022)	(0.021)
Death of k x Ranking of k's University (log)				0.022^{***}	0.021^{**}
				(0.006)	(0.007)
Death of k x k Career Age (log)				-0.047	0.025
				(0.039)	(0.042)
Death of k x Prior Ack'ments of i & j (log)					-0.006
					(0.012)
Death of k x Max Years Since i or j Last Worked with k					-0.006^{*}
					(0.003)
Death of k x Indirect Ties between i & j (log)					-0.036^{+}
					(0.021)
Death of k x Proximity of i & j in Knowledge Space					-0.087^{**}
					(0.028)
Death of k x Share of i's & j's Papers Published Together					-0.455^{***}
					(0.100)
R^2	0.496	0.498	0.498	0.544	0.558
Clusters	274	274	274	208	208
Observations	277206	277206	277206	184535	178936

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$