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Personal Publication Productivity: scientists, their friends and other collaborators

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Introduction

The question of what drives productivity in science has motivated studies of scientific communities for some time. Work focused on the productivity effects of individual level collaboration in science (Lee and Bozeman 2005, Jons 2007, Gersick et al 2000, McFadyen et al 2009, Rost 2011) have pointed to the importance of personal relationships for publication productivity In science, productivity is an outcome of a collaborative process, in which range of knowledge production factors matter (Levin and Stephan 1991), including contextual such as collegial exchange, orientation and activities of coworkers, and organizational freedom (Fox 1983).

Scientists develop a range of colleagues throughout their careers. Among these relationships, there are likely many different types of interactions, levels of trust, and other relationships. One possible link that academic scientists may have is that of friendship. Of all informal relationships between individuals, *friendship* is omnipresent in human life (O'Connor 1992). Metaphorically speaking, friendship is seen as a form of social glue (Pahl 2000, Spencer and Pahl 2006) and an "increasingly important architectural dimension" of an organization (Dickie 2009, p 128). Some suggest that friendship is at the heart of social organization in general (Kaufman 1992). This body of literature has linked friendship to a range of individual and organizational outcomes, including work satisfaction, commitment, productivity and other factors (Berman, West and Richter 2002, Crabtree and Space 2004, Farrell 2001, Nielsen et al 2000). A gap exists, however, in our understanding of this personal relationship in the social structure of science. Does friendship among scientists exist within the professional environment? And, if so, what is friendship, what distinguishes it from other professional relationships, and how does it affect the function and outcomes of science? This paper addresses this generally overlooked relationship in science, and addresses it prevalence and role in the productivity of academic scientists. We ask: to what extent does friendship exists in the scientific community, and how does it matter?

Relationships & Social Capital in Science

Attention to networks of professional relationships in the context of science has included observation of important productive and knowledge-related ties of co-authorship and knowledge-based citation ties (Beaver 2001, Lee and Bozeman 2005, Glanzel and

Schubert 2005, Hansen et al 2005, Lehmann et al 2003, Wagner 2005, Wagner and Leydesdorff 2005 among others). More recently, attention to specific resources, or *social capital*, that is accessed via these networks has attracted attention of the social science research community. Social capital refers to social obligations, which under certain conditions can be converted into economic or political capital (Bourdieu 1986). In the context of science, social capital functions to mobilize scientific resources available in scientist's quest of knowledge (Bourdieu 1991). Overall access to social capital is indeed based on social relationships, of which some are closer than others, some have higher levels of trust than others, and some are purely utilitarian relationships, while others may be considered close friendships, namely relationships that comprise both social and personal dimensions. Social capital facilitates goal attainment by signaling and affirming an individuals' capacity, and demonstrating potential resources that might be accessible to them (Lin 2002). Moreover, it transcends contexts and resources that are created in one context can be transferred to other contexts (Bourdieu 1986). Therefore, those professional networks that are composed of friendships, which by definition imply multiple roles thus spanning multiple contexts, and/or containing both social and personal dimensions, are qualitatively different from networks that are composed of market-only relationships (Uzzi 1997). Such networks should be more conducive for mobilization (Lin 2001) of social capital.

There are various benefits of developing personal relationships within professional networks. Scientists consult each other when they confront complex or ambivalent issues, exchange information and knowledge, free calculations, methods or equipment, and ideas and emergent knowledge for work in progress (Bouty 2000, McFadyen and Canella 2004, Nahapiet and Goshal 1998). From the perspective of social capital, personal relationships such as friendship may provide different types of resources within professional and other networks because of the intensely personal nature of these relationships (Krackhardt and Kilduff 1990, Kilduff and Krackhardt 2008, Uzzi and Spiro 2005), and affect productivity of scientists differently than their other collaborative ties.

Prior work on friendship in general show that patterns of friendship vary by the social division of a given society (Allan 1998, O'Connor 1992) such as status, values, class, culture, age, and/or gender (Adams et al 2000, Lazarsfeld and Merton 1954, Sheets and Lugar 2005, Verbrugge 1977). What explains this variation? Friendships evolve through *repeated interactions*, with each interaction affecting the further course of relationships (Hinde 1967, Feld and Carter 1998). This repeated interaction might cause people to raise value of relationships, which they value highly by increasing the number of roles that the same person plays (Hruschka 2010). Given that social capital is cumulative and scientists maintain productive relationships over time (Bozeman et al 2001, Bozeman and Corley 2004, Dietz et al 2000, Murray and Graham 2007) we could think that scientists with longer tenure in science have had more opportunities to meet others whom they regard as being their close friends. *Personal autonomy* is also seen as a necessary precondition of friendship dictated by its voluntary nature (Krackhardt and Kilduff 1990, Kilduff and Krackhardt 2008, O'Connor 1992, Oliker1998, Smart et al 1999). Personal autonomy enables individuals to follow their internal sentiments and to disregard or overcome external pressures of the professional environment, or interests (Carrier 1999). A choice to collaborate with friends may be based on personal preferences of scientists (Bozeman and Corley 2004, Katz and Martin 1997, Uzzi and

Spiro 2005). Scientists in higher academic ranks have more autonomy (McEvily et al 2003) and their reciprocity potential is higher.

Age may also matter in individual friendship ties. One study observed that older individuals tend to have fewer ambivalent relationships in their networks, and are more likely to view their relationships with friends and acquaintances as close (Fingerman et al 2003). Here, the socio-emotional theory of selectivity (Carstensen et al 1999, Lansford et al 1998), suggests that individuals are selective and include only the most rewarding relationships in their networks, and that close ties improve with age. Older individuals may dismiss their less rewarding relationships and retain close ones, and they tend to view their close ties with more positive feelings. For younger adults, in turn, the primary concern is learning. To this end they establish and maintain a variety of relationships that range from close to ambivalent or even problematic.

Finally status homophily, is stronger for some groups than others, and may affect who is a friend with whom (Lazarsfeld and Merton 1954, Verbrugge 1977). In the context of science, more senior scientists and engineers not only have had more opportunity to meet others similar to them to form friendships, but also they are more attractive as a potential friend to those who are less senior. Similarly, scientists who have higher reputation or who control more production-relevant resources are more attractive as potential friends.

Thus, given the importance of time in building and accumulation of relationships, and the tendency of people to be selective, and to work with their friends, and to increase the value of their esteemed relationships, the requirement of friendship for individual autonomy and reciprocal altruism, as well as the discussed age-specific differences in ways in which individuals perceive their relationships, I hypothesize that:

H1: Senior academic scientists have more friends in their collaborative networks than junior academic scientists.

As we consider the question of productivity, friendship may create an added value or “integrative social capital”, which enables collective action (Bozeman et al 2001), increases efficiency of use of human or economic capital (Burt 1992, 1997), reduces transaction costs (Adler and Kwon 2000), facilitates performance (Burt 1992, 2004, Krackhardt, 1999, Reagans and Zuckerman 2001), increases ability of scientists and engineers to contribute knowledge (Bozeman and Mangematin 2004), and supports creation of new intellectual capital (Nahapiet and Ghoshal, 1998).

Quoting Emerson who defined a friend as someone before whom one “may think aloud”, Blatterer suggests, that even though “thinking aloud is risky, because we may at times think the unthinkable”, with our friends we can safely “speak the unspeakable” (2010: 40). With friends one can say things that are “indecent” or questionable not only in the eyes of some judgmental or critical observer, but even what is against our own best judgment. Because of its normative flexibility, friendship facilitates emergence of a shared cognition between collaborators, and therefore, is instrumental for creation and maintenance of cognitive social capital (Lin 2001). Trust associated with friendship increases ability of involved parties to cope with complexity and serves to reduce uncertainty that is inherent in any social interaction (Coleman 1994, Luhmann 1979, Nahapiet and Ghoshal 1998). The norm of cooperation implied by reciprocal altruism of friendship (Vigil 2007) facilitates the motivation of engagement and an anticipation of results from joint activities. Similarly, norms of high valuation, openness to criticism, and a tolerance of failure are important in that they reduce the potential for the emergence of a phenomenon of groupthink and lock in (Smith-Doerr and Powell 2005).

Professional friendships by definition imply multiple roles and span multiple contexts. Importantly, friendships introduce personal, non-working roles in the relationship and are characterized by a broad spectrum of interactions, and by many layers of different exchanges within the same relationship and across different roles (Ashforth et al 2000, Hinde 1976, Hogan and Antoncic 2003). Empirical literature often treats multiplexity of relationships as a structural measure of trust (Isset and Prowan 2005). The most important aspect of multiplexity in the context of social capital is the capacity of such relationship to transfer capital created in one context to another (Bourdieu 1986, Hruschka 2010). In the context of science the instrumental roles in professional relationships often involve collaboration. Scientists collaborate not only in order to pool knowledge for solving complex problems and to access complementary resources such as expertise, tacit knowledge, equipment, or funding, but also because of the pleasure collaboration brings (Beaver 2001, Kraut et al 1987-88, Katz and Martin 1997, Melin 2000, Thorsteinsdottir 2000).

Perhaps, the most important added integrative value of friendship is solidarity (Bourdieu 1986). Because of the self-reinforcing nature (Skvoretz 1998) solidarity serves as an integrating and focusing factor in the pursuit of common goals (Bozeman et al 2001). In science, solidarity is one of the preconditions of joint knowledge creation – it supports the joint pursuits of agreed-upon goals (Bozeman et al 2001). It also increases scientist’s ability to recognize opportunities for knowledge exchange, and thus affects the anticipation of results from knowledge exchange and combination, and supports the motivation to participate in it (Nahapiet and Goshal 1998).

Well-developed relationships such as friendship may also reflect the extent to which individuals are integrated in the broader science community. Such integration may result in greater trust with respect to quality of scientists (Merton 1973[1972], Latour 1987, Wagner and Leydesdorff 2005). Thus, scientists with greater integrative social capital generated by their professional friendships have an advantage in situations of uncertainty.

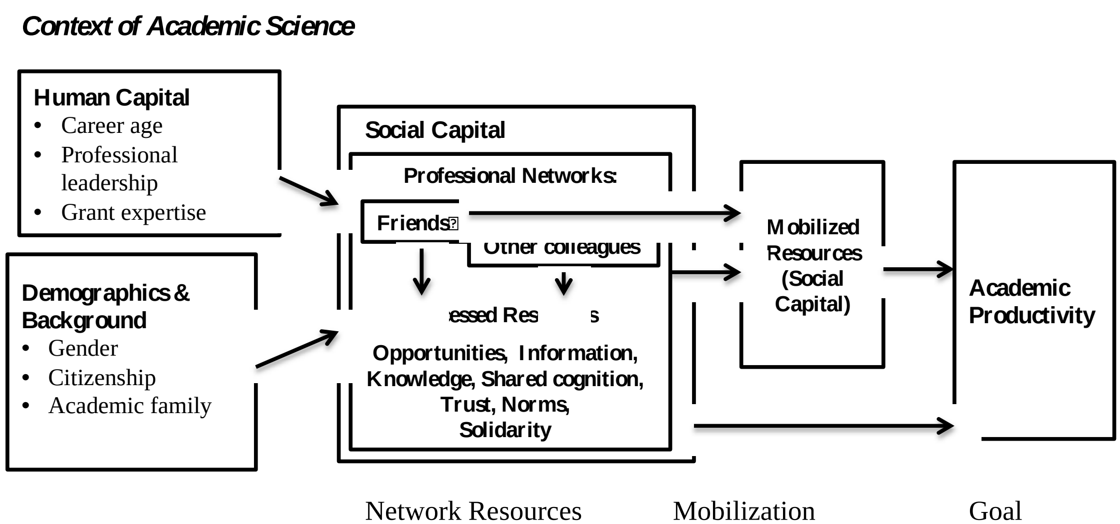
Ultimately, whether individuals are able to benefit from their social capital is determined by their own activity, and by the willingness of others to share their resources (Lin 2001). Thus, because of its unique properties, friendship may play an important role in helping scientists to mobilize their social capital for the productivity purposes. From the network perspective, friendship is an integrative element of social capital. The main mechanisms of this effect are integration of professional networks and intensification of interactions within these networks, which then increase the total of resources mobilized for productivity as well as efficient use of these resources. Therefore, we expect that scientists and engineers who have friendships in their networks will be more productive. We hypothesize that:

H2: Scientists with more friends in their professional networks are more productive than scientists with fewer friends.

A Model of Friendship in Science

In consideration of the social structure of science, and the overall prevalence of friendship as a "glue" in social environments in general, we propose that friendship is in fact a building block of scientist's social capital, and a catalyst of publication productivity (Bozeman et al 2001, Lin 2001, 2002). The analytical model of the productivity effects of personal professional relationships is presented in the Figure 1. Theoretically, friendship is a part of collaborative relationships, and thus an important determinant of scientist's social capability to pool productivity relevant resources and to mobilize their social capital for the purposes of the productivity.

Figure 1 Model of the productivity effects of personal professional relationships



Friendship ties are distinct from other collaborative ties and contain different social capital than other collaborative ties. The prevalence of friendship in the personal professional networks varies across the groups of scientists, which may be explained by properties of scientist's human capital, and by the demographic background. Friendship affects productivity by facilitating mobilization of all resources, which scientists can access through their personal professional networks for productivity purposes. In this, friendship facilitates mobilization of both tangible resources, such as information or knowledge, and intangible resources, such as opportunities, shared cognition, trust and solidarity. Friendship also facilitates mobilization of network resources for productivity purposes by integrating network relationships through its inherent flexibility, its multiplex role structure and homophily, as well as the trust and solidarity it induces. The model rests on two assumptions about academic science. First, productivity is a positive function of production factors, which are distributed across individuals (Stephan and Levin 1992), and, second, scientists invest in their relationships to pool all resources that are needed to advance the scientific knowledge (Bourdieu 1991, Lin 1999). In this, friendship is an inherent part of the networked social capital of academic scientists. It plays an important role of integration in the mobilization of social capital for productivity purposes. It facilitates mobilization of social capital by supporting resource mobilization from personal networks, and by integrating personal networks, thus increasing the efficiency of these networks, and ultimately - higher productivity.

Data And Analysis

Data. To address the research questions and hypotheses, the analysis presented here is based on a recent U.S. National Science Foundation-funded longitudinal (2006-2010) study of academic scientists and engineers in six scientific disciplines fields in Research Extensive universities in the United States (NSF Grant # REC-0529642). This study involved a national survey of academic scientists, coupled with lifetime bibliometric data gathered from the Thomson Reuters Web of Science (WoS.)

First, for the survey data, the study used an ego-centric social network survey design, which included multiple role and function-based name-generator and name-interpreter questions (Burt and Minor 1983, Wasserman and Faust 1994). Respondents were first asked to write the names of individuals who form their personal professional networks into six name generator questions. Respondents were asked provide the names of their closest collaborators within the past two year a) within their home-university and b) outside of the home-university. Collaboration was defined as proposal generation, working on a research project, writing/presenting an academic paper/book or book chapter, or developing industrial products or patents. Next network name generators asked respondents to name individuals with whom "they talk about their research but have never collaborated." Respondents were also asked to name individuals to whom they turn for career-related advice, and individuals with whom they discuss important departmental matters.

After respondents of the survey provided names, they were next presented with series of name interpreter questions about each of the individuals they had named. These questions asked about specific collaboration (for example, co-authored papers advice sought from network members, and about the types of support provided by network members.

Relational data were asked, addressing a range of ways in which individuals were connected to their named network members. This included whether the respondent considered the named individual to be a "close friend." Other relational data included, the age of relationship, frequency of interaction, and the origin of acquaintance. With respect to the similarity between respondents alters, the survey asked about the gender and comparative seniority to the respondent, as well as the relative closeness of research expertise, and comparative grant getting ability.

Next, bibliometric data were also collected for each survey respondent. This included data about peer-reviewed journal articles and conference proceedings, were collected from Thomson Reuters ISI Web of Science (WoS) Science Citation Index Expanded (Web of Science n.d.). The bibliometric data was extracted manually from WoS and imported into data analysis software (The Vantage Point n.d.) and cleaned through a name disambiguation and name matching process (Wang et al 2012).

This paper uses a subset of the survey data and corresponding bibliometric data, which include data for 1191 respondents in five academic disciplines (biology (21%), chemistry (21%), computer sciences (19%), earth and atmospheric sciences (23%), electrical engineering (16%). Overall, the sample reflects the overall diversity of U.S. workforce: 68% of respondents are native-born U.S. citizens, 13 % naturalized U.S. citizens, and 14% are foreign citizens with permanent visas and with 5% temporary visas.

Analytical Models

Descriptive and explanatory analysis was conducted to address the questions of the prevalence and effects of friendship in science. Descriptive analysis (frequencies and means) was conducted to understand the trends and general evidence on friendship in science. An important goal in this work, however, and one that is allowed for by the robust data on which this analysis is based, is a deeper statistical understanding of the factors that explain friendship and its effects in the scientific environment. Given this, two models were developed to test a) factors that explain who has friends in science, and b) how the existence of friendship in collaborative relationships in science may matter for productivity. First, to test the hypothesized seniority effects for the prevalence of friendship in collaborative networks I use the following empirical model.

Friendship = f (seniority, demographic characteristics, context)

The dependent variable is friendship, and is measured as a self-reported number of individuals whom respondents consider “close friends” in their collaborative networks. Friendship is coded as the total number individuals whom respondents consider “close friends” (Model 1). The seniority is conceptualized as both career age and accomplishments, and is captured by these three independent variables. Career age, measured as a number of years since respondents were awarded their Ph.D. (Long 1992, Allison and Stewart 1974, Lee and Bozeman 2005), number of officer positions in professional associations, and number of grant proposals respondent have submitted as PI or co-PI over past two years. The model includes two variables that capture whether familial ties to the academic profession matter in the relationships that scientists develop in their careers. This is addressed via parents, but also spouses who have had academic careers.

To test the hypothesized productivity effects of friendship I use the following empirical model.

Productivity = f (friendship, network characteristics, demographic characteristics and context)

The dependent variable is publication productivity. It is measured as a count of peer-reviewed journal publications over the three-year period from 2007 to 2009 (Model 2.1), and an average fractional count of publications over the two-year period from 2007 to 2009 (Model 2.2). Friendship is measured as the predicted value of the total number of friends in the personal collaborative network (to address endogeneity issues.)

Control variables are included to account for effects of the mobilized resources and other productivity-relevant aspects of social capital, the variation in productivity across the demographic groups of scientists, and the specifics of the discipline of science. The size of the personal collaborative network (measured as a number of named collaborative ties) is a primary measure of a social capital: larger networks allow access to more resources. The second social capital variable depicts productivity effect of resources, which respondents mobilize from their networks and is constructed as a summation of five resource: practical knowhow and knowledge related to scientists work (revisions of papers and grant proposals, which they were not coauthoring), collaboration opportunities (introductions to collaborators outside of respondents own university), endorsements of reputation (nominations for awards or as invited speakers), joint work on grant proposals and co-authorship (collaboration of journal paper or book chapter). If a respondent indicated that they had interacted with their named collaborator in these ways, their positive answer was coded as 1. The resulting scale measures the construct of mobilized network resources with a Cronbach's Alpha of .73 (DeVellis 2011.) The proportional EI-index captures the external orientation of the collaboration network (Krackhardt and Stern 1988). In the context of productivity, external ties may affect productivity by being a source of non-redundant information and allow scientists to access knowledge production factors, that they do not have themselves (Beaver 2001, Fox and Mohapatra, 2007, Katz and Martin 1997, Lee and Bozeman 2005, McFadyen et al 2009, Singh 2000, Oh et al 2006).

In addition to social capital variables, the model includes a variable that captures the effect of the respondent's research grants as the number of graduate students currently supported by the respondent's research grants. Both models also include several demographic characteristics that may account for variation in productivity in the model. The set of demographic characteristics and context variables includes gender, citizenship, and the age of career and science discipline.

Results

Results show that more than half of respondents (53%) have at least one close friend among their closest collaborators (Table 1), and that the number of friends in one's network varies. For example, the number of friends in the network of closest collaborators ranges from 0 to 8, and the mean number of friends is 1.17 (standard deviation 1.53).

Table 1 Respondents who have at least one friend, by discipline

	N	Mean
All disciplines	1191	.54
Biology	248	.55
Chemistry	249	.50
Computer science	227	.50
Earth and atmospheric sciences	281	.61**
Electrical engineering	187	.47
Legend: * p<.05; ** p<.01; ***p<.001		

Friendship vs. other collaborative ties. A distinct property of friendship, which is especially important in the context of mobilization of the social capital, is its inherent flexibility. The inherent flexibility of friendship allows for bridging the difference and integrating social structures (Anderson 2001, Blatterer 2010, Krackhardt and Kilduff 1990, Kilduff and Krackhardt 2008, Merton and Lazarsfeld 1954.) An indicator of the normative flexibility of friendship is its ability to accommodate diversity (Krackhardt and

Kilduff 1990, Rezende 1999), which reflects in the extent to which friendship in comparison to the other collaborative ties is heterophilous, or just opposite, homophilous (Lazarsfeld and Merton 1954, Verbrugge 1977, McPherson et al 2001). The analysis of the tie dataset allows examining several aspects of similarity/difference, which are important in the context of social interactions and productivity in science. It appears that friendships of U.S. scientists and engineers are formed primarily within status groups, and not across them (Table 2). Friendships are more homophilous by all three homophily counts: status (mean heterophily .07 for friends vs. .14 for others), funding (mean heterophily .14 for friends vs. .20 for others) and gender (mean homophily .61 for friends vs. .54 for others). The lower score on the status and funding heterophily for friends than other relationships suggest, that friendships exist between more similar individuals, whereas other collaborative relationships between more dissimilar people. Interestingly, both the perceived status and funding heterophily is positive, which suggests that it is upwardly biased, respondents on average consider their collaborators to be of higher and not lower status and better grant-getters, than themselves. While this result in part may reflect respondent's consideration and respect towards their collaborators, this also may reflect tendency of people in the middle and high prestige occupations to connect with higher status others (Verbrugge 1977). It also may reflect the primary social divisions of academic community, which has described as inherently hierarchical (Bourdieu 1991, Fox 2006)

Further, a considerable variation in the three homophily accounts can be observed across the groups of respondents defined by rank, gender and citizenship. Friendships of assistant professors are characterized by greater status and funding homophily than their other collaborative relationships (mean status heterophily .38 vs. .61, mean funding heterophily .38 vs. .61). Friendships of full and associate professors, in turn, are characterized by greater gender homophily. Similarly, friendships of men are characterized by greater status and funding homophily than their other relationships, whereas friendships of women, by higher gender homophily than their other relationships. This finding may be explained with the suggestion from the social psychology that members of so called "edge" groups, such as the groups of highest status or minority, tend form more homophilous relationships (Verbrugge 1977). The explanation for this phenomenon is that individuals with rare properties tend to be treated differently (i.e. valued, envied, or discriminated) by the majority, and therefore form a special bond and solidarity between each other. By citizenship, friendships of the native-born U.S. citizens are characterized by greater gender homophily than their other collaborative relationships, whereas in friendships of the naturalized U.S. citizens and foreign citizens are no more or less gender homophilous than other collaborative ties. However, for status and funding heterophily standard deviations are high (.75 for status heterophily and .68 for funding), which suggests considerable variation across individuals. The gender homophily, in turn, seems to be more consistent.

Table 2 Status, Funding & Gender heterophily: Difference in means for friendships vs. other collaborative ties

	Status		Funding		Gender	
	Not Friend N=4640	Friend N=1399	Not Friend N=4510	Friend N=1652	Not Friend N=4640	Friend N=1399

All respondents	0.14	.07**	0.2	.14**	0.55	.61***
Within demographic groups						
Assistant professor	0.61	.38***	0.61	.38***	0.58	0.55
Associate professor	0.21	0.17	0.19	0.2	0.52	.66***
Full professor	-0.18	-0.14	-0.18	-0.14	0.55	.60**
Men	0.11	.00***	0.11	.00*	0.85	0.84
Women	0.16	0.16	0.16	0.16	0.22	.35***
Native born U.S. citizen	0.1	.05*	0.1	.05*	0.53	.61***
Naturalized U.S. citizen	0.74	0.71	0.07	0.16	0.54	0.6
Foreign citizen, permanent visa	0.3	0.2	0.25	0.15	0.61	0.56
Foreign citizen, temporary visa	0.65	.37*	0.41	.17*	0.65	0.71
Legend: * p<.05; ** p<.01; ***p<.001						

Another property of friendship, which is important for mobilization of social capital, is strength of relationship. Two indicators of tie strength are knowledge closeness and number of roles within the relationship (Marsden and Campbell 1984, Hruschka 2010, Verbrugge 1979). Table 3 reports results from the One-Way ANOVA test for the first two indicators relational strength. Knowledge closeness is measured by the self-assessed degree to which respondents understand expertise of their collaborators (where (1) limited knowledge, (2) working knowledge, and (3) detailed understanding. The results show that friendships are stronger than other collaborative ties, both in terms of understanding collaborators expertise (mean 2.97 vs. 2.81) and in the terms of roles within the relationships (mean 1.40 vs. 1.16). The results hold for all demographic groups of scientists and engineers (not shown here). The results show that scientists and engineers turn for advice to their friends more often than to other collaborators (mean .18 vs. .07). This result is consistent with prior research and suggests that people both feel more comfortable turning to their friends for advice, and are more willing to help their friends (McGrath et al 2003, Saint-Charles and Mongeau 2009). Similarly, respondents discuss department or university-related issues with their friends more often than with other collaborators (mean .21 vs. .08), which is consistent with the consensus-building role of friendship in organization (Krackhardt and Kilduff 1990, Kilduff and Krackhardt 2008). Thus, the comparison of friendships to other collaborative relationships shows that friendships are stronger than other workplace relationships. On average, friendship forms within status groups defined by the perceived seniority, grant-getting ability and gender.

Table 3 Strength of relationships: Difference in means for friendship vs. other collaborative ties

	Mean	Std. Dev.	Min	Max	Mean	Mean
	All N=6039				Not Friend N=4640	Friend N=1399
Strength indicators						
Knowledge closeness	2.86	.51	1	3	2.81	2.97***
Number of roles	1.21	.50	1	3	1.16	1.40***

Role specifics						
Turn to for advice	.10	.295	0	1	.07	.18***
Talk about university issues	.11	.317	0	1	.08	.21***
Legend: * p<.05; ** p<.01; ***p<.001						

Friendship Prevalence. Which scientists develop close relationships with their collaborators? Results (Table 4) show that while seniority has no impact on having more close friends among collaborative ties, scientist's accomplishments do. Those respondents, who are in leadership positions, and who are more active in the science community, have more friends in networks of their closest collaborators than less central and active scientists.

Does the prevalence of friendship vary across the groups of scientists? The results show that this personal relationship is not equally present in the collaborative networks of academic scientists and engineers. U.S. native-born scientists, and those scientists who have academic spouses are more likely to have friends among their closest collaborators. Scientists, who are more central and active in the science community, have more friends. Naturalized U.S. citizens and foreign citizens have fewer friends than native-born U.S. scientists. The prevalence of friendship is primarily explained by scientist's demographic characteristics, standing in the professional community, and productivity-related accomplishments. This finding is consistent with the work that speaks of the existence of a core social group in U.S. science or inner circle which is well integrated within the interpersonal networks of science, and for which science is a "way of life" (Austin 2002, Crane 1972, Etzkowitz et al 1994, Fox 1991, Wagner and Leydesdorf 2005). However, the result that overall seniority has no effect on the prevalence of friendship in collaborative networks is contrary to expectations.

Table 4 Prevalence of friendship: Logistic and Negative Binomial models

N=906	Has at least one friend (Model 1.1[1])		Number of friends (Model 1.2[2])	
	Coef.	% change	Coef.	% change
Independent variable:				
Seniority and accomplishments in the science community				
Career age	.00	-1.0	.00	.0
Number of offices in professional associations	.23	25.7	.17*	18.6
Number of grant proposals	.01	1.3	.01*	7.0
Other Independent Variables: :				
Demographic Characteristics and Context				
Female	.11	12.0	-.05	-2.6
U.S. Naturalized citizen	-.36	-30.2	-.25*	-8.3
Foreign Citizen	-.61**	-45.9	-.37***	-13.6
Academic family background	-.17	-16	-.08	-3.1
Academic spouse	.64***	89.1	.21*	10.0
Department Size	.00	.3	.00	2.3
Chemistry	-.34	-28.8	-.32**	-30.6

[1] Logistic regression
[2] Negative binomial regression

Computer science	-.03	-2.7	.05	.5
Earth and atmospheric sciences	.26	29.4	.28**	32.4
Electrical engineering	-.33	-27.8	-.32*	-27.2
Legend: * p<.05; ** p<.01; ***p<.001	LR chi2(13)=52.50 Prob>chi2=0		LR chi2(13)=82.17 Prob>chi2=0	

Productivity effects of friendship. Results (Table 5) demonstrate that friendships with collaborators facilitate both collaborative and personal publication productivity. Each friend in respondents collaborative network increases the expected mean count of publications by 22-23% (Table 5). This result is consistent with the literature, which suggests that networks that of relationships, which are comprised of both social and personal dimensions are more conducive for the mobilization of social capital (Uzzi 1997, Lin 2001). It is also consistent with the literature, which suggests that people nurture their productive relationships (Conradson and Lathan 2005, Hruschka 2010). It is interesting to note that the size of collaborative networks has no effect on the publication productivity. This result is consistent with prior research that has observed, that the number collaborative ties may not have direct effects on the publication productivity (Lee and Bozeman 2005).

To extend this analysis, the social capital literature suggests that different ties may be a source of different types and quality resources (Coleman 1988, Podolny and Baron 1997). The results show that the total of resources mobilized from other collaborators does have a positive productivity effects. However, the resources mobilized from friends have slightly smaller effect, than the resources mobilized from other collaborators.

As could be expected, the external orientation of the network (EI-Index) has a positive effect on the collaborative publication productivity (Burt 1992, Nahapiet and Goshal 1998, Oh et al 2006). With respect to the variation of productivity across the demographic groups, the results suggest that women are as productive as men, in terms of publication count, but less productive in terms of personal productivity. Consistent with prior research, foreign citizens are more productive that U.S. native-born citizens. Finally, each additional year since Ph.D. decrease the expected mean productivity by .6-.8% (Model 3.1b in Table 4-7 and Model 3.1d in Table 4-8). This result is consistent with the literature, which has observed that publication productivity decreases with career age (Levin and Stephan 1991, Carayol and Matt 2006 among others).

Table 5: Effects of Friendship on Academic Productivity

N=906	**Total Publication Count 2007-2009**		**Fractional Publication Count 2007-2009**	
	Coef.	% change	Coef.	Beta
	Independent variable			
Predicted number of friends	.2**	22.2	.37*	0.1
	Other Independent Variables: : Network properties			
Network size	0.01	1.4	0.01	0.01
EI-Index	.16***	17.2	.36***	0.09
Mobilized total of resources	.02***	2.5	.03*	0.08
	Resources			
Grant resources (#of graduate students)	.07***	7.6	.32***	0.4

Demographic Characteristics and Context				
Female	-0.09	8.9	-.37***	-0.09
U.S. Citizen (naturalized)	0.09	1	0.24	0.04
Foreign citizen	.39***	47.6	.80***	0.15
Career age	0	-0.3	-0.01	-0.03
Chemistry	.26***	29.5	.49**	0.1
Computer science	-.61***	-45.5	-.97***	-0.18
Earth and atmospheric sciences	0.04	-4.1	-0.11	-0.02
Electrical engineering	0.01	-1.3	0.09	0.02
Legend: * p<.05; ** p<.01; *** p<.001	Negative Binomial LR chi2(14)= 346.6 Prob > chi2=0		OLS regression Adj. R-squared=.23	

7. Conclusion

The results of this analysis show that more than a half of the collaborative ties in the personal collaborative networks of respondents are friendships. However, friendships of U.S. scientists and engineers form primarily within the ascribed status groups defined by the perceived seniority, grant-getting ability, and gender. The inherent flexibility of friendship, which according to the reviewed literature, contributes to the integration of social structures, manifests in the friendships between individuals whose status differences are defined by their institutional roles, and friendships with peers with whom respondents were Ph.D. students together.

The reviewed literature suggested that prevalence of friendship in the personal professional networks of academic scientists might be explained by their seniority and accomplishments in the science community. Therefore, we hypothesized that more senior and more central scientists and engineers will have more friends. The rationale for this hypothesis was that more senior scientists and engineers might have had more time to find similar colleagues, that older individuals tend to be more selective in their social contacts, and perceive them more positively. More senior and more central individuals also have higher job autonomy and are given preference by those who are less senior or central. The results support this hypothesis only partially. The accomplishments within the science community (conceived as number of current offices and grant getting activity) have a positive impact on the number of friendships among collaborative ties. The seniority (conceived as time since Ph.D.), in turn, has no effect on having friendships among collaborative ties. It appears, that whether respondents have at least one close friend among closest collaborators is primarily explained by the demographic factors. Having a faculty spouse doubles the likelihood of having a close friend among their closest collaborators. Being a foreign citizen, in turn, decreases likelihood of having a close friend by 65%. Taken together with the finding of the descriptive analysis of properties of respondents collaborative networks, which show that scientists with friends have larger, more U.S.-based networks that are comprised of stronger relationships, this may suggest, that friendships form between scientists and engineers who are better integrated in the U.S. academic community. This finding is consistent with the general argument from the anthropological literature that patterns of friendship vary by the major social division of a given society (Adams et al 2000, Allan 1998, Doyle and Smith 2002, Lazarsfeld and Merton 1954, O'Connor 1992, Verbrugge 1977).

The core finding of this work is that collaboration with friends have positive effect on scientist's publication productivity. We hypothesized that scientists with more friends in their professional networks are more productive than scientists with fewer friends. The results show that friendships have a positive effect on scientist's publication productivity: each friend both increases the expected mean number of publications by 22%, and has positive effect on the personal productivity. The relative strength of the effect of friendship is similar to effects of the size and external orientation of the collaborative network. This finding contributes to the small but growing recent body of literature that links properties of personal networks of scientists and engineers to knowledge creation and productivity. Findings of my work are consistent with, and complementary to, findings of McFadyen et al (2009), Rost (2011), Sosa (2011) and Tortoriello and Krackhardt (2010). This literature has pointed at the importance of both network structure and quality of relationships, and suggests that sparse networks of strong relationships may benefit scientific productivity.

Finally, the findings presented here contribute to the discussion about the micro foundations human action. Several authors have pointed at the gap between the level of analysis of the research aimed at the understanding of organizational level outcomes, such as organizational culture (Krackhardt and Kilduff 1999, Kilduff and Krackhardt 2008) or research excellence (Rogers 2000). These authors suggest that management scholars typically focus their attention to the level of organization whereas activities that determine both the culture and research excellence take place at the individual level. As pointed out by Kilduff and Krackhardt (2008), organizational literature traditionally addresses organizational culture from the top-down perspective. From this perspective, organizational culture is seen as being generated by mechanical solidarity, which emerges from shared norms in the organization, and to which managers socialize new members of an organization. In reality, however, organizational culture is two-dimensional.

Friendship networks generate a key dimension of organizational culture. Friendship networks typically emerge around shared values (Lazarsfeld and Merton 1954), and in these networks meanings are negotiated. As pointed out by Kilduff and Krackhardt (2008), different circles of friends may interpret the same norm or rule completely differently, or even oppositely. Therefore, the inherent ambivalence and uncertainty of knowledge production processes, as well as its changing nature of science (namely increasing diversity, globalization, and accountability to public) necessitates an understanding of friendship patterns. The heart of research competitiveness is scientific excellence. The primary activity of achieving excellence is collaboration taking place at the individual or team level, whereas analysis of research competiveness has been conducted at the institutional level (Rogers 2000). The findings of my analysis emphasize the importance of individual level factors, namely personal collaborative communities (conceived as ego-centric networks) of academic scientists and engineers for their publication productivity. This may have implications for how grants and collaborative projects are managed, and how institutions support collaborative work.

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