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Differential Social Network Effects on Scholarly Productivity: An Intersectional Analysis

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Abstract

Academic productivity is realized through resources obtained from professional networks in which scientists are embedded. Using a national survey of academic faculty in Science, Technology, Engineering, and Mathematics (STEM) fields across multiple institution types, we examine how the structure of professional networks affects scholarly productivity and how those effects may differ by race, ethnicity, and gender. We find that network size masks important differences in composition. Using negative binomial regression, we find that both the size and composition of professional networks affect scientific productivity, but bigger is not always better. We find that instrumental networks increase scholarly productivity, while advice networks reduce it. There are important interactive effects that are masked by modeling only direct

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effects. We find that white men are especially advantaged by instrumental networks, and women are especially advantaged by advice networks.

Keywords
academic productivity, gender, underrepresented minorities, social networks, advice networks

In modern scientific disciplines, scholarly productivity is rarely realized on one's own. Successful scientists rely on professional networks of collaborators and advisers to share resources and information that foster scientific productivity. Consistent with other applications of social network theory to occupational productivity, we hypothesize that professional networks enhance the scholarly productivity of academic scientists. Our primary objective, then, is to examine how professional networks affect scholarly productivity and to assess whether some kinds of network resources are more valuable than others in promoting productivity. The questions are complicated, however, by social processes that have consistently shown that social networks of women and members of underrepresented racial and ethnic minorities (URM) tend to have different size and composition of social networks than white men and that they also have lower levels of scholarly productivity than white men. Our desire to explore the relationship between social network characteristics and scientific productivity is therefore complicated by gender and racial dynamics that may operate differently for different groups. Hence, we pursue an intersectional analysis that examines both direct and interactive effects of ascriptive characteristics on the relationship between professional social networks and academic productivity.

Scientists benefit immensely from the resources they obtain from their work-related social networks, and a productive network of colleagues is critical for career growth (Bozeman and Corley 2004; Gaughan and Bozeman 2016). Professional networks are not only academic but also include ties to government and industry in addition to academia; Hong and Zhao (2016) found that the impact of professional ties on scientific outcomes varied by the sector of the tie. Forming relationships that provide not only tangible resources but also other supportive resources and advice may matter for career development and outcomes, just as it enhances productivity in other employment sectors. In recent work, Fox (2015) found that the intensity of informal discussion networks about research was as important for men academics and more important for women academics as formal institutional mechanisms for conveying tenure clarity. What is not known is whether some kinds of tangible professional network resources are more important contributors to scholarly productivity than others. If so, then examining network size alone may mask important dynamics related to the composition and behavior of such professional networks.

Research suggests that URM scientists are often excluded from professional networks (Brown et al. 2013; Pearson and Pearson 1985), particularly those directly relevant to productivity (Etzkowitz, Kemelgor, and Uzzi 2000). While there has been increased attention and support to improving the work climate for and retention of underrepresented faculty, recent work finds that barriers remain an issue for many URM faculty (Brown et al. 2013) and women (Etzkowitz, Kemelgor, and Uzzi 2000). Little is understood about the structure and functioning of the professional networks of women and URMs in comparison with those of white male academic scientists.

Empirical studies document disparities in representation of URMs and emphasize pipeline and retention issues (National Academy of Sciences [NAS] 2010), while other studies address concerns about differential rates of career advancement for women (Ginther and Kahn 2006; Long, Allison, and McGinnis 1993). Research has pointed to lower rates of publication and grant-related productivity for both URMs in science (Toutkoushian and Bellas 1999; Ginther et al. 2011) and women (Fox 1983, 2005; Leahey 2006; Long, Allison, and McGinnis 1993; Xie and Shauman 1998). Given the importance of academic production for career advancement, visibility, professional reputation, and mobility (Long, Allison, and McGinnis 1993; Renzulli et al. 2013), our focus is on the factors that might explain race- and gender-based differentials in academic productivity while accounting for the effects of professional networks on such productivity.

Diverse Faculty in Diverse Academic Institutions

Substantial national policy effort and funding have been dedicated to addressing concern about the representation and advancement of members of URM groups and women in academic science (NAS 2009, 2010), but they have tended to focus on either minority status or gender rather than their intersection (Malcom and Malcom 2011; Matchett 2013). Practically, such analyses have been hampered by a lack of data with sufficient power to allow intersectional analysis (Choo and Marx Ferree 2010; Leggon 2006; McCall 2005). Data consistently show that URM doctoral scientists make up less than 8 percent of all full-time faculty employed in institutions of higher education and even less in the research universities (National Science Foundation, National Center for Science and Engineering Statistics 2015).

While low representation is a critical issue, there is also evidence of significant barriers to career development and advancement for URM groups, who hold fewer tenured and full professor positions (Perna 2001) and on average have lower salaries, fewer publications, and less external funding other scientists (NSF 2015). Evidence of discrimination in academic environments suggests barriers to participation in academic production and career advancement (Turner 2002). These barriers may also explain the significant and dramatic racial disparities in National Institutes of Health (NIH) grant success (Ginther et al. 2011). Women as a group have made progress in representation on university faculty in some Science, Technology, Engineering, and Mathematics (STEM) disciplines, but they continue to be underrepresented in all of the STEM disciplines (NSF 2015). Studies continue to be limited by an inability to study important gender, race, and ethnicity interactions because of small cell sizes (Leggon 2006). Finally, while Asian faculties are not included in the National Science Foundation definition of underrepresented minorities, evidence of disadvantage for Asian women has received attention (Malcom and Malcom 2011; Matchett 2013). In this research, we bring gender, race, and ethnicity together in an intersectional analysis of the social network determinants of academic productivity in academic science and engineering.

Scholarly Productivity

We focus on scientific productivity because it is a widely recognized metric of professional success (Fox 1983), because it is an important predictor of other kinds of career success such as promotion (Long, Allison, and McGinnis 1993), and because prior research has developed sound analytic models. Women's lower publication productivity has been documented (Fox and Mohapatra 2007), but there is accumulating evidence that the gender gap is closing (Toutkoushian and Conley 2005). In developing science systems, network studies found no gender difference in publication productivity in China (Hong and Zhao 2016) or the Philippines (Ynalvez and Shrum 2011). What little evidence there is of racial and ethnic productivity differences supports the idea that members of URM also have lower publication productivity (Matchett 2013), but care must be taken not to group all underrepresented minority faculty together. Prior work has shown different patterns of academic productivity across

Hispanic and African American faculty in academia generally (Toutkoushian and Bellas 1999) and in STEM (Sabharwal and Corley 2008), where African Americans produce less than Hispanics. By contrast, Asian male faculty consistently have higher levels of publication productivity than other groups (Mamiseishvili and Rosser 2010).

A number of explanations have been offered for differentials in publication productivity rates typically related to demographic factors. Other research has addressed specialization (Leahey 2006), structural barriers (Xie and Shauman 1998), and discrimination and climate (Pearson and Pearson 1985) to identify factors beyond demographic characteristics. If access to professional networks matters for academic productivity, and if individuals are excluded from or are unable to develop ties in these professional networks, then there should be resulting effects on scholarly productivity.

Professional Networks in Academic Science

Social networks refer to the set of multiple individuals or entities that are connected by sets of ties (Borgatti and Foster 2003). Network structures are not uniform, and their resources are not equally accessible. Studies of labor markets have shown that networks are uneven and create different opportunities and resources across individuals (Granovetter 2005). These benefits may be categorized as professional social capital, where resources are obtained through network relationships in which one interacts (Coleman 1988; Lin 2001). Lin (2001) conceptualizes the content of such relationships as having instrumental and expressive characteristics; instrumental actions help to achieve valued goals, while expressive actions help to maintain network resources. Faculty operate within a social and organizational framework, where professionally based relationships provide access to resources and create or reinforce barriers to career development, work satisfaction, and productivity (Fox 2015; Fox and Mohapatra 2007) by increasing the amount and quality of resources accrued to the networked individual (Burt 2000; Granovetter 1973; Renzulli, Aldrich, and Moody 2000). Due to the interdependent and collaborative nature of science, faculty can potentially benefit from one another through coauthorship; sharing financial, technical, and knowledge resources; active engagement in funded research; and professional advice and guidance (Gaughan and Bozeman 2016; Katz and Martin 1997). In the scholarly context, instrumental resources include those related directly to producing scholarship; Lin's concept of expressive resources may be represented by such actions as professional advice and guidance and is also analogous to Fox's (2015) concept of informal information resources.

In studies of networked social capital, network size is important because larger networks suggest access to resources that potentially translate into stronger productivity (Borgatti and Foster 2003; Burt 2000; Granovetter 2005; Podolny and Baron 1997). In the academic setting, larger networks would suggest more opportunities for coauthorship, funding, information, and other resources. Conversely, smaller networks yield fewer resources, suggest exclusion from certain resources, and could limit opportunities for advancement. Thus, one explanation of why URMs and women experience lower levels of academic productivity may be due to smaller professional social networks. When networks are examined by gender, women and men develop and maintain different work-related network structures and access different resources through them, with women typically having smaller non-kin networks (Ibarra 1992; Marsden 1987; Moore 1990). In a panel study of scientists in three developing countries, Miller and Shrum (2012) found that women had smaller networks than men and that the networks shrunk over time. Members of racially underrepresented groups are more likely to have smaller networks that comprise lower-status and homophilous ties (Freeman and Huang 2014; Mehra, Kilduff, and Brass 1998), and they tend not to be part of more general collegial groups and networks (Combs 2003). They are further disadvantaged because ethnically homophilous collaborations are associated with lower publication productivity and impact (Freeman and Huang 2014). Networked social capital may be even sparser for underrepresented minority women, where there is evidence of greater exclusion (Ibarra 1993). Unwelcoming local climates may result in smaller networks within the institutions of URM faculty, resulting in fewer proximal ties (Pinheiro and Melkers 2011). Research on chilly climates, discrimination, and exclusion suggest potentially limited opportunities for access to high-value networks that are important for productivity (Fagen and Olson 2007). In brief, because social network composition differs by race, ethnicity, and gender, we must account for these factors in order to understand the effect that professional social networks have on scholarly productivity.

Intersectional Analysis

Intersectionality as a term was introduced formally in legal studies by Crenshaw (1991), who highlighted the complexity of the legal rights and lived experiences of persons occupying multiple marginalized statuses.

Intersectionality is grounded in critical African American feminist theory that highlighted the heterogeneity of experiences among women and people of color (Collins 1990; Davis 2008). A growing body of critical theory and qualitative and comparative research uses the analytic perspective of intersectionality, which argues that multiple interacting factors influence lived experience and that those factors are intertwined in complex ways (see, for reviews, Browne and Misra 2003; Collins and Bilge 2016). From a methodological perspective, this complexity presents a number of research design and analysis problems. Quantitative analysis applied to intersectional theory has been limited by small cell sizes, an issue explicitly addressed in the research design that supports this research. There is a general consensus that intersectional analysis—whether qualitative, quantitative, or mixed method—should focus on the interaction among statuses and not just on additive processes that would be revealed by studying direct effects only (Bowleg 2008; Choo and Marx Ferree 2010; Weldon 2008). Our approach follows McCall's (2005) guidance about using intercategorical analysis of multiple groups strategically to test hypotheses about how professional social network resources influence scientific productivity.

Hypotheses

We focus on how the size and composition of professional networks vary by race, ethnicity, and gender and how the effect of professional networks on productivity may vary by the nature of network resources. While overall network size has implications for access to resources, individuals are typically embedded in multiple networks, which in turn provide different types of resources important for career productivity and advancement. In other words, only examining overall network size may mask important network resources critical for productivity. Some academic professional networks may provide more instrumental resources directly related to productivity (e.g., collaboration and financial support). By contrast, advice-based networks provide information useful for navigating collegial interactions, departmental culture, or providing psychosocial support (Brass 1992), but which may not be related to productivity. Hong and Zhao (2016) conceptualize these mechanisms as "resource acquisition" and "information communication" but posit that the information communication mechanism predicts publication productivity, while the resource acquisition mechanism predicts grants and awards productivity. In our study, we focus exclusively on publication productivity, and we study the relative contributions of instrumental and advice mechanisms directly.

Given the underrepresentation of women, and racial and ethnic minorities in science, evidence of exclusion and professional isolation, and barriers to accessing professional resources, we hypothesize that

> **Hypothesis 1:** Underrepresented minority and women faculty members' professional networks are smaller.

Network resources may be structured or accessible in different ways for URMs and women as compared to members of majority groups. In other cases, members of underrepresented minority groups may seek out supportive networks that provide psychosocial support and advice, possibly substituting these relationships for other collaborative ones (Baez 2000). Access to instrumental networks can be particularly important for scientific productivity. As individual faculty members engage in different networks, they gain access to a range of resources across these networks. If underrepresented faculty have less access to high value networks (Fagen and Olson 2007), whether due to exclusion, discrimination, or personal network strategies, we hypothesize that

> **Hypothesis 2:** Members of underrepresented racial and ethnic minority groups and women receive fewer high-value instrumental network resources related to productivity and more low-value career advice network resources compared to others.

The first two hypotheses address the extent to which women and members of underrepresented minority groups have different size and composition of professional network resources. Having examined simple bivariate relationships between scholarly productivity and race, ethnicity, and gender, we then assess the effect of professional social network characteristics on scholarly productivity. The first social network hypothesis test is simple:

> **Hypothesis 3:** Scientists who maintain larger professional networks will tend to produce more scholarship.

Because of the complexity of professional networks, volume alone is a crude measure of such professional networks. The actual resources and behavior flowing through these networks are likely to have different effects, depending on how much they contribute to scholarly productivity. Scientific professional networks are composed of instrumental and advice resources that contribute differentially to scholarly productivity.

> **Hypothesis 4:** Instrumental professional networks resources will increase scholarly productivity while advice resources will not.

Our next hypotheses test alternative conceptualizations regarding the effects of social network and demographic characteristics and how they work together to affect productivity. Professional network characteristics may confer different advantages and disadvantages based on the demographic characteristics of the respondent. In the first conceptualization, the network effects on productivity are hypothesized to operate similarly across demographic categories, productivity effects being explained by the demographic differences in social network characteristics (not by differences in how those social network characteristics operate). A test of direct social network effects follows:

> **Hypothesis 5:** The direct effects of gender, race, and ethnicity are mediated by social network characteristics such that gender, race, and ethnicity affect network structure, but network structure is the main productivity determinant.

By contrast, an alternative hypothesis is

> **Hypothesis 6:** Social network characteristics affect scholarly productivity differently, depending on the demographic characteristics of the professor.

If supported, such a hypothesis is consistent with the argument that social network characteristics operate differently to determine productivity. If supported, this would be consistent with intersectionality arguments, whereby gender and other demographic characteristics interact to explain different outcomes.

On the basis of our study, we will be able to understand if the inclusion of social network characteristics in productivity models accounts for demographic differences in productivity (mediation, Hypothesis 5) or whether social networks operate differently to explain productivity (moderation, Hypothesis 6). If either of these two hypotheses is supported, our results would suggest that earlier models of scientific productivity demonstrating group-level differences in academic productivity were missing an important construct. Further, if we find support for the hypothesis that professional social networks affect scholarly productivity, then we can begin to understand the nuances of the various networks in which faculty engage and how these different network types have an impact on productivity.

Data and Method

We use data from the NETWISE II study, a national survey of academic faculty in four disciplines: biology, biochemistry, civil engineering, and mathematics. We selected STEM disciplines based on their high (biology and biochemistry), medium (mathematics), and low (civil engineering) representation of women in faculty ranks (NSF 2015). All STEM disciplines have low representation of faculty members of color, so this was not a factor in our disciplinary choices. Our sampling frame included all research extensive universities (149), all research intensive universities (110; Carnegie Foundation 2000), all historically black colleges and universities (HBCU) institutions in the White House Initiative (forty-three, total across institutional types), all Hispanic-serving institutions meeting our criteria ($n = 49$), all Oberlin fifty liberal arts institutions, and nineteen women's colleges. We drew a 15 percent sample from the master's I and II institutions, which resulted in a sample of ninety-six institutions (Carnegie Foundation 2000).

The stratified sample of 9,925 was drawn from a population of 25,928 academic faculty members in 521 academic institutions in the United States. Participants were contacted through their university e-mail accounts, which were collected once the stratified sample was drawn. We used Sawtooth to program an online survey whose link was included in the recruitment e-mails and follow-ups; respondents were generous with their time, as each survey took between thirty and forty-five minutes to complete. We received a total of 4,196 valid responses (response rate = 40 percent), although missing network data resulted in a final usable sample of 3,076 respondents, including 193 African Americans and 150 Hispanics, employed in 487 academic institutions in the United States. This response rate is typical for this population of researchers but not ideal: sensitivity analyses showed that women were somewhat more likely to complete surveys and that faculty working at HBCU was somewhat less likely to complete surveys. Consistent with Winship and Radbill (1994), the inclusion of each variable in multivariate analysis will minimize this potential for selection bias.

The sample was designed to be representative but required oversampling of women and members of underrepresented groups in order to generate subsamples large enough to sustain intergroup comparisons. Hence, all statistics reported are weighted by inverse of the probability of inclusion in the study, which varied by gender, race, ethnicity, and institutional type. The weighted distribution of respondents is consistent with other national studies:

Table 1. Descriptive Statistics of the Sample, Weighted.

Variables	Mean	Standard Deviation
Demographic characteristics		
Female	0.29	0.70
Non-Hispanic white	0.79	0.63
African American	0.04	0.29
Hispanic	0.04	0.32
Asian	0.13	0.53
Foreign-born	0.32	0.72
Married	0.83	0.59
Career characteristics		
Year of PhD	1990	17.94
Assistant professor	0.22	0.64
Associate professor	0.31	0.72
Professor	0.47	0.77
Biology	0.41	0.76
Biochemistry	0.12	0.50
Civil engineering	0.17	0.58
Mathematics	0.3	0.71
Institutional characteristics		
Research extensive	0.51	0.77
Research intensive	0.16	0.57
Liberal arts	0.07	0.39
Master's	0.15	0.56
Historically black colleges and universities	0.04	0.29
Hispanic serving	0.06	0.37

women are somewhat less than one-third of respondents, while nearly four-fifths identify exclusively as non-Hispanic white. Four percent are African American and Hispanic, similar to their low levels of representation in the academic STEM population. More than one-third of respondents are foreign-born, and four-fifths are married, reflecting the high rates of marriage that characterize this population. The average year of completion of the PhD is 1990, with a broad range of eighteen years. Nearly half of respondents are full professors, one-fifth are assistant professors, and almost one-third are associate professors. Over half work in research extensive universities, 10 percent work in minority serving institutions, and slightly more than two-fifths of respondents work in different kinds of educational institutions, such as a master's comprehensive, a less intensive research environment, or one of the liberal arts institutions included in the institutional sampling frame (Table 1).

Measure of Academic Productivity

We conceptualized productivity broadly as the sum of peer-reviewed journal articles, peer-reviewed proceedings, public presentations, and book chapters produced over the past two years. This measure of productivity better represents the full scope of scholarly activity accomplished by the scientist and as such provides a richer measure of productivity than counts of peer-reviewed publications.[1]

Focal Network Characteristics

The survey used an egocentric network design to gather relational data through social network questions that asked respondents to name the closest members of their professional network alters including the names of dissertation chair, postdoctoral supervisor, mentors, individuals with whom they regularly discuss teaching issues, individuals who are closest research collaborators, and individuals with whom they discuss university or department issues. Each respondent had the opportunity to nominate up to twenty-six network members.

Many kinds of resources may be provided through networks, resulting in multiplex relationships that may provide differential benefits on such outcomes as scholarly productivity. Once the names of social networks members were provided, they were used to prompt the respondent to answer about specific activities that related to instrumental resources and general advice resources for each network tie.[2] Network characteristics vary along many dimensions. For this study, we use two constructs: size and composition. To address the integration of women and URM faculty members in their professional networks, we analyzed the network size of these relationships, which not only captures a key dimension of an individual's network structure but also serves as a measure of integration in the academic community (Marsden 1987). Network size also represents an individual's social capital as the network resources that may be accessed through those relationships (Lin 2001).

We used confirmatory factor analysis to determine that there are two major dimensions of behavior in the professional network. We used eight indicators to represent the construct of instrumental resources in networks ($\alpha = .85$); these indicators measure interactions related to scholarly productivity, such as work on grants and papers, and discussions about research activity (the latter similar but not identical to Fox [2015]). The second construct was advice resources about the work environment ($\alpha = .89$);

the five indicators measured interactions about teaching, colleagues, and departmental politics. To assess the effects of both size and composition on scholarly productivity, we standardize the composition variables by calculating the proportion of instrumental resources in the network and the proportion of advice resources related to the work environment.[3]

Other Explanatory Variables

Controls for professional age, rank, discipline, and institutional type are included because scholarly productivity varies by career stage (Levin and Stephan 1989), discipline (Becher 1994), and institutional context (Fox and Mohapatra 2007). O'Brien (2012) finds that propensity to coauthor has increased over time but finds support for both age and cohort replacement effects. We represent institutional complexity with three dummy variables: research extensive, research intensive, and HBCU.[4] The institutional reference group is a heterogeneous group of faculty members from the remaining institutional types; faculty members in the reference group have similar network and productivity profiles.

Results

Bivariate Analysis of Focal Variables

We present bivariate analyses of focal variables in Table 2. We find that women have lower productivity than men, African Americans have lower productivity than whites, Asians have higher productivity than whites, and there is no difference between non-Hispanic whites and Hispanics. The distributions of racial and ethnic groups and men and women also differ for other determinants of scientific productivity, such as discipline, nativity, and institutional type (not shown).

Men and women differ in network composition: women have larger networks (9.5 members compared to 9 members), their networks are composed of more advice resources and fewer instrumental resources. Over half of the resources flowing through men's networks are instrumental in nature while over half of the resources flowing through women's networks are related to advice. Asians have smaller networks compared to other groups (7.2 alters), but their networks are predominantly composed of instrumental resources (59 percent), and have especially low levels of advice resources (33 percent). Other racial and ethnic groups do not differ in terms of either instrumental resources or advice resources flowing through their networks.

Table 2. Productivity and Scientific Networks Characteristics by Race, Ethnicity, and Gender.

Variables	All	Men	Women	White	African American	Hispanic	Asian
Focal dependent variable							
Two-year productivity	10.13	11.16	7.56	9.81	6.82	9.34	13.10
Significance between white and focal		—	—		***		***
Significance between men and women			***	—	—	—	—
Focal independent social network variables							
Network size	9.13	8.98	9.52	9.39	9.27	10.24	7.20
Significance between white and focal		—	—	—		**	***
Significance between men and women			***		—	—	—
Instrumental resources	0.51	0.53	0.46	0.50	0.50	0.50	0.59
Significance between white and focal		—	—				***
Significance between men and women			***	—	—	—	—
Advice resources	0.45	0.42	0.51	0.47	0.44	0.48	0.33
Significance between white and focal		—	—				***
Significance between men and women			***	—	—	—	—
Sample size	3,076	1,723	1,353	2,095	193	150	638

*$p < .05$, two-tailed tests.
**$p < .01$, two-tailed tests.
***$p < .001$, two-tailed tests.

Bivariate analysis shows that there are systematic social network differences between men and women, and between different race and ethnic groups, that may explain productivity differences. The results diverge from our first hypothesis in that women and Hispanics have larger networks; indeed, only Asians have smaller networks than whites. With respect to the composition of social networks, Hypothesis 2 is only partially supported: For both African Americans and Hispanics, the relative composition of networks does not differ from those of whites. Asians networks are characterized by more instrumental resources and by a lower volume advice resources. By contrast, women's larger networks are composed of significantly higher levels of advice resources than instrumental resources.

Multivariate Results

Multivariate analysis allows the inclusion of all potential determinants simultaneously, overcoming that limitation of bivariate analyses. The scholarly productivity variable is a count variable that is not normally distributed, and so we employ negative binomial models to estimate the explanatory model. As discussed above, because of the complex sampling design and differential response rates, we weight all analyses by the probability of selection into the sample.

Table 3 shows the weighted negative binomial estimates of effects on two-year publication productivity. In model 1, we see the focal network measures operating as hypothesized: the overall size of the professional network is positively related to publication productivity. Furthermore, instrumental networks increase scholarly productivity, while greater levels of advice resources in the network are associated with lower scholarly productivity. As in other models of publication productivity, we observe that women and URM groups have lower levels of productivity, while the foreign-born are significantly more productive. Career characteristics and field effects matter, where more recent PhDs are more productive (a cohort effect), and full professors are significantly more productive than assistant or associate professors (an experience effect). The productivity of biochemists and mathematicians is similar to, and civil engineers are more productive than, biologists. Finally, academics working in research extensive, research intensive, and minority serving institutions are all significantly more productive than those working in master's comprehensive or liberal arts institutions.

To this point, our analysis has demonstrated that network size and composition are important determinants of scholarly productivity, while

Table 3. Negative Binomial Regression of Network Size and Resources on Two-year Productivity, Weighted.

Variables	Model 1			Model 2		
	Baseline 1[a]			Baseline 2[b]		
	Est.	*SE*	Sig.	Est.	*SE*	Sig.
Intercept	−24.11	4.35	***	−24.74	4.35	***
Network characteristics						
Network size	0.02	0.004	***	0.02	0.004	***
Instrumental resources	0.54	0.09	***	0.53	0.09	***
Advice resources	−0.68	0.09	***	−0.68	0.09	***
Demographic characteristic						
Woman	−0.09	0.04	*	−0.08	0.04	*
White	—	—	—	0.15	0.04	***
African American	−0.29	0.09	***	—	—	—
Hispanic	−0.20	0.08	*	—	—	—
Asian	−0.10	0.05		—	—	—
Foreign-born	0.54	0.04	***	0.55	0.04	***
Married	0.01	0.04		0.02	0.04	
Career characteristic						
Year of PhD	0.01	0.002	***	0.01	0.002	***
Assistant professor [c]	−0.65	0.060	***	−0.66	0.06	***
Associate professor	−0.46	0.050	***	−0.47	0.05	***
Biochemistry[d]	0.03	0.050		0.03	0.05	
Civil engineering[d]	0.18	0.050	***	0.18	0.05	***
Mathematics	−0.04	0.040		−0.04	0.04	
University characteristic						
Research extensive[e]	0.53	0.04	***	0.53	0.04	***
Research intensive	0.37	0.05	***	0.37	0.05	***
Minority serving	0.23	0.06	***	0.21	0.06	***
Dispersion	1.26	0.04		1.26	0.04	
Measures of model fit						
Deviance/*df*	1.2			1.2		
AIC	18,964			18,966		
N	3,052			3,052		

*$p < .05$, two-tailed tests.
**$p < .01$, two-tailed tests.
***$p < .001$, two-tailed tests.
Note: AIC = Akaike information criterion; Est. = estimate; *SE* = standard error; sig. = significance.
[a]Reference group for race and ethnicity is Non-Hispanic white.
[b]Reference group for race and ethnicity are African American, Hispanic, and Asian.
[c]Reference group for rank is full professor.
[d]Reference group is biology.
[e]Reference group are comprehensive master's, women's, and liberal arts colleges.

controlling for known determinants of such productivity. Model 1 therefore represents our multivariate tests of direct effects. We do not have the power to run fully interacted models because of small cell sizes; furthermore, there are few guides to conducting quantitative intersectional analysis using fully interacted models. In model 2, we replace the series of variables for African American, Hispanic, and Asian (all of which had negative effects on productivity) with a single dummy variable for nonwhite. Certainly, this is not ideal, but by testing this simplified model, we learn whether it will be worth gathering sufficient data to test more complex race and ethnicity effects. Note that the direct pattern of network effects remains the same: being female continues to be negative, and being white continues to be an advantage. Therefore, we will use variations of model 2 to test the hypothesized interactive effects in Table 4.

To give a sense of the magnitude of the effects, we exponentiated the coefficients of model 2 to obtain the incidence rate ratios, which for a negative binomial model is analogous to odds ratios in logistic regression. Consistent with theoretical predictions, the rate of women's publications is about 10 percent lower than men's, and the rate of white's publications is 13 percent higher than for nonwhites. For each additional member in network size, scholarly productivity increases by 2 percent. To evaluate the effect of network resource composition, we dichotomized the variables to represent the highest levels of each kind of resource network. For example, if at least three-quarters of the professional network provides instrumental resources, then the dummy variable is "1." Similarly, if at least three-quarters of the network advice resources, the variable is "1."[5] Faculty members in the top quartile of instrumental resources have a 48 percent higher rate of publication than those in the lower quartiles. By contrast, faculty members in the top quartile of advice resources have a 44 percent lower rate of publication than those with a smaller percentage of their networks devoted to advice.

In Table 4, we estimate a series of interaction models to examine mediating and moderating effects by race and gender. First, we look at the effect of network characteristics across the models: absolute size and instrumental networks increase scholarly productivity and advice networks decrease it. In other words, there is evidence that direct effects of network characteristics on scholarly productivity remain strong irrespective of model. Do race and gender mediate or moderate the relationship? In model 3, we estimate the effect of white instrumental networks: The results indicate that whites are particularly advantaged by productivity networks, and direct effects of race are fully mediated (i.e., there are no direct race effects), and being a white woman continues to have a direct negative effect. Contrast this

Table 4. Negative Binomial Regression of Network Size and Resources on Two-year Productivity, Interactive Models Weighted

	Productivity Networks						Advice Networks					
	Model 3			Model 4			Model 5			Model 6		
	Race			Gender			Race			Gender		
Variables	Est.	*SE*	Sig.	Est.	*SE*	Sig.	Est.	*SE*	Sig.	Est.	*SE*	Sig.
Intercept	−24.14	4.36	***	−25.06	4.34	***	−24.75	4.35	***	−25.41	4.35	***
Network characteristic												
Network size	0.02	0.004	***	0.02	0.004	***	0.02	0.004	***	0.02	0.004	***
Instrumental resources	0.35	0.12	**	0.61	0.09	***	0.53	0.09	***	0.52	0.09	***
Advice resources	−0.64	0.09	***	−0.71	0.09	***	−0.67	0.13	***	−0.83	0.1	***
Interaction terms												
White × instrumental	0.28	0.13	*	—	—		—	—		—	—	
Woman × instrumental	—	—		−0.38	0.13	**	—	—		—	—	
White × advice	—	—		—	—		−0.001	0.14		—	—	
Woman × advice	—	—		—	—		—	—		0.48	0.13	***
Demographic characteristic												
Woman	−0.09	0.04	*	0.1	0.07		−0.09	0.04	*	−0.31	0.07	***
White[a]	−0.01	0.08		0.15	0.04	***	0.15	0.07	*	0.15	0.04	***
Foreign-born	0.55	0.04	***	0.54	0.04	***	0.55	0.04	***	0.54	0.04	***
Married	0.02	0.04		0.02	0.04		0.02	0.04		0.03	0.04	
Career characteristic												
Year of PhD	0.01	0.002	***	0.01	0.002	***	0.01	0.002	***	0.01	0.002	***
Assistant professor[b]	−0.65	0.06	***	−0.65	0.06	***	−0.66	0.06	***	−0.65	0.06	***

(continued)

Table 4. (continued)

	Productivity Networks						Advice Networks					
	Model 3			Model 4			Model 5			Model 6		
	Race			Gender			Race			Gender		
Variables	Est.	*SE*	Sig.	Est.	*SE*	Sig.	Est.	*SE*	Sig.	Est.	*SE*	Sig.
Associate professor	−0.46	0.05	***	−0.47	0.05	***	−0.47	0.05	***	−0.47	0.05	***
Biochemistry[c]	0.03	0.05		0.03	0.05		0.03	0.05		0.03	0.05	
Civil engineering[c]	0.19	0.05	***	0.19	0.05	***	0.18	0.05	***	0.19	0.05	***
Mathematics	−0.04	0.04		−0.04	0.04		−0.04	0.04		−0.04	0.04	
University characteristic												
Research extensive[d]	0.52	0.04	***	0.53	0.04	***	0.53	0.04	***	0.53	0.04	***
Research intensive	0.37	0.05	***	0.38	0.05	***	0.37	0.05	***	0.38	0.05	***
Minority serving	0.21	0.06	***	0.21	0.06	***	0.21	0.06	***	0.21	0.06	***
Dispersion	1.26	0.04		1.26	0.04		1.26	0.04		1.26	0.04	
Measures of model fit												
Deviance/*df*	1.2			1.2			1.2			1.2		
AIC	18,963			18,959			18,968			18,954		
N	3,052			3,052			3,052			3,052		

*p < .05, two-tailed tests.
**p < .01, two-tailed tests.
***p < .001, two-tailed tests.
Note: AIC = Akaike information criterion; Est. = estimate; *SE* = standard error; sig. = significance.
[a]Reference group for race and ethnicity is African American, Hispanic, and Asian.
[b]Reference group for rank is full professor.
[c]Reference group is biology.
[d]Reference group are comprehensive master's, women's, and liberal arts colleges.

finding with model 5, in which we estimate the effect of white advice networks, the direct positive effects of being white persist while there is no particular race advantage in the effect of advice resources.

In models 4 and 6, we estimate interactions of gender with the network composition. In model 4, the interaction of gender with instrumental network suggests that women are disadvantaged by productivity networks and the direct positive effects of being white persists. In model 6, the direct negative effect of gender on scholarly productivity persists, while the positive effect of being white also persists. The significant positive gender interaction with advice networks shows that the negative direct effect of being a woman is moderated by advice resources. Advice networks are disadvantageous for everyone, but women's advice networks somewhat counteract the disadvantage.

We exponentiate the coefficients to estimate the magnitude of the effects. Across models, the effect of an additional network member on scholarly productivity is about 2 percent, the negative effect of being female is 9 percent to 15 percent, and the positive effect of being white is 14 percent. The positive effect of being in the top quartile of instrumental resources ranges from 28 percent to 55 percent, while the effect of being in the top quartile of advice resources reduces productivity between 42 percent and 51 percent. Whites in networks in the top quartile of productivity resources have a 21 percent productivity advantage over others (model 3), but there is no longer a direct effect of being white. In other words, whites are especially advantaged only by networks with a higher proportion of instrumental resources. There is no interactive effect of race and advice resources, but the direct effect of being white persists (model 5). The negative effect of being a woman is entirely moderated by their lower gains to instrumental resources: women in the top quartile of instrumental resources have a 20 percent lower productivity rate than men (model 4). Finally, women in the top quartile of advice resources have a 51 percent increase in their productivity rate, although the direct negative effect of being female persists.

To summarize our main results, we found that professional networks are structured differently, according to the gender, race, and ethnicity of the scientist (Hypotheses 1 and 2), and that network characteristics affect scientific productivity. Specifically, we found that larger social networks and greater instrumental network resources have positive effects on scientific productivity and that advice networks have a negative effect on scientific productivity (Hypotheses 3 and 4). Evaluating the performance of the models with interaction terms supported the intersectionality idea that the combinations of gender, race, and ethnicity matter for network size, resource provision, and productivity. We find support for Hypothesis 5, which posited that networks improve scholarly productivity for everyone. However, we also find support for Hypothesis 6, which posited that network effects differ based on the racial, ethnic, and gender identity of the scientist. White men are especially positively advantaged by instrumental networks (model 3) and women are especially disadvantaged by instrumental networks (model 4). By contrast, white men are disadvantaged by advice networks, although the direct negative effects of being female and a member of an ethnic or racial minority group also persist (model 6).

Discussion

We have focused on the size and composition of the professional networks of academic scientists. In light of social capital theory and the nature of scientific inquiry, we expected that larger networks represent more resources and that larger networks characterized by relatively more instrumental network resources would result in higher levels of scholarship. The finding that size matters—bigger networks confer greater benefits—was robust and persists in all of the models we specified. We also found that the composition of network resources matters, but it did not affect scholarly productivity exactly as we hypothesized. We expected that instrumental networks related to the research function of professors would improve scholarly productivity, a hypothesis that was supported by all of our models. It is not surprising that collaborating on papers and grants and engaging in discussions related to papers and grants would lead to higher scholarly productivity. To the extent that any of these results warrant advice to other scholars, it is to invest in professional relationships that focus on the production functions related directly to scholarly activity

We hypothesized that receipt of advice about the workplace would have no impact on scholarly productivity; in fact, professional networks composed of relatively more advice-giving ties had consistent, direct, negative effects on scholarly productivity. This finding was unexpected and warrants additional consideration. The variable is the sum of receiving advice about teaching, institutional politics, colleague interactions, and work–family balance, which captures discussions about the work environment that do not relate directly to scholarly productivity. Perhaps the effect is negative because people engaging in larger amounts of time discussing the work context are also spending less time in productive discussions. Such a finding is also consistent with the idea that people who spend more time in institutional service or teaching will manifest that greater interest in their discussion networks. There may also be issues with the quality of information flowing through such discussion networks—just because a colleague is giving advice does not mean it is good advice. Alternatively, it may be that the person is receiving good advice about teaching and students because he or she is having a hard time with that part of the job, a scenario that surely would detract from time to spend on scholarly productivity. These are all interesting ideas about the role of workplace advice on academic careers, but these data do not allow us to get traction on any of them. Indeed, a more qualitative approach is warranted to observe these "water cooler" interactions in the academic workplace to get a more nuanced understanding of their content and why they may have a negative effect on scholarly productivity.

We maintain with confidence that larger networks through which instrumental resources flow are conducive to higher levels of scholarly productivity, and this constitutes good general advice irrespective of gender or race and ethnicity. However, our intersectional analysis demonstrates that there are important moderating effects—both positive and negative—that arise at the intersection of gender, race, and ethnicity. First, we found that African Americans, Hispanics, and Asians have lower levels of scholarly productivity than whites, and this effect was consistent across models. We also found that women have lower levels of scholarly productivity. More specifically, we looked at how gender, race, and ethnicity intersect with the composition of social networks. In the only model that does not find direct negative effects of race or ethnicity, we found that white men are especially advantaged by relatively larger networks that provide instrumental resources. This finding does not change our recommendation for scholars to invest in instrumental networks—the direct effects are still compelling—but perhaps it is important for department chairs, mentors, and other academic and disciplinary leaders to recognize that whites in general, and white men in particular, get more from their professional instrumental resource networks than members of other groups. What that something extra special is we leave for further research aimed at understanding the particular ways that white men's collegial behavior operates to confer productivity advantages. It is interesting to note that in the final model, the negative effect of advice networks is somewhat lessened by being a woman of any race or ethnicity. It would seem that men are somewhat more disadvantaged by relying on water cooler discussions about the workplace than are women, another intriguing finding best pursued qualitatively.

The study makes a number of contributions, including a large and representative sample of scientists that includes many types of higher education institutions and sufficient numbers of women and members of underrepresented groups to sustain the intersectional analyses we present. It uses several measures of professional networks to examine their impact on scholarly productivity and demonstrates that the effects of such networks vary by demographic characteristics. We note a number of limitations. First, this study takes place in the US context, which differs substantially from other major science systems in its size, the diversity of its higher education institutions, the professional roles that professors play, its dependence on foreign-born academics, and the multicultural diversity of its domestic population. Second, to include sufficient numbers of women and members of URM in our sampling frame, we limited our study to the four disciplines of biology, biochemistry, civil engineering, and mathematics. This has the major limitation of excluding the social sciences and humanities as well as other large and important fields of STEM itself. Third, our 40 percent response rate is low in standard social science terms, but we note that this is typical in studies of PhD-level scientists. Because the construction of the sampling frame requires collection of specific data, it is possible to examine whether response rates vary by gender, rank, institution type, discipline, and race and ethnicity. As with most survey studies, women were slightly more likely to respond than men, and those working for HBCUs were less likely to respond than those working in other kinds of higher education institutions. Because we control for these variables directly, we are confident that they have minimal impact (Winship and Radbill 1994). Finally, this article operationalizes intersectionality in a limited way. We are pleased to have a large enough sample of underrepresented racial and ethnic professors to conduct multivariate and intersectional analyses, but we recognize that using simple categorical variables to denote racial and ethnic group membership (McCall 2005) pales in comparison to the nuanced theoretical approaches to within- and between-group heterogeneity represented by intersectionality theory (Browne and Misra 2003; Collins and Bilge 2016).

The research adds to a large body of research on scholarly productivity by explicitly modeling social network characteristics as determinants of this critical activity. In a general way, network resources related to being an academic translate directly into higher levels of productivity, a finding that is consistent with decades of theoretical predictions and empirical inquiry. Importantly, however, we demonstrate that size alone is not a sufficient determinant of scholarly productivity and that not all network resources flowing through those professional networks are equally valuable. Instrumental resources tend to improve scholarly productivity, while advice resources tend to have negative effects on productivity. The direct effects of these two mechanisms are consistent and do not mediate the negative effects of being female or a member of a racial or ethnic minority group. At the same time, there is evidence of moderation effects, whereby white men are particularly and uniquely advantaged by productivity networks while being disadvantaged by advice networks.

These findings suggest that professional networking strategies of academics should emphasize the cultivation of instrumental ties over advice-giving professional networks. Feminists have argued that the experiences of men should not be generalized to women. Intersectional theorists push this line of reasoning further by arguing that the experiences of whites should not be generalized to members of other racial and ethnic groups. Our results support both of these perspectives and challenge the academy to continue to examine how the social system works to systematically advantage white men while systematically disadvantaging members of all other groups.

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Notes

1. We also estimated models using two-year peer-reviewed productivity and five-year average peer-reviewed productivity as the dependent variables. The pattern

of results was the same as the more comprehensive measure of scholarship we present here.

2. For example, the survey prompt used to generate information about the instrumental resources network was worded, “Colleagues often support each other in aspects of career development. Please indicate (check all that apply) if the people you named have reviewed your papers or proposals prior to submission (on which they were not a co-author), introduced you to potential research collaborators, invited you to join a teaching or research grant proposal team.”
3. Due to endogeneity concerns about the instrumental ties construct and scholarly productivity, we also ran models without the coauthorship tie in the productivity network measure. This sensitivity analysis yielded the same pattern of results for the focal dependent variable.
4. Research extensive universities award at least fifty doctorates per year across fifteen fields; research intensive universities award at least ten doctorates per year across three fields or twenty doctorates per year overall (Carnegie Foundation 2000). We used the [Obama] White House initiative on historically black colleges and universities to identify forty-three institutions for inclusion.
5. The coefficients in the tables report the continuous measures, but we dichotomize for the thought experiment to make the later interaction effects interpretable.

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