The NSF ADVANCE Network of Organizations

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Abstract

Since 2001, the NSF ADVANCE program has funded organizational change projects promoting gender equity in academic science, technology, engineering, and mathematics (STEM) fields. The connections between institutions and individuals involved in the ADVANCE program form a network of potential conduits for information sharing on how institutions can better address gender inequities in academic sciences. As the ADVANCE program celebrates its 20th anniversary, we describe the growth and composition of the organizational network over the past two decades to explore the breadth and reach of the ADVANCE program in the U.S. higher education system. We find that through interpersonal and organizational connections, the ADVANCE program has reached more than three times the number of organizations than have been directly funded. Furthermore, we outline several ways in which future ADVANCE awardees and stakeholders can better utilize the existing network structure to expand the knowledge created through the ADVANCE program to a more diverse institutional audience.

Keywords: organizational network, institutional transformation, gender equity, STEM

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Since 2001, the NSF ADVANCE program has funded organizational change projects promoting gender equity in academic science, technology, engineering, and mathematics (STEM) fields and careers. Most ADVANCE programs focused on specific interventions or on individual colleges, universities, or small organizational partnerships, leading extant research to examine the myriad ways ADVANCE teams within institutions have enacted organizational change programs (Bilimoria & Liang, 2011; Laursen & Austin, 2020; Stewart & Valian, 2018). Yet these projects do not occur independently from each other. They benefit from the knowledge creation of other sites, through interpersonal and interorganizational exchanges NSF ADVANCE has created, and a network of practical and theoretical knowledge and personnel (Nelson & Zippel, 2021; Zippel & Ferree, 2019). As the ADVANCE program celebrates its 20th anniversary, we seek to describe the growth and composition of the ADVANCE organizational network over the past two decades to explore the breadth and reach of the ADVANCE program in the U.S. higher education system. Based on these findings, we offer four main implications for stakeholders and organizations invested in promoting systemic gender equity change.

The connections between institutions in the ADVANCE network are potential conduits for information sharing on how institutions can better address gender inequities in academic sciences and reveal the scope of the ADVANCE program within and beyond ADVANCE-funded institutions. Research examining organizational change identifies multiple mechanisms through which information and innovations spread through a network (Borgatti & Foster, 2003; Rogers, 2010). Some ADVANCE awards have had the explicit purpose to promote the dissemination of knowledge through meetings, conferences, and publications, such as the ARC network (DeAro et al., 2019; Laursen & De Welde, 2019). While we expect that much informal information

exchange occurs through such channels, we identify here additional possible conduits of knowledge sharing between organizations based on awards and interpersonal networks.

Data and Methods

To construct the NSF ADVANCE organizations network, we use an original dataset based on NSF Awards data, survey and online search data, and publicly available information about the programs, organizations, and individuals involved (detailed in the online methodological appendix). Specifically, we began by searching the NSF Awards Database and identified 273 awards funded by the ADVANCE program from 2001-2018 not including conference funding. Seventy of these awards were large institutional transformation (IT) awards, which span five years and average $3.3 million. The other 203 awards include smaller and shorter awards (Leadership, PAID, IT-Catalyst, Adaptation, etc.) focused on a specific outcome such as preparing an institution to apply for an IT award or adapting the innovations from previous awards. From this award data, we identified 195 unique organizations funded by ADVANCE which each entered the network in the year of their first award. We then connected organizations based on four tie types:

1. Partnership: We identified 20 collaborative NSF grants, called leader-partner awards, and linked participating organizations in the network.
2. Co-authorship: We identified 824 publications listed either on the NSF website as outcomes from ADVANCE awards or were listed in Google Scholar as having funding attributed to these awards. These publications include conference papers, articles, book chapters, etc. We linked 562 of these to records in Microsoft Academic Graph (MAG) (Sinha et al., 2015). Using the author affiliation information from MAG, we then linked organizations through shared co-authorships.

3. Advisory: From the NSF award data, ADVANCE site's websites, and an email survey to ADVANCE sites, we collected the names of internal team members employed by each ADVANCE site (PIs, co-PIs, program directors, and other key administrative and research personnel). We also identified external contributors to the award such as advisory board members, evaluators, or consultants. Each forms an "advisory" tie between organizations in which an awarded organization is linked to each award's external advisors', consultants', and evaluators' home organizations.
4. Mobility: For the internal and external team members, we used information from internet searches and the email survey to collect individual demographic information and 20 years of job history (2000-2019), including each individual's organizational affiliation after their first involvement with an ADVANCE award. We then linked organizations based on these individuals' job mobility starting after their first involvement in an ADVANCE award.

This paper aims to understand the breadth and reach of the ADVANCE organization network, and we thus consider an undirected and unweighted network of organizations (see online methodological appendix). This network contains individual organizations as nodes, and the ties between organizations as edges. Nodes which are not connected to any other node are known as isolates, and nodes connected to other nodes, either directly or indirectly, form a component (though not all components are connected to each other). These network features provide a simple determination of the number of organizations connected to the ADVANCE program in the last two decades, as well as the means to identify organizations who play a key role in connecting disparate nodes.

Results

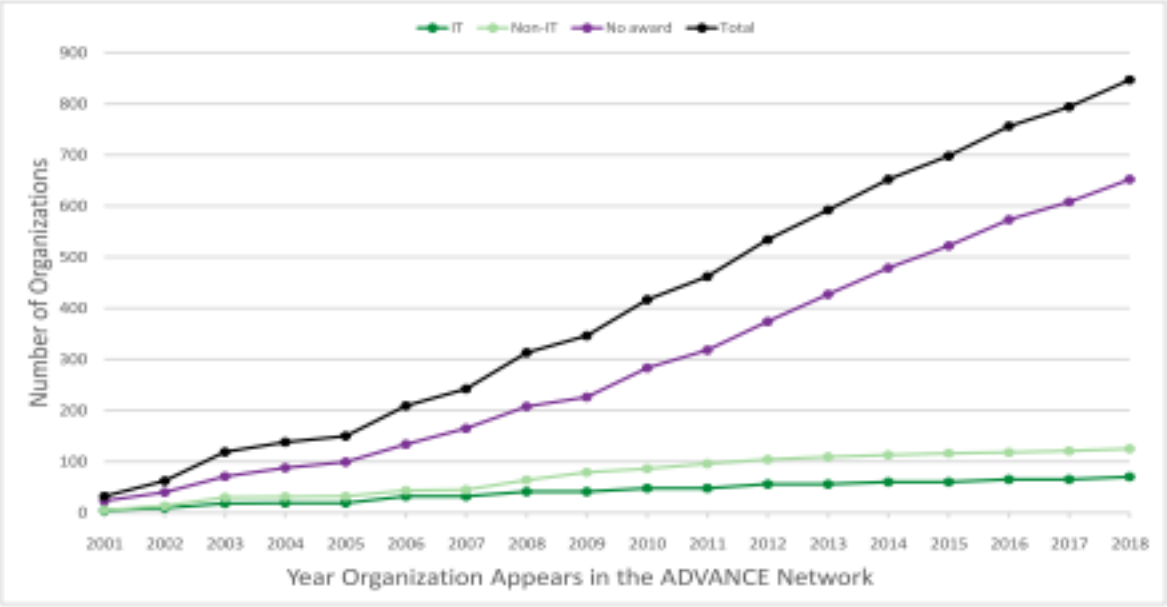
This complete network reflects the extensive scope and reach of the ADVANCE program over the last 18 years. Based on the advisory, mobility, and co-authorship relationships, the network extends beyond the ADVANCE-funded organizations by three times, containing 847 nodes and 1643 edges.

The multiplicative reach of the ADVANCE program has been fairly consistent over its lifetime. In 2001, four organizations received IT awards, and five organizations received non-IT awards (see Figure 1). These organizations were also connected with 23 other organizations that had not yet received ADVANCE funding but were already integrated into the network through 18 advisory and 7 mobility ties. By 2010, the network grew to 48 IT organizations and 86 non-IT organizations, combined with 283 organizations without an award.

The ADVANCE network of organizations reflects a strong level of connectivity induced by job mobility (826 edges) and external advisory boards (529 edges). The co-authorship relationships (284 edges) and partnership connections (66 edges), while fewer, contributed to densely connected sub-groups in the network.

Figure 1

Growth of the ADVANCE Network of Organizations by Award Types

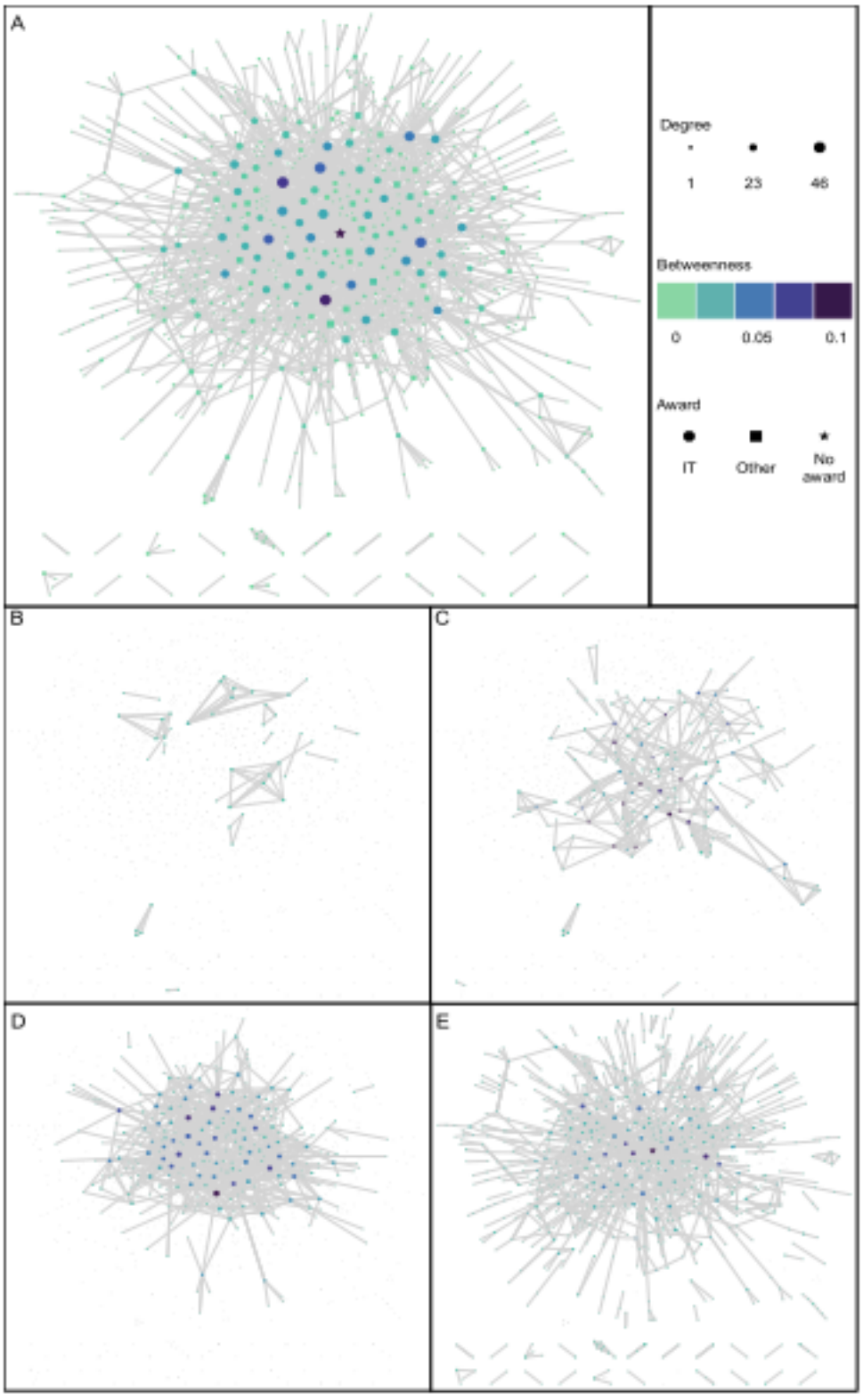


Note. The cumulative number of organizations in the ADVANCE network from 2001 to 2018 (black), broken down by ADVANCE grant type: IT award recipient organizations (dark green), non-IT award recipient organizations (light green), and no award organizations (purple).

As depicted in Figure 2, the network structure immediately suggests several interesting features of the ADVANCE community. First, several isolated nodes and disconnected smaller components reflect islands of organizations that lack an interpersonal channel of communication to exchange ideas. There are 12 organizations which received ADVANCE awards, but are not connected to any other organization in our network, and the network contains an additional 23 connected components beyond the 12 isolates, ranging in size from dyads to 775 organizations in the largest connected component. All of the 70 IT awarded organizations are found in the largest connected component.

Figure 2

The NSF ADVANCE organizational network



Note. A) The organizational network using all tie types. The ADVANCE IT sites (circles), other ADVANCE award sites (square), and other organizations (stars) are differentiated by node shape. The position of each node is determined using a force directed layout that tends to place close to each other directly connected organizations and helps uncover densely connected clusters. Node size reflects the node degree, while the color captures the node's betweenness centrality. We also show the four sub-graphs for each tie-type: B) partnership, C) co-authorship, D) advisory, and E) mobility; node positions are the same as in A), but size and color reflect properties of this subgraph. The 12 isolated organizations are not shown.

Next, we analyze how organizations vary in their network structural roles through several measures of network importance. The degree of an organization measures the total number of connections to other organizations in the network. The ADVANCE organization network reflects a broad degree distribution, with 349 sparsely connected organizations having only 1 connection, and three heavily connected hub organizations having 40 or more connections.

Interestingly, the NSF has the most connections to other organizations in our network with a degree of 46. This high level of connectivity is primarily due to the movement of faculty who were involved in ADVANCE grants from their home institution to the NSF to be rotating program officers, and then return to their home institution or move to another institution. This faculty flow resulted in 39 connections to the NSF; the additional 7 edges were formed from co-authorship relationships with individuals who were both rotating program officers at NSF and full time NSF researchers.

On average, organizations that received IT awards are significantly more connected than other types of organizations in the network. This substantial role of IT recipients is primarily

driven by high levels of connectivity formed with external advisors, and only partly attributed to mobility links. IT recipient organizations have a mean degree of 18.4 compared to 4.6 for organizations that received other ADVANCE awards, and 2.25 for organizations that did not receive an award. The average degree of co-authorship relationships is 3, irrespective of the type of the awards an organization received, meaning that the extent of inter-organizational collaboration is comparable across all organizational award types.

The betweenness centrality of a network node measures the relative frequency with which it lies on the shortest path between all pairs of other nodes, and is an important measure in the study of network diffusion. Nodes with high betweenness centrality can act as brokers between otherwise disconnected organizations. They are also often sites of innovation themselves, as they have access to a greater diversity of ties than nodes with lower betweenness centrality (Burt, 2001; Shaw-Ching Liu et al., 2005). Once again, the NSF is the most central organization. Overall, the betweenness centrality has a strong, but not perfect, correlation with the network degree (Spearman rank correlation of 0.86). This means the network structure highlights some organizations as more central despite having only moderate levels of direct connections.

Summary and Policy Implications

Based on this descriptive analysis, we highlight four main takeaways for stakeholders and organizations interested in promoting systemic gender equity change. First, the exponential growth of the organizational network over the past two decades (driven primarily by job mobility and advisory ties) suggests that the reach of the ADVANCE program extends far beyond the directly-funded organizations. This brings in three times the organizations which are potentially exposed to ADVANCE innovative practices and research promoting gender equity in academia.

This reach gives us a glimpse at the potentially nation-wide, and even global, impact of NSF ADVANCE and creates a network structure with a more robust periphery of organizations which may be sites of innovation themselves (McGrath & Krackhardt, 2003). The heart of the ADVANCE program lies in fostering nationwide institutional change to increase gender equity in academia. These results suggest that the extensive reach of the program through individual network connections may drastically increase NSF's return on investment in creating change by funding specific innovative or change projects at specific organizations and universities.

Second, we find that primarily due to job mobility ties, the NSF maintains a prominent position in the ADVANCE network in both degree and centrality. Thus, the NSF does not only fund the ADVANCE program, but is also a key player in creating potential pathways for interaction and information flow about the programs' goals, concrete interventions, and lessons learned. We suggest that the NSF should continue to leverage this structural advantage in connecting individuals from core and peripheral organizations in the ADVANCE network. No other organization in the ADVANCE network connects disparate organizations through interpersonal ties at the level of the NSF, and these connections may encourage greater longevity of ADVANCE ideas beyond the scope of specific awards.

Third, we find that IT awarded organizations were much more effective at creating more numerous and diverse connections, while non-IT award institutions were much more likely to be isolated or outside of the largest connected component. Thus, large-grant awardees should extend their external board members beyond already well-connected organizations, and stakeholders should look for more opportunities to connect peripheral organizations to the core. Innovation research suggests that innovators are often peripheral actors who need ties to a network's core in order to gain acceptance of new or radical ideas (Rogers, 2010). Funded organizations

intentionally broadening their network through advisory boards may be a route to introducing new ideas and new personnel to the network with a broader diversity of knowledge. Additionally, organizational research has identified board interlocks (mutual board members between organizations) as a way for organizations to reduce uncertainty concerning the adoption of new innovations (Borgatti & Foster, 2003). With the goal of gender equity and institutional transformation, greater connectedness may contribute to colleges and universities adopting new and sometimes uncomfortable strategies to enact change.

Finally, we note that the tendency for co-authorship across organizations is comparable across all organizational award types. This is impressive, as it suggests that the collaborative knowledge generated from ADVANCE organizations is not dependent on award type or amount. In many ways, coauthor ties are the strongest indication of shared knowledge creation across organizations. The similarity in inter-organizational co-authorship relationships across awarded institutions may indicate that other forms of interpersonal network ties foster collaboration at all types of institutions. We suggest that further research examines what types of knowledge are generated from these cross-organizational collaborations, as well as what types of organizations are most likely to collaborate.

Alexander J. Gates is a Computational Social Scientist in Northeastern University's Department of Sociology, and an affiliate of the Network Science Institute. He employs a highly interdisciplinary approach—combining tools and techniques from Data Science and Network Science with theory from Sociology—to draw insights from large datasets and uncover the interplay between the behaviors of individuals and the emergent structure of organizations, societies, and markets. Alex received a joint PhD degree in Informatics (complex systems) and Cognitive Science from Indiana University, Bloomington, an MSc from King's College London in complex systems modeling and a BA in mathematics from Cornell University.

Jessica R. Gold is a Postdoctoral Researcher in the Sociology department at Northeastern University. Her work focuses on organizational analyses of gender and racial inequality, including university faculty hiring and scientific teams. She primarily uses computational text and network analysis methods to uncover patterns in big data related to the gendered and racialized contexts of modern work organizations. She received a PhD in Sociology from the University of California, Davis, and a BA in Sociology from the College of William and Mary.

Syed Arefinul Haque is a Ph.D. candidate in the Network Science Institute at Northeastern University. He is interested in studying the diffusion of ideas and the sociology of knowledge. Currently, he is using Network Science and NLP techniques to quantify gender and racial diversity in researchers and experts, and how ideas related to gender diversity move from one organization to another. He has recently published articles in journals such as Nature Communications, Clinical Microbiology and Infection, and Physica A.

Miranda C. Melson is a PhD student in the Sociology department at Northeastern University. She employs mixed-methods to advocate for and reduce social inequity among marginalized populations. She is currently researching Chinese-American adoptees in the US and their diverse experiences and identities. Miranda received a MA in Sociology from Northeastern University and a BA in sociology, French, and global studies from the University of Nebraska–Lincoln.

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Kathrin Zippel is Professor of Sociology at Northeastern University and a co-chair of the Social Exclusion and Inclusion Seminar at the Minda de Gunzburg Center for European Studies at Harvard University. She has published on gender politics in the workplace including The Politics of Sexual Harassment in the United States, the European Union and Germany (Cambridge University Press). She has explored gender and global transformations of science and education in Women in Global Science: Advancing Careers Through International

Collaboration (Stanford University Press). She is the PI of the project to study the Network that the NSF ADVANCE program has created among individuals and organizations (#2000713).

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