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Networks for the Future: A Mathematical Network Analysis of the Partnership Data for Sustainable Development Goals

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Abstract: This research project analyzes the Partnership Data for Sustainable Development Goals to determine geographical coverage of the projects as well as the relationships of project proponents working in support of sustainable development. We perform a network analysis of the project proponents and measure connectivity through a variety of mathematical modeling techniques including degree rank, betweenness centrality, cut degree and pagerank metrics. We observe that the network consists of one giant component containing a majority of entities surrounded by a corona of small independent clusters. We conclude that mathematical modeling supports existing scholarly literature that proclaims sustainable development as a soft law paradigm with widespread support.

Keywords: sustainable development; network analysis; partnership data for sustainable development goals; United Nations; voluntary commitments

1. Introduction

The Partnership Data for Sustainable Development Goals (PD4SDG) database is an online platform that is aimed at improving transparency, accountability and the sharing of work being carried out by multi-stakeholder partnerships and voluntary commitments in their support of the sustainable development goals as articulated in the 2030 Agenda for Sustainable Development. The PD4SDG database was initially developed in response to a mandate set out by the Rio+20 United Nations Conference on Sustainable Development, but has since been improved to better respond to the 2030 Agenda [1]. This online platform was intended to provide space for sharing knowledge and expertise among different groups and people that are involved in multi-stakeholder sustainable development goal-related partnerships and voluntary commitments and to provide space for periodic updates on their progress [2]. The database was also developed on the basis of an independent technical assessment which took into account best practices and lessons learned from other initiatives, within and beyond the United Nations [3].

The United Nations created the PD4SDG database in September 2015 as a beta version of the current platform on the internet as of June, 2019. [4] The United Nations PD4SDG database records projects submitted to the United Nations either directly through an online interface or indirectly through presenting information at a meeting related to sustainable development [2]. The "new" version of the platform was launched in 2015 and made available in the beginning of 2016 at the

Partnership Exchange special event. This "new" version was developed as a result of United Nations member states asking for ways to improve transparency and to communicate experiences more expeditiously [5]. The PD4SDG is open to all stakeholders and includes many new features to promote learning globally, in particular the creation of the so-called SMART criteria (Specific, Measurable, Achievable, Resource-based, with Time-based deliverables).

Thus, we ask the question, "What can mathematical models reveal about project proponents working towards sustainable development?" The authors review data related to this research question as recorded in the PD4SDG database. Having providing a brief background on the formal creation of the PD4SDG database in 2016 as an introduction, in the second section the authors propose that a dense network is a necessary element to support sustainable development. The third section within the paper explains the mathematical tools available to model dense networks with an emphasis on graph theory, in particular an unweighted, undirected graphical model. In the fourth section, the authors present the results of the mathematical modeling of the connectivity of the project proponents within the PD4SDG database followed by a fifth section detailing how the modeling results tie in with our conceptualization of a dense network as a key component within global governance. The sixth, and final section, details the next steps forward with this broader research agenda.

2. Theoretical Review

International regime theory arose in the 1970s as a way to examine underlying concepts and assumptions in international politics [6]. Researchers were concerned that these concepts and assumptions were being obscured by a formal study of law and organizations [7,8]. The motivation for regime theory was the encroachment of nongovernmental organizations (NGOs), along with transnational corporations and intergovernmental authorities, into the once inviolate realm of states in international politics during the post-World War II period. According to many assessments, states during this period failed to meet the needs of their citizens through their inability to secure global peace without resorting to the threat of nuclear weapons, to develop new nation-states, to solve the North-South income gap, and to effectively engage with issues that transcend state boundaries [9].

Krasner [10] provides the classic definition of a regime when he states that "regimes can be defined as sets of implicit and explicit principles, norms, rules and decision-making procedures around which actors' expectations converge." In short, regimes are institutions with agreed upon rules about a singular issue area. The temptation to subdivide international environmental politics into a series of regimes is significant as shrinking the subject under study allows for parsimony in all phases of research. Hence, it has become commonplace and ordinary to speak of the ozone depleting substances regime, the climate change regime, or the tuna fisheries regime.

Scholars have tended to put states at the center of regime theory [11,12]. As a result, scholars need only to look at the rise and fall of state power at the center of the regime to understand changes in the strength of the regime over time [13]. Regimes have rarely encompassed non-state actors as a central focus; however, Arts [14] points out that If non-state actors have the ability to impact political processes, then it is highly likely they are important actors during time periods of structural changes.

Within regime theory, the concepts of nested regimes, where one regime might reside within another distinctly separate regime, and overlapping regimes, where two or more institutions exercise authority over the same issue area have been used to explain situations where a single-issue area becomes linked to other single-issue areas [15–17]. Utilizing the single regime as a building block, it then becomes possible to create regimes that match any and all configurations. This phenomenon has come to be known as a complex regime.

Raustiala and Victor characterize the regime complex as a non-hierarchical space where simple regimes converge and/or overlap each other [18]. Helfer [19] points out that international actors such as states and NGOs "regime shop" to find institutional arrangements most amenable to their interests, and that regime shopping is more likely to occur when the regime density is high. Altier and Meunier [16] distinguished domestic regimes from international regimes on the basis that domestic regimes are more likely to successfully reconcile conflicts in political authority whereas international political authority conflicts can be difficult to resolve [15].

Orsini et al. [20] provides six characteristics of a regime complex, the issue characteristic most applicable here is the first one—that the "constitutive elements of regime complexes must be clearly defined." It is on this basis that analyzing sustainable development as either a singular regime or as a regime complex breaks down. To claim that sustainable development is a regime is perhaps premature as sustainable development fails to meet the definition of a regime on multiple points. First, sustainable development cannot be conceptualized as a singular issue area; it also cannot be conceptualized as a complex regime with constitutive elemental regimes. While sustainable development seeks to incorporate singular regime areas such as climate change, sustainable development is perhaps best thought of as an area where elemental regimes coincide with proposed principles that have yet to form a regime. In other words, sustainable development consists of regimes and non-regimes.

Second, there are no formal norms, values or beliefs around which either state actors' or non-state actors' expectations have converged in either a singular regime or as a regime complex. If actors' expectations had converged around a new set of norms, values, or beliefs implementing sustainable development, there would not be a need for the United Nations to promote activities implementing sustainable development through a database because all actors would be currently practicing sustainable development. With regards to a regime complex, we note that conflicting or synergistic regime linkages may occur. However, the development of the regime complex arena was never intended to encompass an issue area that continues to have problems delineating boundaries. While we note Le Blanc's [21] work describing the network of specific goals and targets that comprise the current set of sustainable development goals, he does not seek to describe sustainable development as a regime or a regime complex. Third, there is no institution devoted solely to sustainable development that serves as a final arbitrator of rules, norms, values or beliefs. Instead, the institutional architecture has incorporated the sustainable development paradigm with its considerable ambiguity into the international system. Within the PD4SDG database, projects are sustainable because they claim to be sustainable; claims appear to be scrutinized before publication of the database, but neither the agent nor the process for determining which projects appear online is readily apparent. Fourth, the time scale of the creation of regimes has tended to occur rapidly, while the emergence of sustainable development has been agonizingly slow.

One potential research question that emerges from the fact that sustainable development is not a regime might be whether network analysis could help us understand the process by which project proponents cooperate in the absence of a regime by examining the rate of change in the size, complexity, and density of the network supporting sustainability. In other words, we theorize that the same network analysis that could be used to analyze complex regimes is also of value in situations where regimes have not yet emerged.

We note that a number of scholars have advocated for network analysis in the past [20,22]. Hafner-Burton et al. [22] argued for using network analysis to measure the relationships between international actors to determine both the structure of isolated groups within the network and the entire network over the entire life-cycle of the relationship, including any observable effects on an individual agent's behavior. We concur that network analysis can be used to measure the quality of the relationship between individual actors within an entire network and that repeated snapshots of the same network can give an approximation of the life-cycle of the network. However, additional data would be necessary to determine the network's effects of an individual agent's behavior.

We conduct this work in order to begin the process of determining the size and connectivity of the network promoting sustainable development by advancing the idea that dense component networks are a necessary precondition for increased acceptance of sustainable development and that this increased acceptance is a necessary step in understanding situations that couple regimes and non-regimes. Thus, the research group hypothesizes that the global nature of sustainable development requires that the transition to a more sustainable society must also include project experimentation in all areas of the world, encompass engagement of all types of entities, and development of dense connectivity between the project proponents in order to communicate and educate others about the successes and failures of this project experimentation.

The dense component network characteristics include widespread geographical coverage, a variety of entity types present in the dense component network, and that the dense component network cannot be separated at any one point. The widespread geographical component means that the entire international system moves together towards sustainable development. A holistic shift in economic structure dictates this condition as one domestic economic system has the potential to permanently negatively alter global environmental and economic conditions. The variety of entity types connected to each other indicates the penetration of sustainable development both between and within societies. The dense component network should not be fragile; that is the network cannot be fragmented at any one point means that each individual entity is embedded within the network. The higher the number of connections, the more deeply the entity supports the goals of the dense component network.

3. Materials and Methods—Mathematical Framework

The mathematical framework for analysis of such networks is called graph theory, which is a part of the field of combinatorics [23]. Graph theory is commonly traced to Leonhard Euler's 1736 paper on the Seven Bridges of Königsberg and has become an indispensable tool used in computer science, epidemiology, logistics, sociology, and many other fields where network structure and function is the primary topic of interest [24].

First, we will establish some definitions from graph theory. A graph consists of a set of vertices (aka nodes) and a set of edges between pairs of those vertices. A graph can be visually represented like a "connect-the-dots" image where dots represent vertices and lines/arcs represent edges with the understanding that the location of dots is irrelevant. Dots can be moved arbitrarily provided no edges are created or destroyed. A pair of vertices is said to be adjacent (or neighbors) If there is an edge between them. Graph variants include weighted graphs, where each edge is assigned a number that typically represents the strength of the connection, and directed graphs, where each edge points in a preferred direction from one vertex to another.

Here, the PD4SDG database is represented as an undirected, unweighted graph where each distinct entity in PD4SDG corresponds to one vertex, and two vertices are adjacent If and only If the two entities they represent appear together on at least one project in the PD4SDG. Future refinements of this analysis may incorporate the count of such collaboration as edge weights to reflect the strength of the relationship between pairs of entities.

The degree of a vertex is the number of edges touching it. A path from vertex A to vertex B is a sequence of edges starting at A and ending at B; a path's length is the number of edges in it. If there is at least one path from A to B, then A and B are connected and the distance between them is defined as the length of the shortest path. Conversely, if there is no path from A to B, then A and B are disconnected. The set of all vertices that are connected to a vertex is its connected component (or simple component). A graph is connected If it has only one component; in this case, there is a path from any vertex to any other vertex. If A and B are not connected, the graph's components are connected subgraphs which partition the graph into pieces that are essentially independent.

Graph theory has been widely applied to model diverse social networks such as academic paper co-authorships [25–27]. Striking similarities have been found in the structure of many seemingly different networks. For example, it is common to see a single giant component containing a large proportion of the vertices and a large number of other, much smaller components (sometimes called the corona). Furthermore, it is common to see a small proportion of vertices with high degree (highly social actors) and a large proportion with small degree. In the results section, we see similar features in the PD4SDG graph.

Graph theory offers several metrics designed to quantify the "importance" of each vertex in a graph. We use four such metrics which capture different types of "importance" of a vertex: Degree, delta component number, PageRank, and betweenness centrality. We give a very brief description of each below.

The simplest metric is the degree of the vertex (in this case, the number of distinct collaborators). Though easy to understand, this metric is quite limited and myopic. For example, consider Figure 1. Starting from the center (level 0), there is one central vertex with three children (level 1), each of which have four children (level 2), each of which have four children (level 3). Their degrees are 3, 5, 5, 1 respectively. Clearly, the central vertex plays a crucial role as a "bridge" within the graph that is not reflected by degree alone. Thus, we need more subtle metrics of vertex importance.

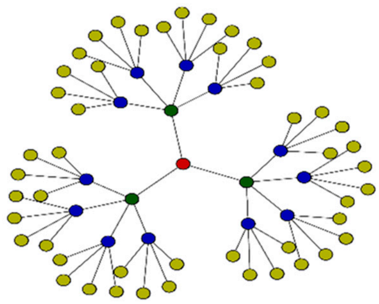

Figure 1. Example Graph.

The example above leads to the next simplest metric. Removal of the bridge vertex splits one component into three components. We define the delta component number of a vertex to be the difference between the number of graph components before and after its removal. (To our surprise, a search of the literature did not find an extant term with this definition). The delta component numbers in Figure 1 are 2, 4, 4, 0 respectively.

The delta component number tends to identify points of high fragility in the network. The network will break down into separate distinct networks If the project proponent vanishes. In terms of public policy, it is critical to ensure at least enough funding to keep entities with a high delta component open and operating at their current level. In other words, delta component number helps identify the most critical points in the network. The higher the delta component number, the more fragile the network. Conversely, a delta component number of 0 means that the project proponent could be removed from the network without splitting the network into multiple distinct networks.

A more refined metric is PageRank, so named for its key role in the famous Google search result ranking algorithm developed by Larry Page and Sergey Brin [28]. It is defined via a simple random walk on the graph described below. Imagine a large number of ants walking on the edges of the graph in such a way that all ants arrive at a vertex simultaneously. Each ant then chooses one edge uniformly at random from the edges touching that vertex for the next leg of its journey and the process continues (for technical reasons, there is a small chance that an ant "randomly jumps" to *any* vertex rather than following an edge). The Fundamental Theorem of Markov Chains guarantees that, under mild assumptions, the distributions of ants will approach a stable state in the long run. PageRank orders the vertices according to the proportion of ants at each vertex in this stable distribution; the vertex with the highest proportion is the most important. The PageRanks (multiplied by 100) in Figure 1 are 1.96, 3.37, 3.80, 0.88; PageRank considers the level 2 vertices to be most important.

PageRank tends to find "core" actors in a network because it places focus on how a network functions rather than simply how it is structured. In the terms of the PD4SDG network, these are the entities that are engaged in the most implementation activities, or stated differently, these entities appear to be most productive. Increased investment at high PageRanked entities should generate the greatest increase in activity.

The final metric of interest is betweenness centrality (BC) [29]. Recall that If two vertices are connected, then there are often many paths between them. BC first selects the shortest path between each pair of connected vertices (with appropriate rules for tie-breaking). Each vertex in the graph is given a BC score based on the number of these shortest paths that pass through it. The betweenness centrality scores (multiplied by 10) for Figure 1 are 6.77, 5.17, 1.24, 0.00; BC considers the central vertex to be most important.

Betweenness centrality identifies "transit points" or "bottlenecks" in the network. It assumes that, to a first approximation, information/ideas/collaborative energy flows through the network along the shortest path and places higher importance on vertices located on lots of these paths. In terms of public policy, investment in these entities should promote greater flow of collaboration across the network.

The research team utilized the coding present in the Goal 14 "Life Below Water" download provided by the United Nations online as a starting point in the summer of 2017. The coding included the project title and a list of entities collaborating with each other along with the goals and targets claimed by the project proponent. The initial classification scheme included United Nations entity, intergovernmental organization, national government, regional government, academic institution, non-governmental organization, scientific community, supranational government, partnership, civil society organization or other relevant actor. We reviewed the initial coding and made the following changes: removed the other relevant actor category; academic institutions were classified as organizations that taught classes while the scientific community conducts research only. We also consolidated civil society organizations, partnerships, and philanthropic organizations into non-governmental organizations. We assigned other relevant actors into one of the other categories based on a case-by-case assessment. Individuals were removed from the database for the very practical reason that we could not locate them.

Next, we attempted to locate the entities' headquarters through a variety of public searches including but not limited to, internet searches, tax records, and other miscellaneous public filings. Entities that could not be located were removed from the project database. National governments and private sector organizations were consolidated into one project proponent. Thus, if six departments of the United States government worked together on a project, that representation would be consolidated into one project proponent represented as the United States government headquartered in Washington D.C. Similarly, private sector entities were consolidated into the main corporation rather than specifying each individual subsidiary. Intergovernmental organizations, with minor exceptions, were consolidated at the specialized agency level. While the project team believes that there is little difference between locating a project at one point inside a country versus another, the same circumstance is not true for entities such as the United Nations where shifting all projects back to North America would seriously misrepresent the amount of activities occurring in Europe or Africa.

While working on "cleaning" the data from the PD4SDG database, two significant concerns emerged about the quality of the data. The first concern, mentioned previously, occurred with project selection. The PD4SDG database is an opt-in with little to no review prior to registration. Additionally, projects that fail to meet the SMART characteristics are not removed from the dataset. Consequently, "projects" might include an announcement that a state supported an item in an upcoming treaty negotiation. In addition to the data quality concerns about projects that fail to meet the SMART characteristics, the research team discovered that the database has no mechanism to remove projects that have ended due to successful completion or due to collapse of one or more members of the project team, including end of funding.

We add a word of caution about the replicability of these results. Given the large and changing nature of the database, we note that the results are subjective in nature given the selection of geographic coverage, timing of the search for an entity, and decisions about the so-called "quasi" organizations. We minimized the potential biases to the extent that we have control over these issues. For example, the entire database was "scraped" by one person at the same time. Additionally, one member of the project team performed all of the coding. Despite these drawbacks, the PD4SDG database remains one of the few large-scale sources of data involving implementation of projects in support of sustainable development.

4. Results

In order to assess our hypothesis that dense proponent networks are a necessary condition during the operational phase of transition management theory, we developed four key principles for the dense proponent network. The first principle states that project proponents should be located in all localities. The second principle looks at the engagement across a variety of entity types. The third principle stipulates that a dense proponent network with a small corona should be apparent. The fourth principle dictates that the network is not fragile and cannot be separated at any one point. We now turn to presenting the data regarding these four principles.

Table 1 presents the overall entity composition within the PD4SDG database. Non-governmental organizations, national governments and the private sector top the participation chart. We note that national governments (states) at first glance, appear to be relatively unimportant as a project proponent type. We are highly uncomfortable with drawing this conclusion. We note that the count is precisely that. We note that the reason why the national government count exceeds the number of states in the General Assembly at the United Nations (193) is because overseas territories are treated as individual countries within certain treaty negotiations and independent projects.

Table 1. Giant Component by Project Proponent Type.

Project Proponent Type	Count	Percentage
NGO	3271	47.14
Private Sector	1535	22.12
Academic Institution	772	11.13
Scientific Community	422	6.08
Subnational Government	413	5.95
National Government	222	3.20
Intergovernmental Organization	186	2.68
United Nations Entity	117	1.69
Supranational Government	1	0.01

We also note that these results are skewed by the fact that we broke out United Nations entities as a standalone category. When you recombine this with the remaining intergovernmental organizations, the total intergovernmental organizations will replace the private sector as the third most important entity type when implementing sustainable development.

Figure 2 contains the geographic network. It indicates that a variety of entity types (represented by dots) participate in promoting sustainable development with different colored dots for each entity type. Red lines indicate connections between project proponents. Connections are the densest between the United States and Europe and this is expected given that key entities within the United Nations such as the United Nations Development Program and the Global Environmental Facility are headquartered in New York City and Washington D.C., respectively. They collectively administer the Small Grants Program that supports non-governmental organizations in the developing countries. High project proponent density in Europe could also be explained by the European Union's staunch support of sustainable development, governmental development aid and assistance, as well as high concentrations of non-governmental organizations. Latin America appears to be underrepresented and this is surprising. We have no insights as to the absence of activities within this area. The Middle East also appears to be underrepresented and this is expected given that the violence in the Middle East in the last ten years would not create an environment conducive to promoting sustainable development. The Small Island Developing States continue to take full advantage of the sustainable development resources available and is a hotbed of activity.

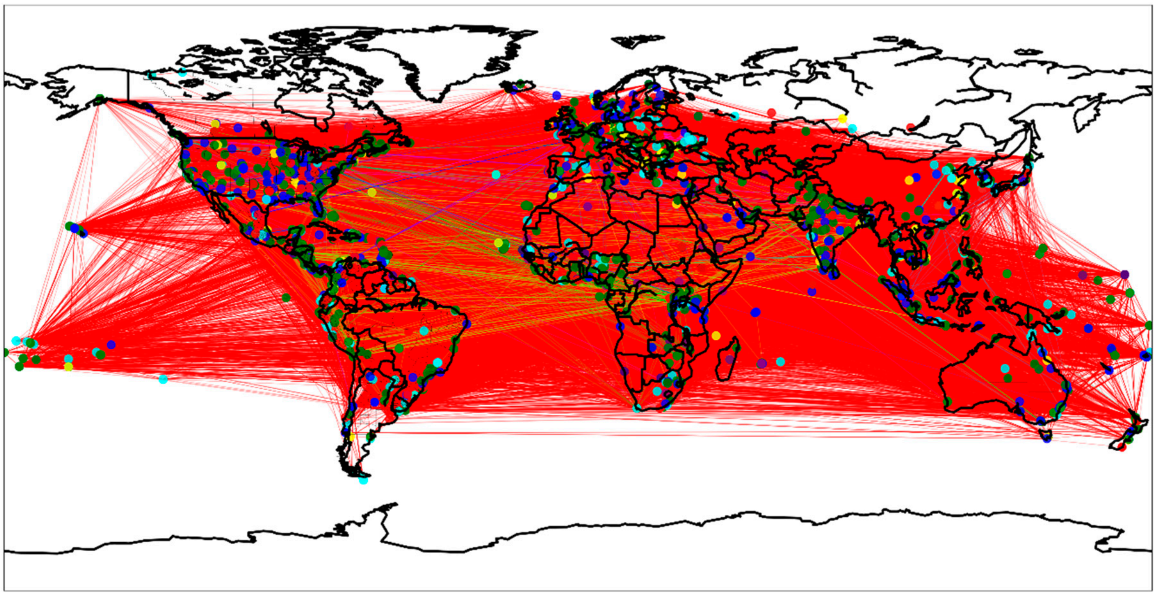

Figure 2. Geographic Distribution of Project Proponent by entity type.

The next set of results maps the connectivity of each entity with each other. We present the results in terms of a giant component and the surrounding corona in Figure 3.

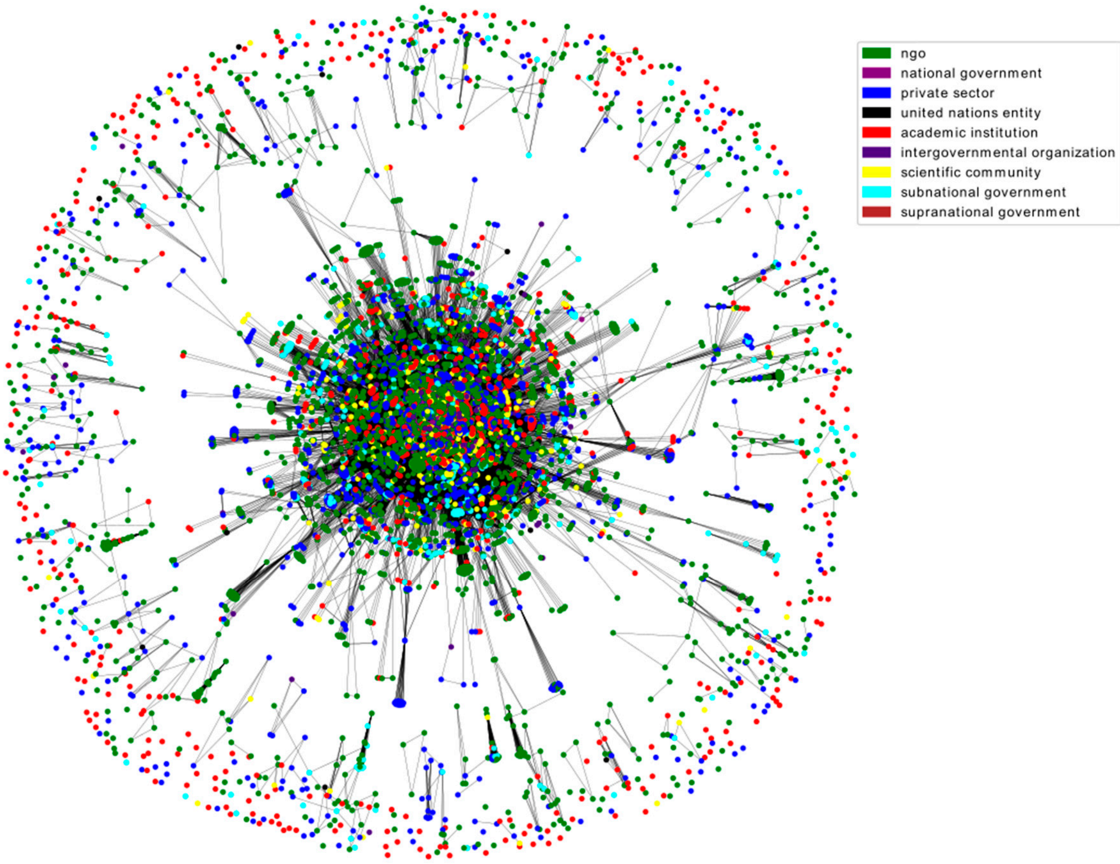

Figure 3. Network Representation for PD4SDG.

The Network Representation for PD4SDG contains 8339 project proponents representing 3801 projects. The network connectivity map contains 817 networks with 215,683 distinct original connections between entities and 254,329 connections including multiple projects among the same pair of entities. The giant component network includes 16,548 strong partnerships that involve two or more projects. The United Nations Development Program and the Global Environmental Facility pairing occurred the most frequently with 78 collaborations. The giant component represents 83.21% of the entities. Table 2 presents the breakdown of data by the number of project proponents in the network.

Table 2. PD4SDG Networks.

Component Size	Number	Percentage of Network
6939	1	83.21
30	1	0.36
22	1	0.26
19	1	0.23
16	2	0.38
15	1	0.18
14	1	0.17
12	1	0.14
10	1	0.12
9	1	0.11
8	1	0.10
7	9	0.76
6	10	0.72
5	18	1.08
4	26	1.25
3	49	1.76
2	72	1.73
1	621	7.45

While we recognize that all of these entities are connected at some level (the United Nations staff became aware of them either through face-to-face contact or through the database existence and registration process), they are not actively collaborating to implement a shared sustainable development project as evidenced by the size of the corona at 16.49%. This data also reveals that the corona contains networks, nine of which contain ten or more project proponents. However, none of them compare in size or activity to the giant network.

Within the giant component, we assessed the importance of each entity via a variety of methods including degree, PageRank, and betweenness centrality. The result of this analysis is presented in Table 3.

Table 3 details the most important project proponents within the sustainable development network. We find that identifying the most important project proponent or entity type varies upon the metric of importance. While hypothesizing about which kind of actors is the most important could occur from this data, we nevertheless consciously refrained from doing so. Certainly, the sheer number of United Nations sponsored projects along with significant support from the European Union and its member states could have been anticipated, along with strong support from environmental NGOs. Nor is it surprising to discover that private entities, subnational governments, academic institutions, or the scientific community lag behind the so-called UN constituency. However, the presence of the United States was less expected as one of our leading states. We presume that the presence of the United States within Table 3 potentially reflects former President Obama's policies supporting increased international aid, environmental policy and sustainable development during his eight years in office. The data scrape that we performed occurred in 2017 and we assume that all of the United States projects should be attributed to the Obama Administration. That having been said, there is no expectation that President Trump will continue to support these issues with the same vigor. Alternatively, the high level of support from the United States could also be a reflection of its international development aid and assistance program.

Table 3. Entity Comparison.

Entity	Type	Degree	Delta Components	PageRank	Betweenness Centrality
United Nations Environment Program	United Nations Entity	2235	6	0.523	5.742
United Nations Development Program	United Nations Entity	1640	8	0.505	5.179
United States	National Government	2144	4	0.447	4.089
UNESCO	United Nations Entity	1276	4	0.326	2.379
European Union	Supranational Government	1343	3	0.314	2.403
World Bank	Intergovernmental Organization	1367	3	0.302	2.120
Germany	National Government	1412	6	0.259	1.607
France	National Government	1406	4	0.275	1.839
World Wildlife Fund for Nature	NGO	1235	3	0.307	3.21
Global Environment Facility	United Nations Entity	772	6	0.241	1.217

5. Discussion

We begin our discussion of the most important entities by noting the agreement of all three methodologies as to the order of the most important entities. We are intrigued at the relative strength of the United Nations Development Program in that the metrics of PageRank page rank and betweenness centrality are relatively close to the United Nations Environment Program despite the fact that the United Nations Development Program occurs much less often. We believe that this is impacted by the relationship between the United Nations Development Program and the Global Environment Facility due to the functionality of the Small Grants Program.

The placement of four United Nations entities validates the importance of the United Nations as a champion of sustainable development. The United Nations Environment Program has long been recognized as a key player along with the United Nations Development Program. However, the presence of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) requires explanation. First, UNESCO focuses on educational programs that by their very nature require outreach to build consensus on new values and standards of behaviors. Second, UNESCO includes the International Oceanographic Commission with its focus on capacity building and information sharing on ocean management. Within the PD4SDG database, more projects are registered under the auspices of Goal 14 "Life Below Water" than any other and this allows entities that are highly engaged on ocean management issues to dominate the PD4SDG dataset.

With regard to entity type, academic institutions are more likely to be found in the corona than in the giant component. Academia makes up 22.5% of the corona, but only 11.6% of entities in the giant component. We believe this phenomenon is due to the history of the PD4SDG database. The Higher Education Sustainability Initiative that occurred as part of the Rio+20 process was incorporated into the database. Many of the "projects" in this database announced that academic institutions would unilaterally incorporate sustainable development into their curricula and their campuses. This database was transferred directly into the PD4SDG database and may be skewing the results in terms of the relative proportion of the corona to the giant component.

As a last comment on the analysis, we turn our attention to the delta component. As explained in the Section 3 Materials and Methods, the delta component indicates the amount of fracture in the giant component If the entity was removed from the dataset; the higher the delta component, the greater the fracture. For this dataset, the United Nations Development Program serves as the lynchpin of the giant component, followed by the other United Nations entities. In addition to the United Nations collectively, both the United States and the European Union serve as potential fracture points for the giant component.

The results presented above give a unique perspective and insight into the workings of an admittedly complex international phenomenon and we recommend its continued use and refinement. On the question of whether sustainable development is in the process of becoming a complex regime, we find this methodology intriguing, but make no statement as to whether that has occurred now or whether it will occur in the future. We merely state our belief that network analysis is one among many suitable metrics used to measure the contours of project proponents seeking to form a regime.

To recap, the Agenda for Sustainable Development seeks to fundamentally alter society through a long-term shift in society by shifting the global culture in the long term to take into account the needs of people across time and space. The PD4SDG database gives us unique insight into the shift as it seeks to publicize the innovative projects undertaken to determine the precise form the transition should take in the short term.

Our hypothesis states that one giant component network is a necessary mechanism to alter societies. From this giant component hypothesis, we derived four characteristics—that a giant component network exists, that it covers a broad section of the globe, that it contains a variety of entity types, and that it cannot be easily separated. When combined with the results presented above, the data partially supports the hypothesis put forward in this paper. First, there is a giant component network indicating that a significant number of entities cooperate when implementing sustainable development. We refrain from declaring sustainable development a regime or a regime complex, and the sheer number of networks supports this conclusion. Second, the giant network covers the vast majority of the world, but there are a few gaps. That these gaps overlap with the areas around the world most in need of sustainable development suggests that project proponents may need to increase their efforts to transition to a more sustainable society in these areas. Third, the giant component contains all entity types from the largest international organization in the wealthiest portions of the world to very small non-governmental organizations struggling to eke out an existence in the poorest of economies. Fourth, the giant component is surprisingly fragile and the fragility of the network occurs not at the fringes, but at the core of the giant component network—in the hallways of the United Nations. We thus conclude that the efforts of the project entities within the PD4SDG database could potentially improve the socio-economic standing of the targeted populations by virtue of completing projects and in doing so create a basis for greater cooperation in the future.

6. Conclusions

This research project examined the PD4SDG database recording project proponents' efforts to transition to a new social structure—sustainable development. In doing so, we learned that international groups of all types cooperate to achieve this goal. While the mathematical models of network analysis are not new, they are rarely used to analyze this type of political science phenomenon. The insights gained from this new tool in analyzing international environmental politics bring to the forefront the need to adjust and improve our fundamental theoretical perspectives.

Additionally, this research pointed out some previously unrecognized facts about the status of sustainable development. While this remains a soft law paradigm within international environmental politics, areas for additional cooperation that might improve the likelihood of success in completing a transition to sustainable development in the future have been discerned. One key issue that should be addressed in the future includes the fragility of the project-proponent network within the key institution working towards change—the United Nations.

This database continues to change over time and we are cautiously optimistic that repeating this research in multiple years will improve our insights as to how networks change and shape societies over a longer time frame. This interdisciplinary research project has yielded unique results and we endorse continued use of these mathematical models.

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References

1. United Nations Partnership Data for Sustainable Development. Available online: https://sustainabledevelopment.un.org/partnerships/ (accessed on 24 June 2019).
2. United Nations Department of Economic and Social Affairs. Partnership Exchange: Advancing the Global Partnership for Sustainable Development 2018 Report. 2018. Available online: https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=2569 (accessed on 15 June 2019).
3. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. 2015. Available online: https://sustaianbledevelopment.un.org/post2015/transformingourworld (accessed on 5 May 2019).
4. United Nations Department of Economic and Social Affairs. Sustainable Development Goals Partnership Platform. 2017. Available online: https://sustainabledevelopment.un.org/partnerships (accessed on 6 June 2017).
5. United Nations Department of Economic and Social Affairs. Supporting the Sustainable Development Goals through Multi-Stakeholder Partnerships—Ensuring that No One is Left Behind 2016. 2016. Available online: https://sustainabledevelopment.un.org/content/documents/2329Partnership%20Report%202016%20web.pdf (accessed rton 15 June 2019).
6. Breitmeier, H. International organizations and the creation of environmental regimes. In *Global Governance: Drawing Insights from the Environmental Experience*; Young, O., Ed.; MIT Press: Cambridge, MA, USA, 1997; pp. 87–114.
7. Vogler, J. Taking institutions seriously: How regime analysis can be relevant to multilateral environmental governance. *Glob. Environ. Polit.* **2003**, *3*, 25–39. [CrossRef]
8. Stokke, O.S. Regimes as governance systems. In *Global Governance: Drawing Insights from the Environmental Experience*; Young, O., Ed.; MIT Press: Cambridge, MA, USA, 1997; pp. 27–63.
9. McCormick, J. The Role of Environmental NGOs in International Regimes. In *The Global Environment: Institutions, Law, and Policy*; Vig, N.J., Axelrod, R.S., Eds.; Earthscan: London, UK, 1997; pp. 52–71.
10. Krasner, S.D. Structural causes and regime consequences: Regimes as intervening variables. *Int. Organ.* **1982**, *36*, 185–205. [CrossRef]
11. Young, O. Regime dynamics: The rise and fall of international regimes. *Int. Organ.* **1982**, *36*, 277–297. [CrossRef]
12. Keohane, R.O.; Victor, D.G. The Regime Complex for Climate Change. *Perspect. Polit.* **2011**, *9*, 7–23. [CrossRef]
13. Keohane, R.O.; Nye, J.S. (Eds.) *Power and Interdependence: World Politics in Transition*; Little, Brown and Company: Boston, MA, USA, 1977.
14. Arts, B. Regimes, Non-State Actors and the State System: A 'Structurational' Regime Model. *Eur. J. Int. Relat.* **2000**, *6*, 513–542. [CrossRef]
15. Young, O. Institutional linkages in international society: Polar perspectives. *Glob. Gov.* **1996**, *2*, 1–24. [CrossRef]
16. Alter, K.J.; Meunier, S. The Politics of International Regime Complexity. *Perspect. Polit.* **2009**, *7*, 13–24. [CrossRef]

17. Abbot, K.W. The transnational regime complex for climate change. *Environ. Plan. C* **2012**, *30*, 571–590. [CrossRef]
18. Raustiala, K.; Victor, D. The Regime Complex for Plant Genetic Resources. *Int. Organ.* **2004**, *58*, 227–309. [CrossRef]
19. Helfer, L.R. Regime Shifting: The TRIPS Agreement and the New Dynamics of International Intellectual Property Making. *Yale J. Int. Law* **2004**, *29*, 1–81. [CrossRef]
20. Orsini, A.; Morin, J.-F.; Young, O. Regime Complexes: A Buzz, a Boom, or a Boost for Global Governance? *Glob. Gov.* **2013**, *19*, 27–39. [CrossRef]
21. Le Blanc, D. Towards Integration at Last? The Sustainable Development Goals as a Network of Targets. *Sustain. Dev.* **2015**, *23*, 176–187. [CrossRef]
22. Hafner-Burton, E.M.; Kahler, M.; Montgomery, A.H. Network Analysis for International Relations. *Int. Organ.* **2009**, *63*, 559–562. [CrossRef]
23. Diestel, R. *Graph Theory*, 5th ed.; Springer: Heidelberg, Germany, 2016.
24. Euler, L. Solution problematis ad geometriam situs pertinentis. *Comment. Acad. Sci. Petrop.* **1736**, *8*, 128–140.
25. Granovetter, M.S. The strength of weak ties. In *Social Networks*; Academic Press: Cambridge, MA, USA, 1977; pp. 347–367.
26. Watts, D.J.; Strogatz, S.H. Collective dynamics of 'small world' networks. *Nature* **1998**, *393*, 440. [CrossRef] [PubMed]
27. Collins, J.J.; Chow, C.C. It's a small world. *Nature* **1998**, *393*, 409. [CrossRef] [PubMed]
28. Brin, S.; Page, L. The anatomy of a large-scale hypertextual web search engine. *Comput. Netw. ISDN* **1998**, *30*, 107–117. [CrossRef]
29. Freeman, L. A Set of Measures of Centrality Based on Betweenness. *Nature* **1977**, *40*, 35–41. [CrossRef]