A NETWORK OPTIC ON DEVELOPMENT

by Ulrich F.W. Ernst

The ubiquity of networks

It is no exaggeration to say that all human social and economic activities involve interactions in networks with other individuals, institutions, and—for lack of a better term—things. Even Robinson Crusoe had, in addition to his Man Friday, the natural resource networks of the island. In fact, molecules in living cells, terrestrial or aquatic food chains, nerve cells in the brain, transportation systems, scientific citations, associations among actors, and of course the World Wide Web constitute networks. All of these structures can be described in terms of vertices (nodes) and edges (linkages). But is the concept of networks merely an easy-to-use metaphor, or does it really help in understanding and interfacing with networks, or actually managing them?

To us, the answer is clear: in recent years (literally just over the last decade or so), network science has made tremendous progress. Using network concepts, we can make better sense of the processes that shape economic, social, and political development, and leverage that knowledge for enhanced impact. Network-centric thinking is a pragmatic approach that goes beyond "purely scientific" applications.

Why has there been such a rapid development in network research? Blame the internet. Before the advent of the internet, tracing human interaction relied on recall. For example, when Iowa State College's Bryce Ryan and Neal Gross did their path-breaking study on the adoption of hybrid corn among the network of Iowa farmers in the early 1940s, they relied on what farmers remembered about where they heard of the innovation and how much stock they put in the information. The internet, in contrast, is a continuously accessible living organism where you can directly measure how many edges (linkages) a particular site has, and how often they are used. You can study these interactions in real time, and test theories.

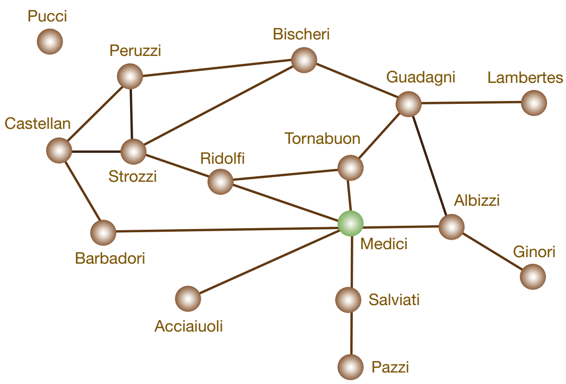
From random to scale-free networks

The first steps in our scientific understanding of networks go back several centuries. People in 18th-century Königsberg (now Kaliningrad, Russia) sought a solution to a puzzle: was it possible to pass over the seven bridges linking the two islands of the city with the shores of the Pregel River without crossing one of them twice? The prolific mathematician Leonhard Euler formalized the problem by interpreting land masses—the two islands and the two shores—as vertices and the bridges as edges. He turned the city and its bridges into a graph. With that, he showed that anyone would have to pass at least twice over one of the bridges. The citizens of Königsberg later built another bridge and, voilà, each bridge had to be crossed only once in the circuit.

The rudiments of graph theory duly established, nothing much happened. But in the 1950s and 1960s, pioneers such as Paul Erdös and Alfréd Rényi, and Anatol Rapoport, revisited graphs and examined their behavior given linkages among the nodes established at *random*: in their model, each node has roughly the same probability to be connected to any other node. Random networks have interesting properties that are helpful in examining real-life networks, but real networks do not demonstrate random linkages. Geographic proximity, shared tastes and preferences, or power relationships affect the probability of establishing a connection.

A major breakthrough in network science occurred in the late 1990s when Duncan Watts and Steven Strogatz (1998) sketched the "small-

FIGURE 1. FLORENTINE MARRIAGE NETWORKS AND THE RISE OF THE MEDICI



One of the explanations of the rise of Medici was the family's marriage acumen. Consider this graph of Florentine marriages, in particular the shortest path between various families (other than the Medici)—the Medici family lies on more than half of such routes.

Adapted from Jackson (2008)

world model." They showed that strong linkages between neighboring nodes—clusters—could be turned into a well-connected network spanning greater distances by a few random linkages connecting some of these clusters. Think of economic clusters à la Michael Porter linked to markets via global value chains, for example. With the small-world model, network science took off at an accelerating pace. As people studied real, dynamic networks, like the internet, it became clear that there was nothing random about the linkages. Vertices with heavy traffic proved more popular, and attracted even more edges—the "rich get richer," in Albert-László Barabási's phrase. (You will notice that many of the names associated with network science have a Hungarian flavor; one suspects that this is another case of the rich getting richer—leading lights in the field attract graduate students from Hungary, and so on. Even so, the preponderance of Hungarian names remains a puzzle.)

Network scientists found that living networks are characterized by a few vertices with lots of linkages—the hubs—and a huge majority with only a few linkages. These networks became known as scale-free networks. The internet is one. So is the air transportation network in terms of actual (scheduled) flights. Understanding these networks and the role of hubs (by volume and centrality) can guide strategic interventions, whether one is building reform advocacy networks or raising productivity in global value chains, which often become value networks.

While the internet and other networks provided a living laboratory for the analysis of network behavior, advances in computing technology also boosted the development of computational economics. Agent-based modeling, where agents—nodes—follow certain behavioral rules that govern their interaction with other individuals and institutions, often produces interesting financial or economic networks. In fact, simulation has been a mainstay in the analysis of existing networks as well, much to the chagrin of mathematicians, such as Rick Durrett (2007).

But don't take our word for it

The rise of network science goes well beyond a promising paradigm for helping to explain features of our world. In their recent book *The Global Brain* (2007), Satish Nambisan and Mohanbir Sawhney explore the "roadmap for innovating faster and smarter in a networked world," pushing for network-centric innovation. They cite a series of practical applications of the new approaches that take advantage of distributed information flows and decision making:

- Network-centric computing: also referred to as grid computing, it uses disparate computers (including desktops) to solve computing-intensive problems by breaking them down into smaller problems and solving those on a set of connected computers.
- Open-source software development: programmers at all levels have developed and refined Linux (an operating system) and have cooperated in developing sophisticated applications.
- Network-centric warfare: this relatively new doctrine, developed by the U.S. Department of Defense, is based on the notion that robust networking of geographically dispersed military

forces will translate an information advantage into warfare advantage—a shift from a platform-centric approach.

- Network-centric operations: originally applied to the field of logistics and supply chain management in business, the term has also been associated with the concepts of "value nets" or "value networks." It has now acquired broader meaning, sometimes used interchangeably with network-centric warfare.
- Network-centric enterprise: a concept related to business ecosystems and virtual organizations, "it involves establishing the 'infostructure' that connects different partners in a company's business ecosystem and supports the different value creation processes" (Nambisan and Sawhney 22). Cisco, for example, has evolved its manufacturing operations into what it calls the "Networked Virtual Organization."
- Network-centric advocacy: network-centricity in social advocacy groups signifies a crucial shift from direct engagement and grassroots management models to an approach where the individual participates as part of a coordinated network. Typically empowered by "Web 2.0," members of the network rapidly share information on emerging topics to identify "ripe campaign opportunities." The network's ability to scale up resources and quickly tighten its focus creates greater flexibility in pursuing opportunities, conducting multiple campaigns simultaneously (with relatively few resources), and discerning and giving up on losing efforts in a timely manner. All of which, as Nambisan and Sawhney note, "brings an element of unpredictability that lowers the ability to counter such social campaigns effectively" (23). The implications for managing policy reform advocacy groups are powerful.

This issue of *Developing Alternatives*

Some of the most interesting work that bridges the macroeconomic work on "growth ladders" with microeconomic approaches to competitiveness—adapting concepts of revealed comparative advantage—has been done by a group of researchers at the University of Notre Dame and the Kennedy School at Harvard University. The first article in this issue, by Cesar Hidalgo and Ricardo Hausmann, provides a glimpse of this research that looks at the "product space"— that is, the parameters that define opportunities for individual countries to upgrade their export offerings. Rather than employ the concept of a growth ladder, Hidalgo and Hausmann's approach incorporates the notion of a three-dimensional landscape, where upgrading opportunities abound but where product gaps may exceed the "leaping ability" of segments of the economy. The product space notion is an exciting field of inquiry, in particular since it adds an empirical dimension to the upgrading discussion.

Bryanna Millis follows up with an article that links global value chains and networks (end market analysis) to the basic economic cluster concepts that stress innovative capacity on the producer side. Linking economic and information flows in a broader context is likely to help practitioners understand relationships, focus interventions to strengthen value chains, and foster innovation. The next article, by Gary Kilmer (a DAI colleague with ample experience as Chief of Party for a range of projects) adds a dose of reality from the development practitioner's perspective. Focusing on the role of assistance projects in "linking up" small producers to global value chains, he stresses the role of trust in building relationships. As a "mutual depository of trust"—small producers may fear being exploited by the larger distributors, and the latter may fret that their small producer partners will be unable to meet standards of quantity and quality—an assistance project can bridge the gap and build lasting networks of relationships.

The next article, by Stijn Claessens, deals with the implications for competition policy in the financial services sector when one considers the network character of many of the services provided. Network industries—traditionally electricity or railroads—have been characterized by high initial investments, but low marginal costs for adding another customer. While falling average costs are one feature of such network industries, the reality is complex. When the article was written, the global financial meltdown was only one scenario; the article makes for interesting reading as the world contemplates stricter financial regulation and the implications for developed and developing economies.

The next article, by DAI's experts in geographic information systems, highlights the potential of Web 2.0 to combine geographic and social information to foster interaction and joint action. It also illustrates the existing applications of geographic and development-relevant information. The penultimate article, by Joseph Siegle, details the role of social networks in promoting democratic development. Finally, an article by Ulrich Ernst examines the use of network concepts in understanding the spread of contagious diseases and the formulation of strategies to contain them.

REFERENCES AND FURTHER READING

Barabási, Albert-László. 2003. *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life*. New York, N.Y.: Plume. (Solid introduction, written accessibly.)

Bornholdt, Stefan, and Heinz Georg Schuster (eds.). 2003. *Handbook of Graphs and Networks: From the Genome to the Internet*. Weinheim, Germany: Wiley-VCH. (A tad on the technical side.)

Durrett, Rick. 2006. *Random Graph Dynamics.* Cambridge Series in Statistical and Probabilistic Mathematics. Cambridge, U.K.: Cambridge University Press. (Not for the mathematically faint of heart.)

Fung, Victor K., William K. Fung, and Yoram (Jerry) Wind. 2007. *Competing in a Flat World: Building Enterprises for a Borderless World*. Upper Saddle River, N.J.: Wharton School Publishing. (The experiences and insights of network orchestrator Li & Fung, which has become one of the world's major textiles suppliers without owning a single factory.)

Jackson, Matthew O. 2008. *Social and Economic Networks*. Princeton, N.J.: Princeton University Press. (Textbook on network analysis.)

Nagurney, Anna (ed.). 2003. *Innovations in Financial and Economic Networks*. Cheltenham, U.K./Northampton, Mass.: Edward Elgar Publishing. (Heavy on computational economics and agent-based modeling.)

Nambisan, Satish, and Mohanbir Sawhney. 2007. *The Global Brain: Your Roadmap for Innovating Faster and Smarter in a Networked World*. Upper Saddle River, N.J.: Wharton School Publishing. (A manifesto for network-centric innovation.)

Newman, Mark, Albert-László Barabási, and Duncan J. Watts (eds.). 2006. *The Structure and Dynamics of Networks*. Princeton, N.J.: Princeton University Press. (Reprints of major contributions to network science, with informative editorial notes.)

Prahalad, C.K., and M.S. Krishnan. 2008. *The New Age of Innovation: Driving Co-Created Value Through Global Networks*. New York, N.Y.: McGraw-Hill. (Reflections on the need to source globally and work with individual consumers to create new value.)

Ryan, Bryce and Neal C. Gross. 1943. "The Diffusion of Hybrid Seed Corn in Two Iowa Communities." *Rural Sociology* 8:15–24.

Theurl, Theresia (ed.). 2005. *Economics of Interfirm Networks*. Ökonomik der Kooperation No. 4. Tübingen, Germany: Mohr Siebeck.

Watts, Duncan, and Steven Strogatz. 1998. "Collective Dynamics of 'Small-World' Networks." *Nature* 393, 440–442. (A seminal paper.)