DEVELOPING ALTERNATIVES

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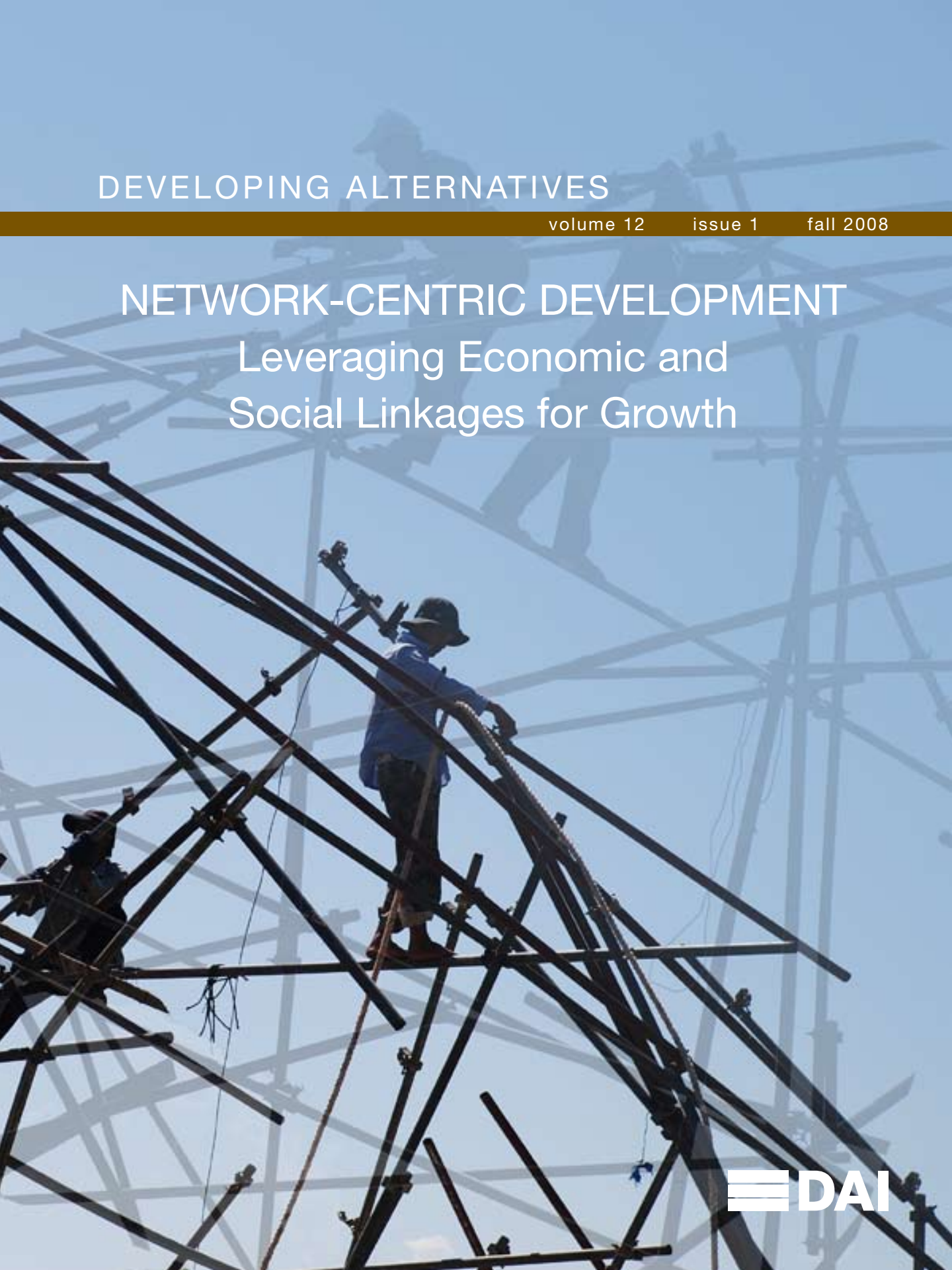
NETWORK-CENTRIC DEVELOPMENT

Leveraging Economic and Social Linkages for Growth



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Guest Editor: Ulrich F.W. Ernst
Series Editor: Steven O'Connor
Copy Editor: Peg Hausman
Designer: Joanne Kent

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DAI Washington, 7600 Wisconsin Avenue, Suite 200, Bethesda, MD 20814 USA
Tel: +1 301 771 7600 www.dai.com

DAI Europe, Suite 440, Southbank House, Black Prince Road, London SE1 7SJ, United Kingdom
Tel: +44 (0) 207 420 8600 www.dai-europe.com

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.

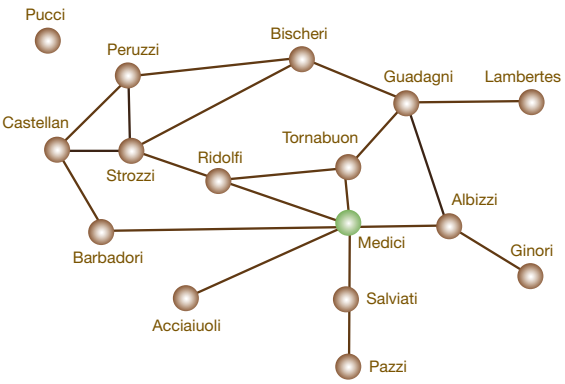
From random to scale-free networks

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.

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A NETWORK VIEW OF ECONOMIC DEVELOPMENT

by Cesar A. Hidalgo and Ricardo Hausmann

Cloth or wine?

Does the type of product a country exports matter for subsequent economic performance? To take an example from the 19th-century economist David Ricardo, does it matter if Britain specializes in cloth and Portugal in wine for the subsequent development of either country? The seminal texts of development economics held that it does matter, suggesting that industrialization creates externalities that lead to accelerated growth (Rosenstein-Rodan 1943; Hirschman 1958; Matsuyama 1992). Yet, lacking formal models, mainstream economic theory has made little of these ideas. Instead, current dominant theories use two approaches to explain countries' patterns of specialization.

The first approach focuses on the relative proportions in which countries possess productive factors (physical capital, labor, land, skills or human capital, infrastructure, and institutions) and the proportions in which these factors are needed to produce different goods (see Flam and Flanders 1991). Hence, poor countries specialize in goods that are relatively intensive in labor and land, while richer countries specialize in goods that use more human and physical capital and demand better infrastructure and institutions. According to these models, the speed at which each factor (physical capital, say, or skills) is accumulated ultimately determines the change in the type of product the country chooses to export. Underlying these models is the assumption that there always exists some combination of goods through which these factors can be expressed. Thus, controlling for initial factor endowments, the particular products a country produces carry no consequence for future economic performance.

The second approach emphasizes technological differences (Romer 1990) and therefore needs to be complemented with a theory of what may lie behind these differences and how they may evolve over time. The two dominant theories—the varieties model of Romer and the quality ladders of Aghion and Howitt (1992) and Grossman and Helpman (1991)—assume a continuum of products in some technological space. According to this line of thinking, there is always a slightly more advanced product that countries can move to as they upgrade their technology. The world of products is abstracted away and ignored when thinking about structural transformation and growth.

But is the nature of the products involved really unimportant in determining the pattern and speed of development? The abstraction from the space of products in standard economic theory is not an act of naïveté, but a natural consequence of the lack of tools available to describe them. In a recent paper, Hausmann, Hwang, and Rodrik (2007) incorporated the product space into our notions of economic development by introducing a one-dimensional variable—the level of sophistication—to the characterization of products. They show that, controlling for the country's initial level of development, the greater the initial sophistication of its export basket, the faster its subsequent growth. However, a one-dimensional scalar description of the product space may not fully account for the rich structure and pattern of product relatedness—a concept critical to economic development. Here we argue for a network view to describe product relatedness and illuminate various aspects of such development (Hidalgo et al. 2007).

A network view of economic development

Traditionally, economic development has been measured through a host of aggregated variables, mainly gross domestic product (GDP), adjusted by power purchasing parity. Yet, as a concept, development has always been associated with an increase in diversity that cannot be captured by such averages. As the human body develops, cells differentiate into neurons, muscles, bones, and other cell types. Similarly, as nations develop, different industries and products are born. Assessing the health of an economy solely based on its wealth is like assessing the health of a child solely based on its weight. A more nuanced view of development should concentrate on understanding how nations develop different industries and products, rather than trying to predict how they accumulate capital. But how do we describe such a complex process?

A GDP view of development can be seen as a ramp or ladder. Within the confines of such a metaphor, a nation's development is measured by looking at the step on the ladder it occupies, regardless of the products and services that allowed it to get there. Development, however, may not be as one-dimensional as this picture suggests. An alternative metaphor would represent nations as navigating through a rugged landscape rather than climbing up a ladder, searching valleys and crossing mountains and oceans in the search for new products and services. We can represent this landscape with a network.[1]

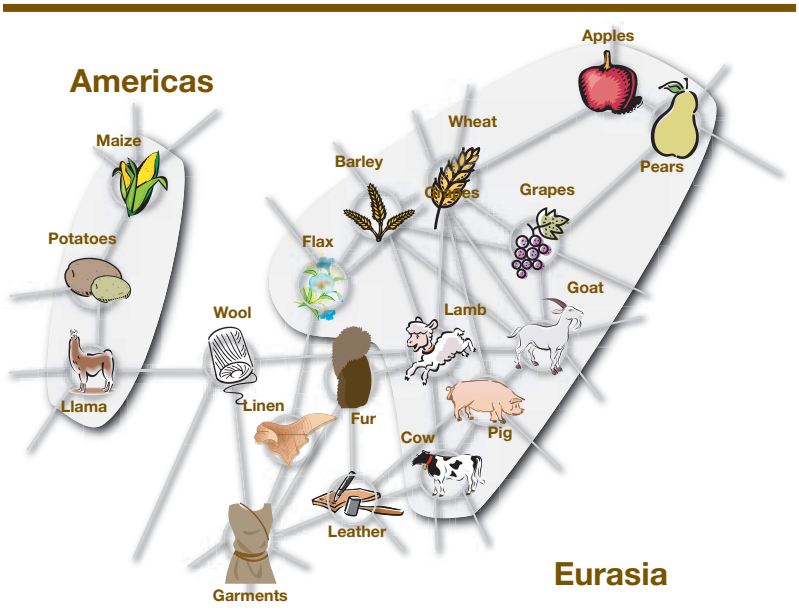
In fact, network representations of physical landscapes are ubiquitous; trivial examples are the subway map or the highway network. And we can illustrate how a network view of economics might look through an example inspired by the view of the world presented in Jared Diamond's *Guns, Germs, and Steel* (1997). Diamond's popular masterpiece is a fascinating view of global development, from our origins as hunters and gatherers through the long history of plant and animal domestication and beyond. Well documented and rich with fact and anecdote, the book discusses the history of many of our first economic products—such as wheat, barley, pork, flax, and corn—and shows how our world was shaped by a few civilizations that happened to be in the right place at the right time. These civilizations developed farming economies enabling them to produce a surplus that allowed individuals to specialize as, say, soldiers or bureaucrats. Consequently, these tribes dominated their neighbors, physically and/or culturally, and transformed our world from a myriad of independent family groups into a few large, dominant civilizations.

But why did some of these advanced civilizations prevail over the others? To take one element of Diamond's argument, since climate changes little with longitude but greatly with latitude, domesticated plants and animals can diffuse more easily if they travel east or west than if they travel north or south. Since Eurasia is a large expanse spread out on an east-west axis, innovations in one part could travel easily across the continent. However, Africa and the Americas are oriented on a north-south axis, so there are fewer areas with similar latitudes that could readily share new varieties of plants and animals. As a consequence, more products were available to the Eurasians than to the Amerindians and Africans.

We can use a network view of development to describe Diamond's explanation of such disparity. Figure 1 graphically represents the product landscape faced by our ancestors. Civilizations grew by discovering products—that is, domesticating plants and animals. These products in turn allowed them to create more complex products, such as garments, tools, and weapons. Yet not all civilizations started in equally dense parts of the product space. Eurasian populations had access to a broader set of opportunities because of the larger base on which they could experiment and

[1] This approach is far from new, as it was used by the 18th-centry Swiss mathematician Leonhard Euler to abstract and solve the famous Konigsberg bridge problem. In fact, he showed that the problem had no solution.

FIGURE 1. SKETCH OF THE *GUNS, GERMS, AND STEEL* PRODUCT SPACE



Note: Links are not scientifically accurate.

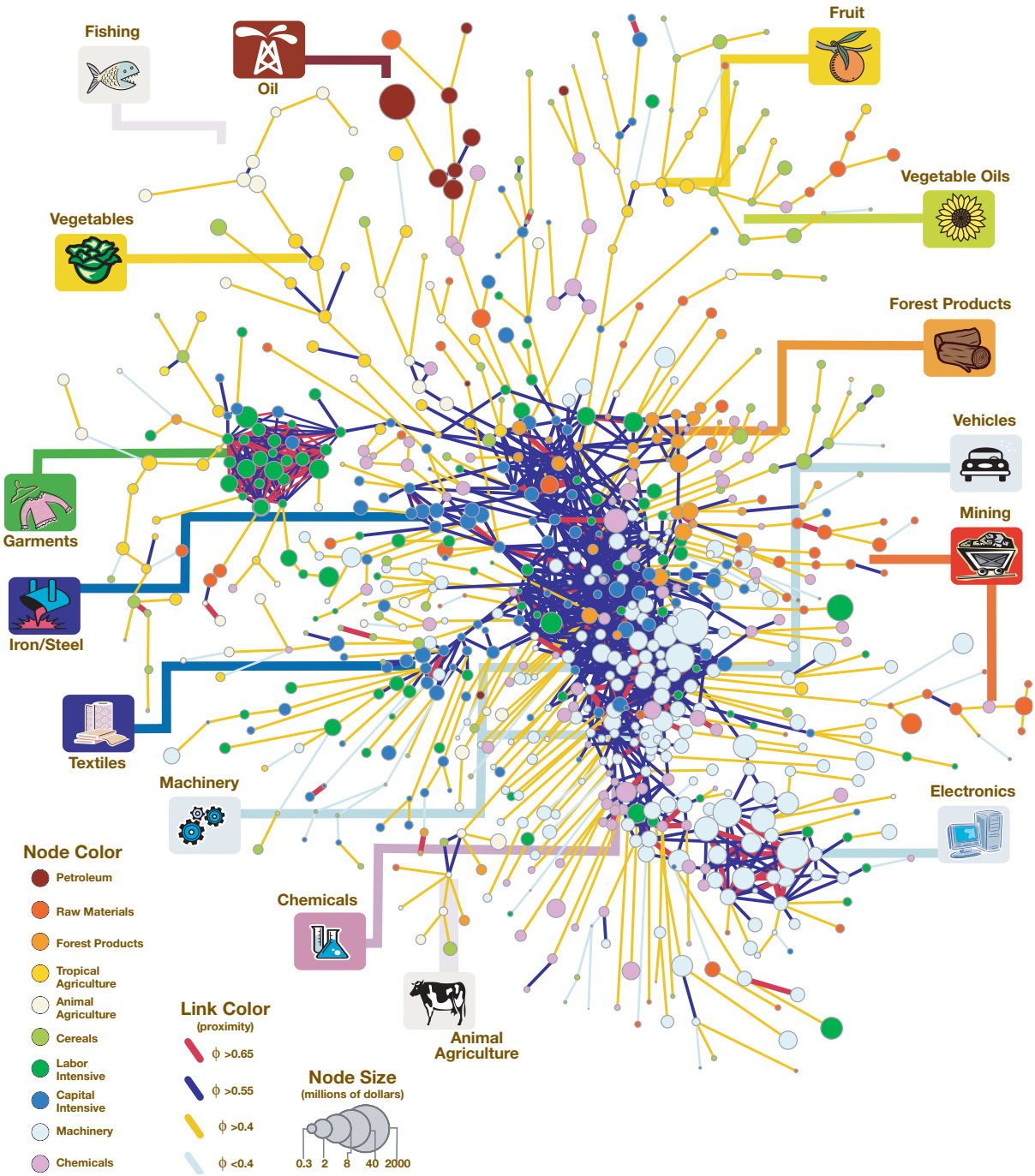
then share innovations. They developed wonderful grasses, for example, such as wheat and barley, plus animals that were relatively easy to domesticate, such as goats, sheep, and cows. Eurasian populations—located in a part of the product space where many goods were close to each other—were able to expand quickly over it. On the other hand, civilizations located in the Americas were located in a much sparser part of the product space, where product diffusion was limited by geographical constraints. This limited the economic diversification of early American civilizations and, consequently, their ability to jump to further products in the product space.

Clues about the nature of the links connecting different products can be gathered by looking at how products are discovered and rediscovered by different populations. Some jumps, like the domestication of apples, can require important technological improvements (in this case, grafting)—improvements that open the door to other developments (in this case, the domestication of pears and plums). Even in ancient times, links between some products or industries were driven by technology. In other cases, some products or industries may be connected to each other by input/output relationships, such as flax and linen or olives and oil. Yet a third way in which products may be connected is similarity in required infrastructure, such as the silos used to store wheat and barley. A network view of development does not require a unique definition of a link: rather, it requires accepting as a reasonable assumption the fact that there are links connecting some products and not others; links through which knowledge, inputs, and workers can flow; links that may be traversed by endeavor or serendipity.

Exploring the network

In a recent paper, we showed that it is possible to use export data to study development as a diffusion process over a network (Hidalgo et al. 2007). To do this, we first created a measure of distance between a pair of products based on the probability that they were exported by the same countries. This simple method allowed us to construct a network where we showed that countries tend to diversify by developing products that are close in the product space to those they already export. In other words, the network shows empirical association (across countries) of different export products—mapping out the most promising avenues for upgrading. It is easier to move from one product to another within the "forest products" cluster than to leap from there to a product in the electronics group. In that publication, we simplified our discussion by concentrating on cases in which the product space is fixed and countries spread over it, which is a valid assumption for short time scales. We showed that ostensibly similar countries face very different opportunities for diversification because they are at very different distances from other products. Given the structure of the product space today,

FIGURE 2. NETWORK REPRESENTATION OF THE 1998–2000 PRODUCT SPACE



most poor countries can only reach the levels of development enjoyed by rich countries if they are able to jump distances that are quite infrequent in the historical record (Figure 2). In other words, the "stairway to heaven" presents some very tall steps.

There are many ways in which this analysis can be extended. It may be interesting to study the product space from a labor perspective. One could relate products based on the similarity of the labor skills required to make them. This would allow companies to exchange skilled workers. A new product can more easily be developed if it uses labor skills similar to those used in making existing products. One could also study the patterns of mobility of labor between industries as workers try to adjust to changes in the demand for their skills.

The product space evolves over time, as new products and new ways of making old products are introduced. Cell phones went from not existing, to being made in rich countries, to being assembled in poor countries. Cell phone service is now ubiquitous. The internet allows for an exchange of information that was hitherto unimaginable. Does this development make it easier or harder for countries to transform themselves?

We can also study the robustness of an economy based on its position in the product space and its ability to move in it.[2]

These are just some of the issues that could be illuminated through study informed by a network perspective. Such analysis opens new avenues to diagnose a country's problems and chart a policy strategy. To do this properly, we will need to redeploy network techniques and concepts developed in other branches of science and adapt them to economics. Additionally, we will need to develop new techniques tailored especially for economic questions and craft a common language to bridge new ideas and more traditional approaches. As large data sets become more common, so will the creation of network maps, as they represent a useful way to surf over new waves of data.

Our own skepticism

Developing a comprehensive description of the world economy as an evolving network is a task requiring many minds and many years, and only time will judge its usefulness. But proposing a network description of the economy is bound to create skepticism. From a theoretical perspective, suggesting that economic development should be seen as a diffusion process over an evolving network is as groundbreaking as proposing that economics could be studied using scalar functions and differential calculus. We often forget that our "Newtonian" view of economics, pioneered by Léon Walras and William Stanley Jevons and continued by Paul Samuelson and others, requires us to assume that the economy can be best described by looking for numerical quantities and functional relationships between them. Most of us forget that assumption because we never made it; we inherited it as college freshmen. Our approach is proposed not to compete against traditional mathematical methods but to complement them, by incorporating tools that can be used to study development from a different perspective.

There are no guarantees that this innovative approach will be useful, just as there were no guarantees for the benefits of using calculus and physically inspired equilibrium processes to describe economics at the beginning of the last century. The proof of the proverbial pudding will have to be revealed by further research.

Acknowledgments

We would like to thank Melissa Wojciechowski for help editing this manuscript.

[2] Hausmann, Rodríguez, and Wagner (2008) show that the position of a country in the product space strongly affects the speed at which it recovers from economic crises.

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VALUE NETWORKS: MOBILIZING KNOWLEDGE FOR PROGRESS

by Bryanna Millis

Toward network-centric development

Leading economic thinkers have long favored policies that promote competition and recognize knowledge as the driving force behind economic growth. Anne-Robert-Jacques Turgot, a contemporary of Adam Smith's, but writing well before the publication of *The Wealth of Nations*, advocated policies to loosen the French government's strangle-hold over the economy (and enacted them as Minister). Turgot stressed "genius" as the engine of economic progress. Running against the prevailing wisdom of the mid-18th century, he believed that nature distributes ability equally, and the way he saw "genius" reads like a precursor of today's notion that knowledge (technology) is in effect an inexhaustible resource: "Genius is spread amongst mankind like gold in a mine. The more you take out, the more metal you will get."

It took mainstream economics a long time to embrace this concept, but today it is difficult to think of any theoretical treatment of economic growth where knowledge accumulation, knowledge sharing, and innovation do *not* occupy center stage. The same holds for business strategy books that focus more on the practical challenges of making enterprises grow. Theoretical growth models emphasize the role of (endogenous) research and development as the driver of growth. Much of the recent literature deals with "quality ladders," where industries grow by getting to the next rung of the product ladder; in a recent contribution, Giordani and Camparelli (2008) employ quality-ladder growth models to explore the policy implications for an economy with industries that differ in their innovative potential. And current research on the product space adds a third dimension to this analysis, focusing on how the proximity of product categories affects the likelihood of upgrading (see Hidalgo and Hausmann's article in this issue).

Welcome advances on the theoretical front deepen our understanding of macro processes but provide little guidance for interventions to improve the competitive performance of enterprises in target areas. To provide such practical guidance, we need to understand how economically important knowledge is generated, how it is shared, and how it is applied. There have been many efforts to deal with these questions strategically, from industrial complex and agricultural subsector analysis to cluster development and the current emphasis on understanding global value chains. The central issue is to determine ways in which economic and technological communications flow among enterprises and government agencies to stimulate both business and policy innovation. These exchanges are neither limited to small geographic areas, as in economic clusters, nor constrained to up-down relationships in a hierarchically structured global value chain.

Economic and information linkages among firms—whether small businesses or global concerns—form a network that creates value by promoting enterprise development and economic growth. Such linkages define a *value network*, a concept that emerged originally from the field of logistics and supply chain management, and its study of network-centric operations. The value network concept draws on our understanding of cluster theory, of innovation diffusion, and of how information flows along governance structures in global value chains. Seen through the lens of the value network, economic activity is not just an exchange of goods and services, but an exchange of economically valuable information from customers, competitors, producers,

and suppliers in other sectors, as well as sector support organizations, research institutions, and government bodies.

Companies are increasingly using network management to pursue innovation and build "dynamic connections between the enterprise, suppliers, customers, and other partners to deliver maximum value to all the entities concerned" (Nambisan and Sawhney 2008, 21). Proponents of the cluster and global value chain approaches, meanwhile, are increasingly incorporating the horizontal and vertical linkages that define the alternate model. Building on these developments, the value network offers several innovations: it serves as a bridge between the cluster and global value chain concepts and incorporates a practical perspective on how innovation is fostered and transmitted through hubs and links, illuminating how personal relationships affect the pace of diffusion, both within groups and along global business processes. While the business literature is discovering the power of network-centric innovation—and of network orchestration as the means to build ad-hoc value chains that meet customer demands—value network approaches to development promise to create a more flexible framework for promoting business and policy innovation, and thereby supporting private sector competitiveness.

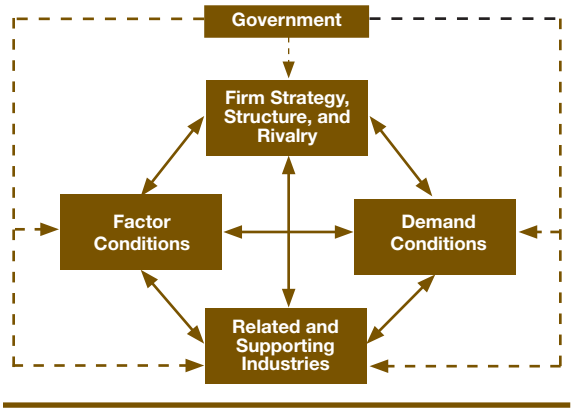
Innovation flows in clusters and value chains

The intellectual taproots of the value network concept run deep. Over the past two centuries of economic thinking, technological change—or the development and transfer of knowledge—has risen from a peripheral to a central role in our understanding of how economic value is created and competitiveness improved. Yet while the importance of knowledge transfer is now widely recognized, in practice the modes and mechanisms by which information flows can support increased competitiveness remain underutilized. For example, we know that agents play a central role in transferring information from end markets to producers along the value chain, but strategies to catalyze their cross-value-chain relationships remain elusive. Even in business, the mechanics of innovation remain poorly understood (although we are seeing great advances in strategic thinking in this field) and this shaky understanding certainly hinders economic development efforts. In part, the inability of innovation to flow freely reflects our poor grasp of how to build or support information channels to ensure that the right information gets to the right people at the right time.

Cluster theory explores links among firms

In 1890, Alfred Marshall expounded his theory of industrial districts in the *Principles of Economics*, writing of how knowledge spillovers were favored by localization, which in turn often stemmed from concentrations of natural or human resources. He observed that the proximity of related industries offered various benefits to firms and industries. In addition to the lower costs of pooled production factors, the higher productivity of specialized inputs, and the lower costs of transportation, "inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas."

FIGURE 1. PORTER'S DIAMOND MODEL FOR THE COMPETITIVE ADVANTAGE OF NATIONS



In 1990, Michael Porter resurrected Marshall's industrial districts as economic clusters, in a series of case studies and a summary chapter in *The Competitive Advantage of Nations*. As described by Porter, industrial clusters are formed by geographic groupings of connected companies and associated institutions. Clusters improve productivity by cultivating opportunities for innovation, and innovation is supported by the geographic proximity of complementary and competitor firms whose ability to communicate face-to-face strengthens relationships and, by extension, increases trust (see Mills and McDonald 1992). Clusters typically develop organically over time, around natural, human, or knowledge-based resources, such as in Boston's biotechnology cluster or in Silicon Valley. The epitome of a successful cluster is the oft-cited example of Napa Valley wines, a cluster driven by the innovative technologies and marketing techniques of Robert Mondavi, but also favored by a supportive regulatory environment and abundant natural resources.

But efforts to promote clusters in particular regions have met with mixed success. Why? The U.S. Agency for International Development (USAID)-supported study, *Cluster Initiatives in Developing and Transition Economies* (Ketels, Lindqvist, and Sölvell 2006), highlights several reasons, including insufficiently tailored approaches to assistance, and points out the need for longer time horizons to measure success. In addition, while clusters facilitate information flows within geographic locations, their fundamentally insular focus compromises their ability to nurture information flows with those outside the cluster. Recent research shows that the inherently self-referential nature of the cluster may actually reinforce outdated ideas rather than disseminate new ones. In the early 2000s, Porter acknowledged this weakness and found that unless individual clusters are networked with others from which new ideas might enter the system, innovation could be stymied. Another lacuna in the cluster model is its supply-driven nature: while innovation research in the 1970s and 1980s (Hill and Utterback 1979; von Hippel, 1988) stressed the important role of users or customers in driving new concepts, the cluster model does not account for the critical feedback from buyers (particularly international buyers, given the cluster's domestic market focus). The challenges facing many firms in reaching global markets—from international marketing to forging trade partnerships and meeting global quality standards—are not adequately addressed in cluster theory.

Value chain analysis adds the link to global markets

According to USAID's value chain approach, as articulated by the Microenterprise Development Office, "value chains encompass the full range of activities and services required to bring a product or service from conception to sale in its final markets" (Campbell 2008). Value chain analysis investigates how an industry works in a country or subnational region, including the internal and external governance of the value chain and the requirements of end markets. This information is used to identify interventions—strengthening links along the chain, reducing transaction costs, and gaining efficiencies—that will make the final product more competitive in the world market.

FIGURE 2. GLOBAL ENABLING ENVIRONMENT

Source: http://www.microlinks.org/ev_en.php?ID=25439_201&ID2=DO_TOPIC

The global value chain framework addresses some of the gaps in the cluster model: value chain analysis is driven by demand conditions in the end market—essentially by buyers for global retailers—so signals conveyed through agents inform changes in value chain production, processing, and transportation. Furthermore, value chain analysis emphasizes the role of government policies (the business environment) at the international, national, and industrial levels, as well as support services, transaction costs, and relationships along the chain that influence productivity. It therefore yields a nuanced view of the role of incentives—and the importance of trust—in facilitating the flow of goods to the end market and of information back to producers.

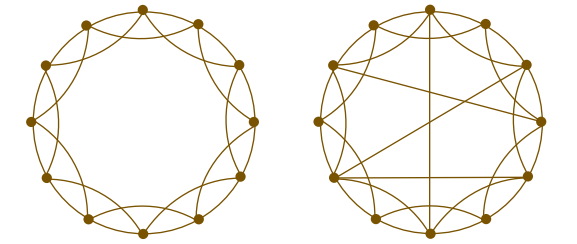
In practice, however, the linear nature of the value chain framework imposes limitations. While the vertical flows of products and information are well represented, the model is weaker in its understanding of horizontal flows, including interactions with support services and linkages between independent value chains. Furthermore, room remains for this model to adequately address the transmission of knowledge and innovation between the value chain and related stakeholders.

Both the cluster and global value chain models have important analytic value, and as they have undergone refinements in both theory and practice, each has begun to integrate elements of the other. Taken in isolation, however, neither adequately models the multidimensional relationships and multidirectional flows of information needed to drive increased productivity. These considerations, among others, are brought together in the value network.

Connecting the dots with value networks

The value network is made up of nodes linked by strong ties at the local level and by weaker ties into other networks, including those at the global level. Value networks therefore provide a model through which to incorporate the strengths of the cluster and value chain frameworks while strengthening the missing dimension of innovation diffusion. To make effective use of the concept, however, it is important to understand the components of the network, how information flows, and how value is created. In the illustration above, from Albert-László Barabási's 2002 book *Linked: How Everything is Connected to Everything Else and What It Means for Business, Science, and Everyday Life*, Duncan Watts and Steven Strogatz demonstrate how a circle of nodes, on the left, becomes a network, on the right, through the addition of just a few links. They show how a series of local clusters (neighborhoods, social groups) can be turned into a network by the addition of a few "cross" linkages that tie them together. These linkages reduce the number of steps between each node. Each node in a local cluster is then only a few links away from any other node on the network. Tight local grouping and cross-linkages account for the "small world" feature of social and economic networks.

FIGURE 3. WATTS AND STROGATZ MODEL



Nodes and links

Simply put, nodes can be just about any type of organization, firm, or individual in a chosen network, while links are the relationships between these nodes. Attributes of specific nodes or links may affect how, and how effectively, information will flow. For example, nodes with an unusually large number of links to other nodes become hubs. A hub may be an industry expert or an umbrella business association. When information reaches hubs it is more likely to flow rapidly throughout the entire network.

The kind of link also matters. As Mark Granovetter pointed out in his 1973 article, "The Strength of Weak Ties," social networks are made up of strong and weak links, reflecting the relative strengths of individual relationships. Granovetter found that when it comes to transferring new information, weak ties are actually more important than strong ones, because by connecting separate clusters of strongly linked nodes, they carry ideas, contacts, and news from different parts of the networks. For example, people are more likely to learn about new job opportunities from acquaintances than good friends. On the other hand, as Everett Rogers showed in *Diffusion of Innovations*, strong links between individuals or institutions are more effective for ensuring that innovations are actually adopted, due to the bonds of trust and confidence among "like" nodes. Rogers discusses the role of "change agents" attempting to communicate health information to targeted communities, for example: to the extent that agents are viewed as outsiders with opinions of little social consequence—whose methods may not be locally appropriate—their recommendations are less likely to be adopted, so the diffusion process breaks down.

More than one kind of value

In her article "Reconfiguring the Value Network," knowledge management consultant Verna Allee identifies two primary types of value within the network, what she calls "tangible" and "intangible" value. The former represents economic value in terms of the goods, services, revenue, and related transactions commonly measured in value chain analysis; the latter represents value in terms of "knowledge" and "benefits," where knowledge encompasses technical issues and innovations, business processes and strategies, and supply and demand conditions, while benefits include trust, political support, and other types of social and political advantage. While the important role that intangible value plays in all human interactions is widely recognized, the ability of development programs to make use of this awareness lags behind.

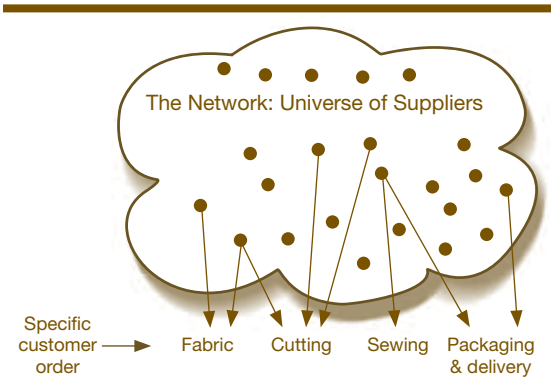
Value networks in action

Economic development programs seek to understand and remove the constraints that hinder the private sector's ability to do business efficiently. Such constraints may be the result of market failures, inadequate human and financial resources, weak physical or knowledge-based infrastructure, an unsupportive regulatory environment, or other factors. Development programs rarely if ever address all the constraints—they often have a mandate to focus on a certain kind—but they aim to deliver the greatest impact for the resources expended. Taking a value network approach to understanding and addressing industry constraints not only broadens the range of tools available to the practitioner: by better understanding the networks created by linking domestic clusters with global value chains, how information and innovations are diffused through these networks, and the power of intangible value, practitioners can identify new approaches to design interventions and overcome development challenges.

The champion as a network hub

Skillful "network orchestrators" can create ad-hoc value chains to respond to specific orders. The experience of Li & Fung in the garment trade demonstrates the power of this approach persuasively (Fung, Fung, and Wind 2008). Figure 4, adapted from their book, illustrates this process: in response to a specific customer order, the network orchestrator chooses among the universe of suppliers according to available capacity and

FIGURE 4. NETWORK ORCHESTRATION



other characteristics to create an ad-hoc value chain for *this particular order*. The orchestrator is responsible for the fulfillment of the order, as well as for maintaining the network of qualified suppliers.

Prahalad and Krishnan (2008) take this notion a step further, in effect replicating the Li & Fung network for other sectors. In their view, the customer and the supplier "co-create" value by working together. The supplier remains the hub for accessing resources and talent globally, but each individual customer's needs differ, and customers in fact use the resources to meet their demands, thereby contributing to value creation. Prahalad and Krishnan cite examples from academic tutoring (TutorVista) to personal technology (Apple's iPod) and point-of-sale systems (NCR). Finally, from the realm of innovation research, Nambisan and Sawhney (2008) point out that barriers to successful internal innovation are increasing, especially for small enterprises, and throw the spotlight on network-centric innovation, exemplified by the rise of open source software.

In all of these cases, the role of the network orchestrator is to ensure that operations meet global market standards and respond to immediate customer demand. Within the value network, this firm or individual is a *hub*—a node linked to a particularly large number of other nodes—but a hub that actively participates in making the nodal connections necessary to improve business processes or information flow. In economic development projects, the project itself may play this role, creating linkages that may be missing, strengthening other nodes to act as hubs in the economy, or facilitating the development of new relationships that may later become self-sustaining. It is critical that the hub occupy, or come to occupy, a position of trust in order to build the necessary relationships and to link nodes that may have been resistant to linkages in the past.

The intangible value of trust and political support is often understood in a tacit rather than strategic way in economic growth programs. Regulatory reform initiatives often seek a "reform-minded" partner in government, one who can shepherd change and work to win over more reluctant colleagues. Yet while a reform-minded advocacy partner is often a necessary component of project success, it is by no means sufficient. We must also understand the power structure that governs how this individual is able to pass along information and ideas. And we must take account of any deeper underlying relationships to ensure that the reform process is sustainable once its original supporters and program are gone.

An issue that often arises during value chain strengthening programs is distrust between segments of the chain. Producers and processors, for example, often view one another as competing over the finite revenues to be extracted from the value they add. More progressive firms realize that rather than behaving as competitors in a zero sum game, actors in the value chain would do better to find mutually optimal solutions. For other firms to reach this conclusion, it may take the intervention of a jointly trusted advisor within the network—an organization or individual. In some cases, that organization might be a business association. The functioning association is effectively a hub, a place for joining different links on the value chain, as well as a voice for firms to be represented to the government. As economic development programs seek to support and strengthen these associations—to improve their ability to serve value chain members—understanding them as hubs may expand the ways in which programs make use of their potential.

In sum, the value network offers a more complete framework through which to understand how firms interact in the global economy and what it takes to be competitive. By building on existing theories of industrial clusters and global value chains, economic development programs that embrace the value network concept can help to identify—or even temporarily play the role of—network orchestrators, and support the building of relationships and trust through which network links will come to effectively transmit knowledge.

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LINKING UP: A PRACTITIONER'S PERSPECTIVE ON THE ECONOMIC LINKAGES THAT SHAPE DEVELOPMENT

by Gary Kilmer

As an economy grows, it becomes increasingly interconnected, both internally and across borders. In poor countries, such linkages tend to be sparse. At one end of the economic spectrum, small farmers and entrepreneurs often operate in the informal sector, typically restricted to local, seasonal markets. They are unable to control their access to needed inputs, or to their final markets. Their inability to access value-adding technologies and international markets—compounded by weak political leverage—anchors them to the lowest rung of the commercial ladder. Abuses of market power, and often erratic (even corrupt) government rule making and application of regulations make long-term planning difficult or impossible. Small producers must operate within conditions as they find them day-to-day.

In contrast, the somewhat larger participants in an industry have the benefit of doing business in the larger national or international economy, with greater economies of scale and adequate capital assets. They have better access to the formal banking system and can, at least collectively, seek to influence the manifestations of government that most affect them. They face limitations as well, however. Overhead costs may be high for processing or marketing the amount of material they can produce themselves, or the expense of an "in-house" distribution system may be more than they can efficiently sustain.

Fostering active commercial links between the larger and smaller participants in an industry can therefore be advantageous to both parties. For the small-scale operators, these links can result in improved productivity and more ready access to needed production inputs. They benefit from a more stable market for their products, and they enjoy reduced costs in the expensive business of seeking other markets. The larger firms benefit from a more reliable supply of required raw materials, semi-finished product, or other inputs or services they need without committing their own financial and human capital in their production. Each side can take advantage of the relative strengths of the other partner while offsetting some of its own weaknesses.

In the field of agribusiness, where I have been most involved, *carefully forged and closely tended* activities to join small-scale farmers and entrepreneurs with their larger counterparts have benefited both sides. The same principles can apply in the garment business, handicraft production, and other areas.

Conceptual models and practical demands

Models for strengthening economic and other linkages among economic actors abound, in particular those that seek to connect small and larger processors and distributors. Not so long ago, cluster development was the flavor of the month in the world of enterprise development. Coined by academics and cloaked in layers of jargon, figures, and charts, the concept was adopted by many in search of a ready answer to our development wishes. Subsector development was a predecessor, built on the old agricultural economics concept of supply chain analysis as a way of understanding how players in an industry interact to add value to a product and bring it to market. Value chain analysis is now on the rise, providing a useful framework for gathering, storing, and analyzing the same sort of information.

These approaches are valuable to the extent that they explain commercial interactions and identify likely points of intervention for those of us who

embrace the promotion of private enterprise as a viable development tool. But they all add layers of complexity that are little understood by the firms, small and large alike, that must make it all work in practice. These complexities can divert efforts from those grassroots, bottom-up, bricks-and-mortar approaches that are required to bring about real change. What these conceptual models miss is the single most important factor in business success: entrepreneurs' ability to implement their ideas within the confines of the existing environment—an environment over which they have little or no control.

Effective linkage building requires an accurate and comprehensive understanding of local development and commercial realities and must be carried out within the limits imposed by those realities. What this process might be if political, economic, and regulatory conditions were somehow "right" is no more meaningful in the real world than is the theory of perfect competition to establishing product prices.

Upstream and downstream linkages

Examples of effective linkages abound in the world of agroprocessing. In what I think of as the upstream model, large numbers of small-scale outgrowers deliver products to a single processing plant or exporter. Without these linkages, the small producers would lack access to processing facilities or export markets. Outgrower products can provide an input to the lead firm's production process (milk for cheese, for example, or gherkins for cornichons) or augment the flow of product through the larger firm's established export channel. These linkages open new market opportunities for the small farmer/outgrower and enable the larger firm to exploit economies of scale.

In the downstream model, a large enterprise may rely on legions of microentrepreneurs to distribute its product. Newspaper publishers or soft drink bottlers or ice cream manufacturers will often rely on large numbers of street vendors to ensure the widest possible distribution of their products. The vendors—each an independent contractor, either by choice or for lack of more desirable options—rely on the logistics managed by the larger firm to provide a steady flow of product. The arrangement, of course, benefits both sides. The man from whom I purchase my newspaper each morning is financially hurt when his supply of newspapers arrives late. The publisher will be harmed if my supplier and any significant number of his colleagues are either forced out of business or find more rewarding means of earning their daily rice and beans.

In neither model is either party necessarily seeking to do a social "good" or fulfill an obligation to less fortunate neighbors. Indeed, linkage arrangements of this sort are most likely to succeed where each party sees a link as in its own interest. Programs where links have been built at the behest of government have been notably less successful. Indonesia's "Bapak-Angkat" (or foster father) program in the 1980s, for example, was in my experience lacking that critical element of perceived self-interest, leaving only a sense of government-imposed paternal obligation of the "Bapak" (lead firm) to its junior partners, and little by way of real benefits for either.

Effective linkages demand trust

Entrepreneurs struggling to operate in difficult (and sometimes downright hostile) environments can generally afford neither the time nor the political risk that are often involved in establishing formal linkages of either variety. While development practitioners tend to suggest that they join together in associations to pursue policy change on the "safety in numbers" principle, this approach is often unacceptable to people whose families' welfare depends on their business and whose distrust of outsiders—even outsiders in the same business—is often justified.

In many cases (especially but not exclusively in the countries of the former Soviet Union), there is a strong and general aversion to creating these types of linkage—on both sides. Each party is

typically reluctant to put its fate in the hands of the other, failing to grasp the contractual mechanisms that can reduce the need for blind trust in the deal and refusing to accept that such a deal can be a "win-win." One frequently encounters the assumption that if one partner wins, the other must necessarily lose.

Thus, small and medium-sized business operators are often reluctant to participate in marketing chains when it requires relinquishing some level of control. Garment makers and footwear producers in Armenia, for example, prefer to establish their own shops to sell only their products, in the adamant belief that relying on others to market their wares would lead to their downfall. I know one Armenian beekeeper who established his own honey "boutique" rather than distribute his product through Yerevan's innumerable markets because he believed they would adulterate his product with honey from other regions. He could only feel safe if he personally controlled the product from beehive to consumer. That is a tough way to grow a business.

The conditions for successful linkages

Every deal is unique, just as every company, every producer, and every political and economic environment is different. So we should be careful about prescribing the conditions for successful linkage building. Any assistance to the process should focus on helping the participants tailor their linkage relationship to best meet their individual needs and the specific requirements of target markets. Refining individual business plans and outgrower agreements is a high priority, complemented by assistance to participants in crop production, post-harvest handling, packaging, crop protection, and the identification and development of commercial relationships with appropriate international buyers. A flexible and context-driven approach is essential.

That caveat stipulated, my experience with many different types of linkage development work suggests there are five factors necessary to the development of successful commercial linkages:

- Shared commercial objectives;
- Perceived mutual benefit and fairness;
- Shared commitment to making the linkage successful;
- Clearly defined rights, responsibilities, and—in the event of nonperformance—sanctions; and
- Transparent management.

Shared commercial objectives

Both parties must be oriented toward the market. In the case of pineapple exports from Ghana, for example, the packhouse operator/exporter and the small-scale outgrower must agree that the objective is to maximize long-term returns to both. That agreement implies providing overseas buyers with the quality and quantity of fruit they want, according to the agreed schedule. If only one party is committed to this objective, while the other is more interested in selling second-grade product that cannot be sold elsewhere, or in purchasing from small producers only when its own production falls short, then the relationship cannot succeed. Standardization, open communication, and predictability are critical in this case. All parties must use the same production systems, coordinate their planting and harvesting schedules to ensure a steady flow of product, agree to payment and credit systems that facilitate the work of each, and stay fully aware of their obligations and rights.

The shared commercial objective can be more difficult to achieve if the end market is less than transparent to all participants. In the fresh pineapples example, participating farmers generally feel themselves to be "exporters." Their product reaches the end market directly. In the case of tomato processing into exportable paste, however, it is more likely that only the processor is going to have the end market in mind. The farmers are simply growing tomatoes for sale to the processor. It is going to be more difficult to convince these farmers of the need for

quality standardization, harvest scheduling, and the post-harvest handling requirements that ensure a smooth production process. Since the end market is indirect, farmers often pay less attention to their products' quality standards. That said, British American Tobacco Company (BAT) appears to have solved this problem in the tobacco farming arena, by close and clear communication with contracted tobacco farmers, coupled with the provision of specialized inputs and cash payment at harvest time.

Perceived mutual benefit and fairness

Each participant must feel that he or she will gain more from being in the program than out of it (which appears to be the key to the success of the BAT program). Equally important, neither party can believe that he or she is somehow being taken advantage of by the other. Even if I am satisfied with my returns from the deal, I may be unhappy if I think that another party is benefiting far more.

While there are many cases of exploitation of small producers by their larger and more sophisticated "partners," there are also many instances where incomplete understanding of market realities leads to unfounded suspicions. I know Armenian beekeepers who have heard that honey sells in American supermarkets for US$10 to $12 per kilogram, for example, and who are therefore offended at being told that the world market price for bulk honey at source is closer to $2. If they could just cut out the middlemen who are "cheating" them, they insist, they could realize 80 to 90 percent of that retail price themselves. Education is often required to clarify participants' understanding of the whole value chain.

Shared commitment to making the linkage successful

All parties must be equally committed to the success of the linkage, and that "success" must be understood in agreed terms. In agribusiness, the least successful linkages have been the result of a large firm agreeing to "help out" smaller neighbors by enlisting them as outgrowers, even though the production of those outgrowers was not seen as materially important to the larger firm's profitability. In a successful outgrower linkage, small farmers benefit by gaining a marketing partner capable of providing them with production inputs they require to produce more profitably; the larger partner benefits from expanded access to the agriculture produce needed to optimize its marketing channels or processing capacity.

Strong partnerships can stand up even in the face of assault from "cowboys" (who try to lure outgrowers into diverting their crops in exchange for the opportunity to avoid repaying production credits or other obligations). The key word here is "partnership." Not only do the two sides need each other to maximize their own benefit, but they know that they need each other and actively work to preserve the relationship. An element of shared risk must be built into these relationships. Sometimes crops fail or prices go down due to factors beyond either party's control. All parties must go into the deal with a common understanding of how these losses will be borne. Otherwise, the shared commitment to the linkage will not survive the first unforeseen glitch in the system.

When the larger firm relies on outgrowers for all or a significant portion of its raw materials because small-scale production is more efficient than larger-scale production, the chances for success are better, as in the BAT outgrower scheme. Tobacco is a labor-intensive crop best cultivated by small farmers. Small-farmers can also be more efficient in the production of tomatoes and crops such as pineapples, vanilla, or paprika, unless the larger operator is willing and able to expend significant financial capital to mechanize operations.

Clearly defined rights, responsibilities, and sanctions

A common problem in Ghana, Indonesia, Armenia, and other countries where I have worked is that the details of linkage relationships are not documented in a way that is clear, com-

prehensive, and understandable to all parties. A pineapple exporter may agree to provide selected farmers with production inputs on a credit basis while the outgrowers pledge to sell their crop to the exporter when it matures. But in the absence of a detailed agreement, farmers do not know exactly what inputs will be supplied, at what prices they will be provided, and on what credit terms. They may not fully understand when the exporter wants the crop to be harvested, or even who will do the harvesting and transport it to the processing plant or packhouse. It may be unclear what grades of pineapple are demanded, what prices will be paid for them, or what becomes of fruit that does not meet export quality standards.

A simple one- or two-page agreement can detail these important elements and serve as the basis for continuing the relationship. The very act of formally signing such an agreement is important in giving "weight" to the deal. This weight may be more social or ethical than legal, but it matters nonetheless, and it provides a basis for the two parties' work together. Accordingly, it is crucial that clear sanctions be applied to any party that does not conform to the signed agreement. Once the linkage is established and valued by all parties, the most severe sanction can be exclusion from future participation.

For many crops, the development of an outgrower production base will attract other buyers, especially for export crops such as pineapple, where numerous exporters vie for the small-farmer production at times when demand outstrips the supply they control. Similarly, in the case of BAT's tobacco production in Indonesia, such schemes attract agents who try to entice small farmers committed to BAT to sell to them for a bigger short-term gain. In Armenia, dairy processing companies and tomato processors compete for the raw materials they need to satisfy their market obligations. In these cases, the larger firm must ensure that the outgrowers in its network are not lured away by other buyers.

In some highly structured traditional cultures, it may be difficult for the larger firm and the outgrower to negotiate as equals and get the results on paper. Very often, however, simply providing a few examples of the mutual benefit that accrues from clear documentation is enough to surmount this obstacle.

Transparent management

Transparency is vital in the linkage relationship. It is not easy to find the right balance between sharing and protecting confidential business information in interactions with linkage partners. Efforts to protect critical information may be construed as secretiveness, raising suspicions. The important principle here is for both parties to make the details of the business they have in common readily available to their partners. The exporter must keep outgrower records current and available for inspection. Outgrowers must also have access to details such as export prices, transport costs, input prices, and foreign transfers. It is equally important that outgrowers be open in their dealings with the lead firm in terms of their use of production inputs, problems encountered during production, or other deals they might be offered.

Development assistance as a linkage catalyst

The value of stable, transparent relationships between small producers and processors or exporters is certainly not universally recognized. In 2002, when I first started talking to Armenian agroprocessors about the need to develop open and comprehensive outgrower contracts with the small farmers they relied on for raw materials, I was told, "This is not necessary in Armenia. I know my suppliers and they will do what I tell them." At the time, small farmers were looking for markets for their produce. Now the situation is reversed: processing capacity has expanded and the processors are competing aggressively for small farmer produce. As early as 2004, we began to see the development of some rudimentary, albeit inadequate, outgrower supply contracts.

Now, some of the companies we worked with in Armenia have asked for assistance in developing a viable outgrower supply network, including arrangements for providing the farmers with production inputs. In the end, it is the economics of the situation that pull the parties together. Our role as development professionals was to represent the "deal" in the negotiations between the two principals. In lending our credibility to the process, we help the parties take the first steps toward crafting a deal that is comfortable for both sides.

Many development projects are designed to create market opportunities for small farmers or entrepreneurs. Linkages to a larger processor provide the means to develop the food safety, traceability, manufacturing, and marketing systems required to be a successful participant in the small enterprise's chosen market. This relationship is certainly not a license to help the rich get richer. Linking up helps those smaller, less powerful, farmers improve their productivity by gaining better access to seasonal credits and other required production inputs. Those same farmers can, when they are ready (and with appropriate assistance), create an association capable of representing their joint interests to processors and others in the industry.

PROMOTING COMPETITION IN A NETWORK INDUSTRY: THE FINANCIAL SECTOR

by Stijn Claessens

Dimensions of competition in financial networks

As in other sectors, competition is expected to drive innovation in financial services, raising both the quality of financial products and the efficiency of their production. Competition also influences access to financial services and external financing for firms and households, thereby advancing economic growth. In fact, making financial systems more open and contestable through lower barriers to entry and exit has generally led to greater product differentiation, more cost-effective financial intermediation, more accessible financial services, and enhanced stability.

Yet excessive competition can undermine financial stability, furnishing the rationale for prudential policies toward banks. Beyond the prudential argument, the case for a competition policy for financial services is also grounded in the growing importance of *network properties* in the production, distribution, and consumption of such services. In production, an example is the creation and use of information networks; in distribution, the use of automatic teller machines (ATMs); and in consumption, the large externalities of stock exchanges and the agglomeration effects in liquidity (greater access to capital improves liquidity for all).

To promote competition in financial markets requires an understanding of the special properties of these markets, in particular the existence of many networks in finance. Competition policy for the financial sector lags behind that for many other sectors, and in many countries is entirely missing from financial sector development strategies, or treated as an afterthought. This paper explores the dual challenges of maintaining stability and encouraging competition in a sector that

Network Industries

Networks consist of complementary nodes and links. Network industries are typically characterized by large fixed costs (building the network) and low marginal costs (adding one more customer).That combination implies increasing returns to scale in production: with a given investment, the average cost per customer (or product) declines as more customers join the network.

However, what really matters are increasing returns to scale in consumption: the more customers (nodes) join the network, the greater the value for each user (until you reach congestion, when value plummets). By joining the network, each customer creates "network externalities"—others benefit from the expansion of the network without having to compensate the new user.

Traditional network industries include railroads, airlines, telephone services, electricity, or broadcasting. The new standard is, of course, the internet. And the role of virtual networks—collections of "compatible goods that share a common technical platform," as Nicholas Economides defines them, such as VHS players, or all computers running Windows—is growing. Common standards are clearly important in network industries.

Ownership of the physical network, or control of the standard, can mean excessive profits and price discrimination. The policy response has therefore always been to regulate and to encourage competition, within the realms of the technologically possible. Stijn Claessens' article looks at the implications of network features in the financial services industry that will pose greater challenges to regulators worldwide, but particularly to regulators in transition economies and developing countries.

For a good summary of the issues, see Economides (2006) or visit www.netinst.org.

exhibits both the physical features of a network (nodes, links, and hubs) and the economic properties of network industries.

What is special about competition in the financial sector? And how does competition matter? In addressing these questions, it is useful to consider three dimensions:

- *Financial sector development:* If the system is more developed, does it provide better financial products or services? Is it more efficient, with lower-cost financial intermediation? And is it closer to some competitive benchmark?
- *Financial sector access:* Does greater competition improve access to financing, particularly for smaller firms and poorer individuals?
- *Financial sector stability:* Does greater competition yield a more stable, less crisis-prone, more robust financial system that maintains its financial integrity?

New challenges for competition policy in financial networks

The evolving financial services industry

Financial services industries are changing rapidly. Driven by the removal of barriers, globalization, a stronger role for nonbank financial institutions, technological progress, and the increased importance of networks, growing competition plays a key role in these changes. Both the United States and the European Union (EU) have achieved large and rapid competitive gains in their financial sectors as a result of deregulation, while enhanced competition has improved financial intermediation. Transition economies and developing countries that opened up their financial sectors—in Central and Eastern Europe and Latin America—also registered gains. Most of these competition policy initiatives relied primarily on traditional means of enhancing competition, such as removing entry barriers or liberalizing product restrictions.

However, progress has been uneven. In 2007, the EU reviewed competition in retail banking and found large variations in merchant and interchange fees for payment card networks, barriers to entry in the markets for payment systems and credit registers, obstacles to customer mobility, and product tying. Over the past decade, many governments have required various retail payments networks initially developed by banks within a nation to be integrated and available to all consumers. Similar measures may be needed today to remove these barriers. Government regulation to mandate a level playing field can be equally necessary in capital markets to ensure fair trading and pricing for small as well as large investors.

Competition itself is also changing, raising new competition policy challenges even in market segments—such as wholesale and capital markets—where competition has been intense and benefits in terms of access and costs have been great. The consolidation of financial services industries, the emergence of global players, the significant investments in information technology and brand names necessary to operate effectively and to gain scale, and the presence of large sunk costs make it difficult to ensure full competition. In turn, unfettered competition without proper regulation and supervision may lead to misuses in this market, and policy measures to foster more effective competition are not easy.

In fact, there is some evidence that the progress in increasing competition may have slowed down since the early 2000s (Bikker and Spierdijk 2007). Causes include increasingly high fixed costs and large sunk costs in the production of wholesale financial services, implying possibly significant first mover and scale advantages. Externalities, say in e-finance in the adoption of payments using mobile phones, can make the adoption of new technologies exhibit critical mass properties. In consumer finance, switching costs may have increased: automatic payments are increasingly linked to one's specific bank account number, for example, so customers cannot and do not easily change providers.

Addressing access barriers

Increased competition can have adverse impacts on access to finance for some classes of borrowers, especially in developing countries and emerging markets. In these countries, institutional weaknesses and higher degrees of inequality may imply higher barriers to access for households and small and medium-sized enterprises (SMEs). Bifurcated markets often prevail: large (international) banks concentrate on large corporations on the one hand, consumers on the other. The "missing middle" segment in that market structure comprises primarily SMEs. The question arises as to whether better information systems and a more flexible contracting environment can bridge the gap between the two market segments and open access for SMEs.

Many countries have made improving competition a priority. But doing so for all types of consumers of financial services has not proven easy. Even in the most developed countries, with sound financial institutions and infrastructures, the degree of effective competition in consumer and retail services still lags that in other financial services segments. While market solutions often more effectively foster competition than government initiatives alone, governments do have a role.

Competition policy for the financial sector is also linked to three objectives important to development practitioners:

- making markets work better for all final consumers (sometimes called "ensuring proper business conduct");
- protecting individual consumers; and
- helping consumers obtain the greatest benefits from financial services provision (for example, through proper information and education), which broadens the concept of consumer protection.

Network barriers to competition

Financial services provision involves the use of an ever greater number of networks, in payments, distribution, and information systems. Network characteristics imply barriers to entry and thereby complicate the application of competition policy:

- Limiting access to the payments system to banks creates network barriers for other financial institutions.
- ATM systems and other distribution networks tend to be limited to banks or only available to nonbank financial institutions at higher costs.
- Access to credit data and other information on borrowers and other clients is often limited to (a subset of) incumbent banks.
- Network externalities, such as the agglomeration effects of liquidity, may occur, especially in capital markets.
- Ownership and governance structures are an issue. In many stock exchanges, derivatives markets, and other formal trading arenas, for example, ownership and governance structures are changing from mutual to for-profit ownership (with fewer owners), creating possible barriers.
- Trends include vertical integration (especially in capital markets, where we see the integration of trading systems with clearing and settlement) and a simultaneous horizontal consolidation in other aspects of the financial services sector.

Each of these features of the sector may entail anticompetitive behavior.

Competition policy is also confronted with the fact that market and product definitions have become more difficult. The increasingly global nature of financial markets may undermine the effectiveness of a competition policy designed for national markets only. On the product side, to take just one example, differences between the markets for pension services (such as company-provided pension plans) and for asset management services (such as 401[k] plans in the United States) are dwindling. Many people can save in both ways and, provided tax rules are harmonized between the two, will do so. And with many nonfinancial institutions providing (near) banking and other financial services, the boundary

between banks and nonbank financial institutions has blurred.

Other network issues can also affect the competitive environment for financial services provision. For example, the competitive structure in the telecommunications market may affect the market for e-finance, as in the case of mobile phone payments.

Implications for competition policy in the financial sector

Three approaches

The need for stability has always posed challenges for policy makers charting competition policy for the financial services industry, and rapid change in the industry only exacerbates those challenges. There are no easy solutions, but effective competition policy generally involves three largely complementary approaches to ensure that:

- entry and exit rules allow for contestable markets in terms of financial institutions;
- the playing field across financial services providers and products is level, thereby enabling effective intrasectoral competition; and
- the institutional environment (for example, payments systems and credit bureaus) is contestable.

The first approach has proven effective and will remain the cornerstone of competition policy in financial as well as other sectors. But in itself it is insufficient to meet new challenges.

Leveling the playing field

The second approach means harmonization among financial services providers (banks, insurance companies, pension funds, asset management, and so on), markets (national, regional, and global), and functionally equivalent types of products offered by banking, insurance, or capital markets providers. Harmonization seeks equal regulatory treatment for products that provide the same functionality. Harmonizing taxes, capital adequacy requirements, transparency and disclosure rules, and so forth across sectors and products improves competition, prevents regulatory arbitrage, and can reduce differences in the net overall regulatory burden borne by products. The emergence of complex financial products that straddle various markets and institutions makes the need for a common regulatory approach all the more pressing.

While regulatory differences across financial providers have diminished, they still exist, often in more subtle form. Some of them may be due to "path dependence"; for example, some products emerged as insurance products but gradually became savings products. Some products are linked to payments systems, which may limit access among providers. Differences may also persist because of linkages with other economic policies, such as preferences for pension products over equivalent savings products. Finally, many financial products are bundled—a checking account may include savings, payments, and credit, for example—making it hard to ensure equal regulatory burdens.

At the same time, differences in regulatory treatment may well be justified on prudential or consumer protection grounds. Efforts to achieve a perfectly level playing field therefore are conceptually and practically difficult. The prevalent current approach, which is largely reactive, thus may have some merit. As producers and consumers are faced with regulatory differences, pressures for harmonization grow.

However, the reactive approach also entails risks: it can trigger a race to the bottom, as the least regulated treatment becomes the norm, and it opens the door to lobbying for favorable treatment. These risks favor a more proactive approach by authorities and competition agencies, but few have opted for it. Even so, agencies could require better data on prices and costs at the level of individual products and make these available to enable users of financial services to make their case.

Ensuring contestability of the institutional environment

An institutional environment is contestable if any interested provider has full access to all inputs in a specific financial service production and distribution chain, including network services such as payments and check systems, or credit bureaus. These inputs should also be fairly and uniformly priced, and efficiently supplied. Such requirements are considered basic in most other network industries where firms are producing and delivering services—telecommunications, energy, or water—using common networks.

Achieving contestability requires the formulation and application of standards, in particular for network compatibility. Standards also avoid coordination problems in firms' technology choices and help consumers forecast whether the specific technology will be widespread. Reduced uncertainty lowers the risk of consumer lock-in and speeds up adoption. In financial services, a good example for this process has been the Society for Worldwide Interbank Financial Telecommunication (SWIFT) protocol for transacting international payments, adopted in 1977.

However, standards may also force users to make a choice, in particular since contracts often rule out joining more than one network. Such provisions can lead to the predominance of a large network, even when more differentiated networks offering greater consumer choices could proliferate. Anticompetitive behavior can then easily follow. Policy makers thus face tradeoffs between promoting critical mass for market development by supporting or promulgating standards, on the one hand, and on the other hand stimulating competition and mitigating the preference for incumbents.

Regulation of networks

Fairly sophisticated competition policies have been adopted for other network industries. For example, to promote fair competition, the ownership or management of the network has often been separated from the provision of services. Access policies and the pricing of network services are frequently subject to government regulatory review. Policy makers, mostly in developed countries, have been able to guarantee access through mechanisms such "universal service obligations," uniform price rules for essential inputs in producing services or key outputs, subsidies, and other incentives. These approaches may also apply to those financial services with large network properties. For example, in payment services, standard uniform pricing rules could facilitate broad access.

Institutional arrangements

Effective competition policy will often require new institutional arrangements. Generally, the body responsible for competition policy should not be responsible for prudential oversight. In many countries, however, responsibility for competition policy still lies with the prudential authority, creating a conflict of interest (Carletti and Hartmann 2002). Better coordination, and preferably consolidation, of competition policy functions—for banking and nonbank financial institutions, for example—is also advisable. Dispersion of functions hinders the buildup of skills necessary for proper competition policy analysis.

Linked to that issue is the question of single versus multiple supervisory agencies. Some countries have moved toward single supervisory authorities, which presumably could reduce unnecessary differences arising from multiple regulatory regimes. Others have charged a single agency with ensuring the systemic stability and prudential oversight of all financial institutions (banking, insurance, and pension funds), but rely on another agency for supervising market conduct. In some instances, the responsibility for systemic stability rests with the central bank, and two separate agencies are supervising prudential and market conduct. Yet other countries, such as the United States, have made no changes and maintain separate and sometimes multiple entities for prudential banking, securities markets, and insurance supervisors.

Are any of these institutional arrangements superior in terms of efficient financial services provision? Research is lacking, and the answers we have remain unclear in any case, given the difficulty of attribution. Even where there is a single supervisory authority, the need for regulatory harmonization across sectors or products may persist. Competitive pressures from both producers and users and their lobbying strength will be most likely to drive harmonization. A more fragmented structure of regulation and supervision may well mean greater progress, since the financial services industries are in a stronger position to argue for regulatory changes, and agencies "compete" with each other for influence.[1]

Harmonization across borders

Financial networks extend beyond borders. Institutional choices in one country may have little relevance for the degree of global harmonization. The challenge of harmonization across markets, already a complex undertaking within countries, will of course be compounded across borders. The EU experience underlines the tenacity needed to create a single market for financial services. Requiring uniformity in regulations—through various directives—is not sufficient. Inconsistencies within and between nations still arise, and adjusting other policy areas takes much time and effort. To give just one typical example: in many developed countries, banks operate across borders without barriers, but liquidity support and lender-of-last-resort facilities are still organized nationally. This state of affairs can lead to inconsistencies in policies for dealing with financial insolvency[2]—inconsistencies with competitive implications. Banks from some countries may have more generous access to the local safety net than banks from other countries.

International standards have begun to shape harmonization across borders. Promulgated by organizations such as the Basel Committee on Banking Supervision, the International Organization of Securities Commissions, the International Association of Insurance Supervisors, and the Committee on Payment and Settlement Systems, these standards form the foundation for a large body of "soft law." Some of these standards are little more than suggestions to achieve a minimum common denominator among existing national requirements, while others actually go beyond existing national requirements (Basel II). Although the standards are voluntary and implementation is left to the countries themselves, some of them can be intrusive. Adapting broad-based, global principles to individual country circumstances within a common framework has proven difficult. Still, these principles will affect the competitive landscape.

Assessing the level of competition

Measures typically used to assess the level (or lack) of competition—such as the Herfindahl index,[3] or concentration indexes of banks or branches within a geographic area—were of limited utility even a few decades ago, and are now even more so given changes in the financial sector. However, the more sophisticated analytical and empirical tools developed for measuring competition in other industries are hard to apply to financial services. The unclear production function for financial services, the tendency to

[1] Obviously, this observation is highly context- and country-dependent, and ignores many other dimensions of the issue. For example, with strong financial institutions and weak regulators, a greater influence of private interests could lead in some countries to lax and low-cost standards, with perhaps greater competitiveness but more risk of financial instability. In other environments, capture of the regulator may lead to rent-seeking by (selected) financial institutions, but with limited risks.

[2] Although liquidity management may be done centrally by the foreign bank in its home country, branches of foreign banks are typically eligible to receive liquidity support from the local host central bank. Should the head bank become insolvent, however, the home country authorities are responsible, which can involve home government resources if the whole bank fails.

[3] The Herfindahl index is an indicator of the amount of competition among firms in an industry. Ranging from 0 to 10,000, it is inversely related to the level of competition.

produce and sell bundles of services, the weakness and volatility of data in the industry, and the presence of network properties greatly complicate the task.

Even in banking, the most traditional financial service for which suitable data are available, tools from the traditional industrial organization literature, such as pass-through coefficients, have proven unwieldy. The difficulty lies largely in the limited number of observations, since most tests require at least 50 bank-year observations. Since the number of banks with good financial information is small in many markets, especially developing countries, comparing the degree of competition over time is tricky. Using data from a larger sample of countries, such as the EU 15, creates other difficulties, such as data comparability.

Network features also give rise to special competition policy issues. In all payment cards markets, for example, two-sided networks effects exist, since larger point-of-service networks are more valuable to both cardholders and merchants. This leads to complex measurement issues, for which the credit card industries provide an interesting example.

Credit cards can be issued by different financial institutions under a common brand name (Visa and MasterCard make up 85 percent of the market). Or they can be closed, proprietary systems, such as American Express. Payment card associations are self-regulating organizations, providing the necessary infrastructure for transactions and interconnection and common operating rules. Visa and MasterCard, which also have some shared governance through common memberships, used to require exclusivity; that is, members could not join rival networks. This barrier to competition was declared illegal in the EU, and in the United States the courts have forced the major credit companies to allow banks to offer competing credit cards.[4] The protracted process of showing some degree of collusion in the credit card industries, however, highlights the empirical and conceptual problems of measuring competition in network-type services.

While the problems involved in assessing competition and devising policy responses remain daunting, they are not insurmountable. Focusing on price setting for specific products or financial functions—what are the fees charged for consumer retail products or for processing individual pension premiums or payments?—can provide insights into the competitive structure. The competitive structure is also reflected in the pricing and availability of inputs necessary to produce financial services. Do all types of financial institutions have access on the same basis to the retail payments system? Again, this type of information should be better disclosed such that users can act on it.

Conclusions

Competition policy in the financial sector is still in its infancy, partly due to the lack of adequate measurement and analysis of competition. Much of the current literature assesses performance relative to financial system structures and regulatory regimes, but provides no formal measures of the level of competition. And traditional measures may be misleading. For example, banking system concentration may not affect competitiveness. Systems with greater foreign bank entry and with fewer entry and activity restrictions tend to be more competitive, confirming that *contestability*

[4] Pindyck (2007) discusses the antitrust suit brought by the U.S. Department of Justice against Visa and MasterCard in 1998.

determines effective competition. The contestability view of competition is, however, not the one typically applied.

Beyond documenting the degree of competition, there are many other challenges and open questions in this area. Foremost are the tradeoffs between financial system performance, access to finance, stability, and growth. These tradeoffs pose both theoretical issues and empirical challenges. Yet a more rigorous application of competition policies to financial services industries is needed. While adaptations are necessary, much can learned from policies already standard in many other industries, especially network industries. Authorities can also greatly enhance the availability of data so that users will have the information needed to assess the costs of different financial services. Finally, the rapid pace of change in financial services industries implies a need to remain agile and adjust competition policies and procedures over time.

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SPACE, THE FINAL FRONTIER? HOW GEOSOCIAL NETWORKING CAN HELP TARGET DEVELOPMENT INTERVENTIONS

by Robert Bouvier, Ioana Bouvier, Erin Goodnough, and Andrew Ross

Space in development thinking

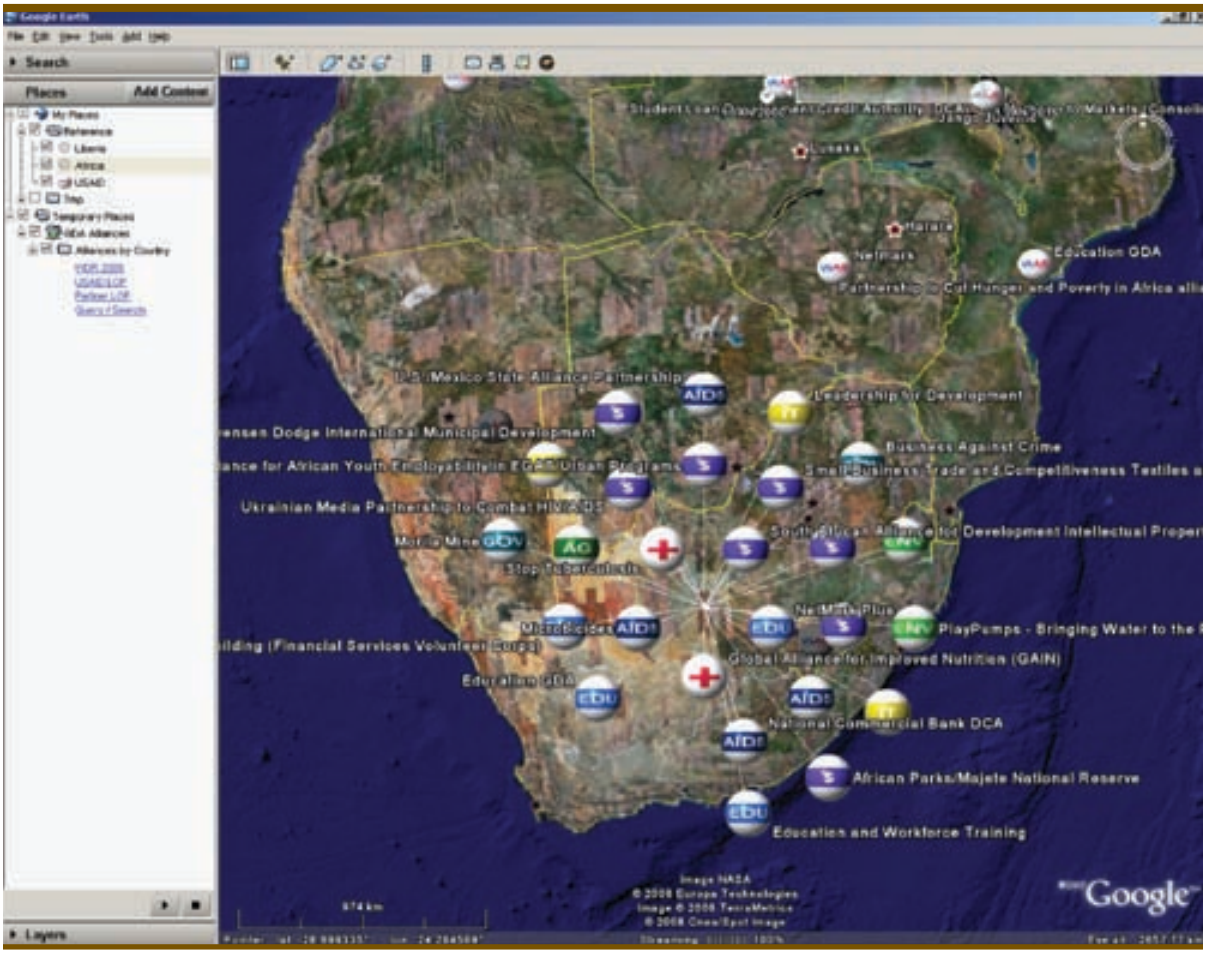
The seminal thinkers in economics were fully aware that growth is not something abstract, but a phenomenon tied to a place. In the 1890s, Alfred Marshall explored the implications of location for stimulating technological progress. (The renaissance of Marshall's "industrial districts" as Michael Porter's "economic clusters" in 1990 took just about a century.) Yet the early writings on economic development in the 1960s, 1970s, and 1980s seemed—as a rule—to downplay its spatial dimension. For example, the index of W.W. Rostow's 1990 history, *Theories of Economic Growth from David Hume to the Present*, has no entry for "space" or "location." It was left primarily to economic geographers, such as Johann Heinrich von Thünen in the early 19th century or Alfred Weber in the early 20th, to worry about the spatial distribution of economic activity. Today, much of the relevant theoretical and empirical work remains the domain of economic geography.

Yet since the early 1990s, economists have begun to catch up. In a 1998 paper for the World Bank, Paul Krugman reviewed the work that economists had done in the 1990s on the role of geography in development. Reacting in part to continuing inequality in the face of increasing globalization, other leading economists such as Jeffrey Sachs and his colleagues—in a 2001 article in *Scientific American*—reaffirmed that "geography matters." These insights have found their way into formal economics. As an example of a broader philosophical view, Jared Diamond's 2005 opus *Guns, Germs, and Steel*, discussed by Hidalgo and Hausmann in this volume, relies heavily on the spatial dimension in its analysis of long-term development patterns. While some observers have proclaimed the "death of distance" (Cairncross 1997), geographic proximity remains an important factor in economic development—and it is now being reinforced by the power of "Web 2.0," as this article explores.

At the same time as "space" is making a comeback in development thinking, web-networking is becoming a fixture in the development community. Connecting the actors in a geographically defined development community around a given topic has proven beneficial for promoting local economic growth, improving emergency preparedness and response, and advancing overarching development goals. Early networking applications, relying on more traditional means of communications, included the kind of early warning systems that prevent local food shortages from escalating into regional famines. Agencies, individual and collective stakeholders, small businesses, financial institutions, and investors can all contribute to and gain from creating and strengthening networks with a particular mission, whether it is a business initiative, access to social services, or policy innovations. Advances in communications and web technologies are enabling connections within such social networks and creating new opportunities at the intersection of business and development objectives. To take just one hypothetical example, imagine a community planning to establish an ecolodge, looking for a potential investor, and posting its business plan in a social network group focused on ecotourism.

An increasingly "open" network presents almost endless possibilities for leveraging social networking advances in development initiatives. This article will address a specialized form of social networking that connects people by introducing a new dimension, space. Understanding where the various actors are located in the biophysical and

FIGURE 1. MAPPING USAID'S GLOBAL DEVELOPMENT ALLIANCES



DAI's evolving geographic data presentation and analytical innovations have been recently described by the U.S. Agency for International Development (USAID) Administrator's Office as a "clear, complete, and concise way of bringing the field to the desktop."

socioeconomic landscapes is critical to assessing available resources, managing logistics, and coordinating responses. This approach involves a new and evolving form of creating human linkages called geosocial networking.

Digital Earth: from vision to (virtual) reality

The development of geographically based networking applications has simultaneously encouraged and been encouraged by the expanding availability of maps and geographic information. Remotely sensed data, including high-resolution satellite images, provide a planning framework even in the remotest areas. And expanding telecommunications links offer the means to share location-specific information widely and quickly. The vision of a "Digital Earth"—the notion that we can see our planet at any given level of detail in virtual reality—gained traction in the 1990s (see textbox). Since then, these visualization concepts have become all but commonplace, manifested in two-dimensional applications such as MapQuest®, Yahoo! Maps®, or Google Maps™, and three-dimensional or "spinning globe" applications such as Google Earth™, Microsoft®Virtual Earth™, and NASA World Wind. All of these tools

have exciting potential as "virtual" conduits for linking communities across the globe.[1]

However, the availability of location-specific information varies greatly. We may be able to see huts in the remotest corners of the world, but we rarely have good information on who is living there or what they do, let alone data on, say, their access to social services. In terms of economic development, for example, we would want to know whether adequate precursor services (transportation, utilities, capital, and other production inputs) are readily available at competitive prices. What are the unused resources for nontraditional crops, such as nontimber forest products, or attractions for ecotourism? For many of the areas where gains in prosperity—economic and social—are most urgently needed, this kind of information is sorely lacking. But new approaches and technologies are coming to the rescue by creating networks that generate, use, and share information. Importantly, people living in the targeted regions become partners in these endeavors.

"Imagine, for example, a young child going to a Digital Earth exhibit at a local museum. After donning a head-mounted display, she sees Earth as it appears from space. Using a data glove, she zooms in, using higher and higher levels of resolution, to see continents, then regions, countries, cities, and finally individual houses, trees, and other natural and man-made objects. Having found an area of the planet she is interested in exploring, she takes the equivalent of a "magic carpet ride" through a 3-D visualization of the terrain. Of course, terrain is only one of the many kinds of data with which she can interact. Using the systems' voice recognition capabilities, she is able to request information on land cover, distribution of plant and animal species, real-time weather, roads, political boundaries, and population. She can also visualize the environmental information that she and other students all over the world have collected as part of the GLOBE project. This information can be seamlessly fused with the digital map or terrain data. She can get more information on many of the objects she sees by using her data glove to click on a hyperlink. To prepare for her family's vacation to Yellowstone National Park, for example, she plans the perfect hike to the geysers, bison, and bighorn sheep that she has just read about. In fact, she can follow the trail visually from start to finish before she ever leaves the museum in her hometown."

–Vice President Al Gore, in a speech at the California Science Center, Los Angeles, California, January 31, 1998

FIGURE 2. THE GLOBAL CONNECTION PROJECT

National Geographic photographs displayed in Google Earth™ as part of the Global Connection Project, a joint program between NASA, Carnegie Mellon University, *National Geographic*, and Google.

The rise of geosocial networking

Rapid advances in hardware and software have turned the internet into a truly interactive forum for exchanging information and organizing for action. The rise of the social web—Web 2.0—is a striking phenomenon. It represents a combination of tools that people can use to connect with each other, establish relationships, and access practical information about their community, a research topic, an event, a business initiative, or whatever takes their fancy. The tools underlying the social

[1] Reference in these materials to any specific commercial products, processes, or services, or the use of any trade, firm, or corporation name is for information purposes only and should not be construed as an endorsement, recommendation, or other such agreement between DAI and another party.

web are constantly growing and include blogs, podcasts, wikis, RSS feeds, and mapping applications. The social web movement is expected to grow at a remarkable speed in the next few years.

The wide availability of digital maps, combined with the expanding role such maps play in consumer consciousness, is multiplying opportunities for what we are here calling geosocial networks, with an emphasis on "geo." Simply put, Web 2.0 participants are increasingly aware that geography plays an important role in social networking. While modern telecommunications ostensibly bridge geographic distance, spatial awareness adds a new dimension to social networks by connecting people and resources in a virtual world. A slew of new software—Loopt, Helio, GyPSii, and the list is growing—allows subscribers to find their friends on a phone-displayed digital map and instantly network with them. They can exchange information on sights, restaurants, and events—place by place. And if they happen to be close by, they can arrange to meet.

The creation of personalized (group) maps through geosocial networking is not a new concept. Collaborative mapping has been around since the advent of maps themselves. What is new is the amazing array of information the geo-web can incorporate and make available in organized and searchable form. The import of these developments goes way beyond finding a friend and arranging a lunch, or the ability to track potential customers and offer "location-based services." The participatory nature of geosocial networks helps to ensure, on a global scale, the free flow of ideas.

Inside a geosocial network, maps and associated information, consumer content, photos, videos, news, and links to resources can provide consumers with extraordinary insight into an event occurring at a given location. Evolving digital mapping platforms allow users to contribute their knowledge about a specific event or phenomenon, helping to establish a community of local and international actors who can synthesize available information to establish connections, forge partnerships, or simply make better informed decisions. Location-based social networks already allow for neighborhood searches, connecting people to services and other people. The "Information Commons" from Maya/Rhiza Labs, for example, is used with great success to identify local human services (Allegheny County, PA, http://www.humanservices.net). Some geosocial networking applications use remotely sensed data to track phenomena of interest on a spatial basis, using information supplied by volunteers. A prime example is a disaster prediction application that relies on a volunteer network to obtain georeferenced data on seismic activity through GeoRSS.[2]

Tools for development: practical examples for the geo-web

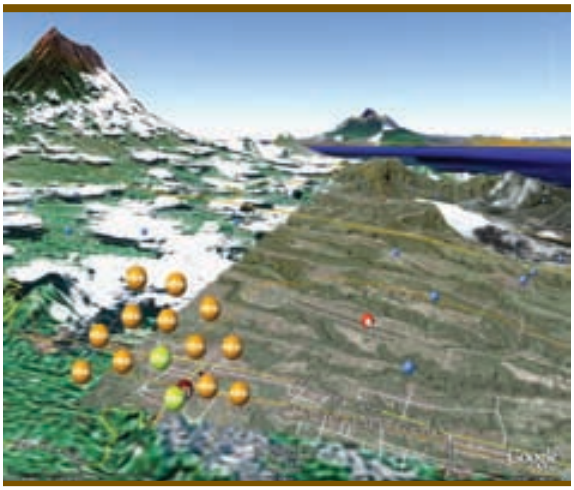
Though still maturing, the geo-web for development is already here. The U.S. Agency for International Development (USAID) Office of Global Development Alliances (GDA)—whose mission is to mobilize governments, businesses, and civil society for development by forging public-private alliances—is using geospatial tools to identify its current public-private partnerships geographically (Figure 1). Developed by DAI, this tool will enable USAID mission staff, GDA/Washington staff, and private partners around the world to access partnership information by sector or geographical region. In this instance, geosocial networking is providing a platform for USAID mission staff and potential alliance partners to connect with the GDA and to gain insight into what companies, agencies, and services are associated with specific business interests at a given location. Digital mapping allows for the integration of thematic data layers, when such data are available. Depending on the availability and

[2] See www.georss.org and the website of the Open Geospatial Consortium (www.www.opengeospatial.org) for additional insight into the advances made in collecting and processing development-relevant information through geosocial networks.

accuracy of the data provided by the geosocial network, missions could evaluate potential business opportunities as they relate to the existing physical infrastructure—roads, schools, and so on—or perhaps to the human and environmental resources for a specified location.

In Indonesia, USAID's Community-Based Avian Influenza Control Project is employing geosocial networking in a different context: avian influenza surveillance and rapid outbreak response. DAI has designed a prototype platform for sharing critical, time-sensitive information within the local avian influenza community of practice. A unique aspect of this platform is its ability to integrate tabular information from various partner data sources that typically use different data management standards. Disparate data resources can be linked and visually displayed based on proximity to a specific geo-located event, such as an animal or human avian influenza outbreak. This form of geosocial networking allows professionals to interact using a virtual globe, fostering coordination among local responders and enabling the exchange of news and advice from other professionals in remote locations.

FIGURE 3. AVIAN INFLUENZA PREPAREDNESS



An example showing available human resources (orange dots represent zoonotic disease experts) located within 5 miles of an outbreak (red dot).

In Southern Africa, researchers, developers, and natural resource management practitioners are using a geospatial platform to share experiences related to the changing landscape of Malawi. USAID/Malawi's Community Partnerships for Sustainable Resource Management, implemented by DAI, is examining changes in the distribution of miombo woodlands to better plan conservation and related management initiatives. See http://gis.daiglobal.net/innovation.

The future of geosocial networking

Geosocial networking has the potential to provide multiscaled economic development and environmental conservation benefits. It is likely, for example, that philanthropically oriented geosocial networks will spin out of local focus groups and communities, as group interaction engages and informs a broader global response to local issues via global technology platforms. In such cases, real-time information delivery systems linked to local communities of practice not only buy precious response time—they offer a dynamic and interactive mass medium that will shape the message and the movement for development.

A geosocial network called Echo myPlace, developed by the Carbon Project, with some sup-port from the National Science Foundation, offers a promising glimpse into the future of geosocial networks. Echo myPlace is described as a free, real-time social networking application that combines two- and three-dimensional mapping (the Microsoft Virtual Earth globe or map) with a people-to-people (or peer-to-peer) network of friends. It will allow users to create virtual neighborhoods, share information tied to particular locations, or reach customers, without going through a central server. The Carbon Project has worked with the OneVillage Foundation to launch a project called "ICT4D sustainability for indigenous peoples" to leverage geospatial networks for creating "place-

FIGURE 4. ECHO MYPLACE, A GEOSOCIAL NETWORKING APPLICATION

based open digital villages" built around local knowledge bases (Figure 4).

It is far from fanciful to imagine a "Digital Earth" encompassing geosocial networking and associated information resources, and made available on mobile phones, which are crucial to the developing world, given the relative lack of landline infrastructure. Network members in turn may contribute relevant content such as time-sensitive information, contextual data, and/or spatial data layers. As development practitioners, we have only begun to scratch the surface of what can be done with this capability.

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SOCIAL NETWORKS AND DEMOCRATIC TRANSITIONS

by Joseph Siegle

Transitions without social networks

Belarus rarely comes to mind when one thinks of pioneers in the global democracy movement. Yet as the Soviet Union drifted toward dissolution, Belarus was poised to emerge as one of Eastern Europe's first democratic states. Opposition political parties had formed in the late 1980s under *glasnost* and had begun challenging the ruling Belarusian Communist Party. After Communist Party leaders were discredited and forced to resign for supporting the failed *putsch* in Moscow in August 1991, opposition leader Stanislav Shushkevich was elected president of the parliament and head of state in September. He proceeded to lead Belarus on a path of political openness, respect for civil liberties, and market-oriented economic reform.

As with other post-socialist transitions, Belarus endured a sharp economic contraction, steep inflation, and botched privatization. The former Communist Party capitalized on popular grievances to charge the Shushkevich government with corruption and agitate for closer ties to Moscow. Lacking a unified democratic coalition and cohesive civil society networks that could counter this rearguard action, Shushkevich was politically isolated and forced from office in January 1994. Six months later, Alexander Lukashenko was elected president. He reinstituted price controls, renationalized key segments of the economy, shuttered independent newspapers, and overrode separations of power established for the parliament and Central Bank. Domestic intelligence agencies were reconstituted and civil liberties repressed. Two badly flawed presidential elections later, social networks remain fragmented and Lukashenko—widely regarded as "Europe's last dictator"—retains power to this day.

"Colored revolutions": the promise and shortcomings of nascent social networks

In the late 1990s and early 2000s, democracy advocates in Georgia, Serbia, Ukraine, and to a lesser extent Kyrgyzstan invested considerable effort developing *networks* for political reform, drawing on the experience and support of established democracies. Building in part on the lessons of the successful resistance to the Communist regime in East Germany—which culminated in the collapse of the Berlin Wall—these networks relied on principles and techniques of nonviolent protest popularized by the "Clausewitz of nonviolent warfare," Gene Sharp. Organizationally, these movements reflected a network-centric approach that eschewed centralized structures and offered a tactical flexibility and maneuverability that helped cope with attempts to repress activities.

The prototype of these opposition networks was Otpor, which played a key role in the "Bulldozer Revolution" that brought about the downfall of Slobodan Milošević's regime in Serbia on October 5, 2000. Otpor, a group of reform-minded young people, claimed 100,000 registered members. Western support ranged from the strategic (internal organization and communications structure) to the mundane (cans of spray paint). While Serbia's 2000 revolution was not "colored" (it claimed the moniker of the Bulldozer Revolution after one of the more memorable episodes from a day-long protest in which bulldozer operator Ljubisav Đokić, nicknamed Joe, fired up his engine and charged the building of Serbia's state television), it offered a new, effective approach to organizing democratic resistance. In the years that followed, similar scenarios played out in Georgia (Kmara, the Rose Revolution), Ukraine (Pora, the Orange

Revolution) and Kyrgyzstan (KelKel, the Tulip Revolution).

The democratic road is frequently a rocky one, though, especially in places where democratic norms and civil society networks are still emerging. The aftermaths to the colored revolutions have been no exception. The assassination of Prime Minister Zoran Đinđić in March 2003 by an unrepentant gunman with ties to the Milošević regime dealt a serious setback to the reform process in Serbia. In Georgia, Mikhail Saakashvili, after winning 96 percent of the presidential vote in 2004 following the Rose Revolution, embarked on vigorous reforms. But the pace soon slackened. By November 2007, tens of thousands of protesters had gathered in central Tbilisi to demand his resignation. He responded with tear gas, a state of emergency, and a media blackout. In Ukraine, the two most prominent leaders and former allies of the Orange Revolution have been locked in an increasingly acrimonious battle for power that has helped fuel a resurgent Communist Party. Kyrgyzstan's Tulip Revolution served notice to Central Asia's leaders that change was in the air, but early enthusiasm soon gave way to political infighting.

Solidarność: the power of a resilient social network

Poland's experience reflects another perspective from the spectrum of democratic transitions. In response to the crushing of workers' strikes in 1976, opponents of Communist Party rule established the Workers' Defense Committee to help those repressed by the government.[1] To advance this effort, an underground press was created, helping to carve out the first independent public space of the modern Polish era. This precedent inspired the formation of other independent organizations, with highly differentiated agendas and geographic coverage. Citizen participation and engagement grew steadily—resulting in an array of political and economic networks that helped organize the population and pressure the government for reform. It was from this backdrop that the Solidarity movement emerged and was officially recognized in 1980.

Intent on reversing this new independent force, General Wojciech Jaruzelski, leader of the military government, declared martial law in December 1981. Thousands were arrested and an estimated 100 people were killed. A curfew was instituted, independent organizations were banned, and media and educational institutions were closed or censored. On the face of it, Jaruzelski's gambit had paid off: Solidarity was banned and could no longer play an official role.

Yet Poland's invigorated civil society networks did not wilt. Instead, they continued their struggle for independence by maintaining a broad underground movement. While the government controlled the official sphere, Solidarity remained the legitimate voice of most Poles. This stalemate continued until 1988, when deteriorating economic conditions—coupled with the opening presented by *glasnost*—led the government to compromise with Solidarity and avoid renewed working class unrest. As part of the deal, Solidarity and other independent movements were relegalized, opposition parties were able to contest some seats in upcoming parliamentary elections, and civil society was allowed to operate freely. The decisive triumph of independent candidates in June 1989 led to a Solidarity-led coalition government and the establishment of parliamentary democracy. Four presidential elections later, Poland has doubled its per capita income and is a member in good standing in the European Union and NATO.

[1] For a more detailed background of Poland's transition, see Michael Bernhard (1993).

Social networks in transition

There are many reasons why some countries experience smoother democratic transitions than others. However, as the experiences outlined above illustrate, one important distinguishing feature is quality of social networks. These networks provide the resilient institutional sinew that holds a reform movement together through the challenges and pushback that inevitably are encountered. Indeed, the relative depth of formal and informal social networks is demonstrably instrumental in the relatively successful democratic transitions of the Baltic states, Benin, Chile, Mongolia, South Africa, and Central Europe more generally. By contrast, the comparative scarcity of robust social networks is one of the factors underlying the faltering experiences of Armenia, Ecuador, Haiti, Ivory Coast, Pakistan, Russia, and Central Asia, among others.

And pushback is a common feature of democratic transitions. Fifty-five percent of all contemporary democratizers have experienced at least one episode of backsliding. A third of these revert, at least temporarily, to autocracy—and the associated higher probabilities of conflict, underdevelopment, and humanitarian crisis.[2] While the process of political transformation is inevitably bumpy, understanding the factors that contribute to more successful democratic transitions can help reduce significant hardship. Understanding how to cultivate resilient social networks in countries with an authoritarian past (or present) is therefore a top priority.

Why democratic networks matter

Networks help overcome collective action challenges

An early hurdle democratic reformers face is overcoming the "challenge of collective action." In autocracies, a small minority monopolizes the key levers of influence—the military, media, financial resources of the state, and key party posts—to the detriment of the majority. The imbalance persists because those that benefit are small in number, easy to organize, and clear about what they would lose by a more inclusive governing structure. In contrast, the disadvantaged majority is geographically dispersed, difficult to organize, and poorly informed. Moreover, individuals face real risks in bucking the system, which they must weigh against the uncertain benefits they would realize from greater pluralism. The result is an increasingly entrenched elite minority with ever greater resources to maintain their hold on power. Overcoming this imbalance requires organizing and educating this majority, then mobilizing it for collective action. Establishing networks of associations, civic groups, chambers of commerce, labor unions, and other citizen groups can do just that. Networks build connections among numerous individuals and small groups, greatly accelerating access to information. This information, in turn, empowers individuals by ending their isolation and showing that their grievances are widely shared.

Network-centric citizen groups, especially given the power of "Web 2.0," can play a major role in building collective action. Such groups connect like-minded people, link the individual to a broader national or global issue, and harness these individual aspirations to a focused plan of action around which the populace can rally. Moreover, exposure to a network's pluralistic governing structure and the sense of ownership that comes from subscribing to a larger cause are powerful and enduring forces for greater political participation. Networks simultaneously limit the need for centralized direction and allow for maximum flexibility in the pursuit of reforms. In so doing, they spread the risk any one person faces while increasing the resiliency of a reform movement.

[2] Notably, 75 percent of democratizers that experience these reversals regain their democratic trajectory within three years (Halperin, Siegle, and Weinstein 2009).

Social networks build trust

Democracies rely on trust to a greater extent than do other systems of government. Citizens must have sufficient confidence in the integrity and regularity of an electoral process, for example, if they are to wait until the allotted time on the electoral calendar to replace unresponsive or ineffective leaders through the ballot box. Where these conditions do not hold, citizens grow alienated and disillusioned with the democratic process. Similarly, realizing that they must be perceived as legitimate if they are to govern, democratic leaders rely on citizens to support them when they pursue policies aligned with the interests of the majority and to participate in the civic institutions on which democracy depends. At its core, then, democracy is a series of compacts, based on trust, between citizens and their leaders.

Participation in networks helps build trust. It develops mutually rewarding relationships between individuals—bonds that increase confidence in and commitment to a society. Horizontal networks allow citizens from different geographic areas, ethnic groups, income classes, or political persuasions to come together around shared interests. The cross-group linkages created in this process are enormously important for building a shared national identity. In this way, social networks are the ties that bind a society together. Importantly, not all associations build trust: they may pursue parochial or criminal interests and be organized internally on nondemocratic lines. Examples include the Ku Klux Klan, the mafia, extralegal paramilitary associations, or financial pyramid schemes.

Creating strong societal networks in pre-democratic societies often requires moving past citizen fear of participation and taking initiative. Surveillance and government informants have taught citizens to be wary of what they share. As the writings of Robert Putnam and others have shown, however, (re)building these social networks is critical to long-term societal health and prosperity. Nations with stronger social cohesion tend to be more stable, better off economically, less susceptible to crime and violence, and subject to lower levels of corruption (Putnam 1993).

Networks ensure accountability

Networks are not dominated by a single person or group but require buy-in from many individuals and organizations. Power is typically diffused and leadership is subject to checks and balances. Because leaders must secure the approval and support of their constituencies, they have incentives to pursue the collective interest rather than a narrow personal agenda. Accountability, in turn, has a moderating effect on the priorities of a political movement, mitigating tendencies toward radicalism.

Access to information is an indispensable feature of accountability. Information aids transparency and allows individuals to assess how well leaders are doing their jobs. Members of a network are more likely to be well-informed and able to incorporate rapidly evolving developments into their decision making—and adapt accordingly. This suppleness and the relative autonomy of each individual or group in a network make networks ideal organizational structures during times of transition.

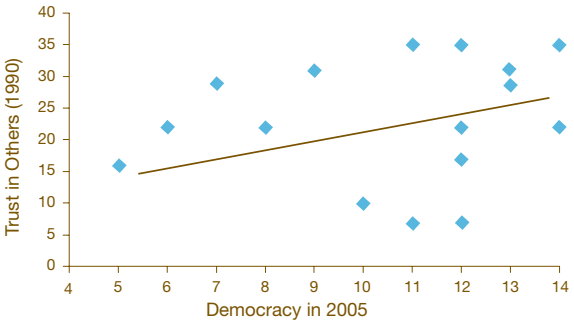
Social networks not only ensure open information flows within a society but also allow members to benefit more readily from the transfer of knowledge, experience, and resources from outside the country. Better access to information helps offset the advantages of the entrenched power structures. Linkages to the outside world also raise awareness of repression—introducing another potentially powerful lever for change. External attention, moreover, constrains the abuses that an autocratic government might want to exert to hold power in the face of an increasingly galvanized opposition. Conversely, ignorance about what is happening in a distant country often blunts concerted international pressure. That is why dictatorships in Zimbabwe and Burma have banned most international visitors, especially the media.

Some lessons learned

Examining the relationship between the existence of networks and democracy is difficult because of the paucity of comparable cross-national data on associations. Defining associations and accounting for differences among them present vexing challenges. One common proxy for the richness of associational life in a society is degree of trust. Citizens in societies with higher levels of trust are more likely to participate in and join associations of various types. Launched in 1981, the World Values Survey now covers 80 countries and some 80,000 people—capturing information on personal values, attitudes, participation in associations, and trust via some 200 questions. These data allow for an analysis of the relationship between trust and democracy, the latter being defined by the Freedom House democracy index.

The relationship between depth of societal trust and subsequent successful democratization appears reasonably strong (see Figure 1).[3] Controlling for income, democratizing societies that had higher levels of trust in 1990 have attained significantly stronger democracy scores, on average, in 2005. For example, Bulgaria, Mexico, Poland, and South Korea all scored in the top quartile on the rankings for trust in 1990. They each subsequently scored in the top 10 percent of the Freedom House index in 2005. Conversely, democratizers such as Brazil, Romania, and Turkey scored below the median on the trust scale in 1990, and rank in a lower democracy tier 15 years later.

FIGURE 1. RELATIONSHIP BETWEEN SOCIETAL TRUST IN DEMOCRATIZERS AND SUBSEQUENT LEVEL OF DEMOCRACY



Sources: World Values Survey; Freedom House

This pattern corresponds to the close links between the richness of associational life and the quality and durability of democracy across provincial governments in Italy famously documented by Robert Putnam. Controlling for income, citizens in northern Italy have tended to participate in voluntary membership organizations at much higher rates than citizens in southern Italy. These organizations were typically recreational and cultural groups, such as soccer clubs, choral societies, hiking clubs, literary circles, and Lions Clubs. Communities with higher association participation also had higher rates of newspaper readership—another indicator of information access and engagement in community affairs. The institutional performance of regional governments in provinces with a richer associational life was far superior—as defined by greater stability among cabinet ministers, more timely approvals of annual budgets, and more extensive and responsive service delivery in day care centers, health clinics, or agricultural loans. Associational density was a far better predictor of institutional performance than other commonly cited explanations for good governance such as social stability, education, urbanization, personnel stability, or political party. Citizens in northern provinces were also far more satisfied with their local governments; they had more direct contact with their local government representative and these discussions tended to focus on issues of public interest rather than on requests for personal help (for licenses, jobs, and so on).

Contacts between politicians and citizens in southern Italy, in contrast, tended to be more typical of client-patron relationships. Predictably, citizens in less associationally rich communi-

[3] Democracy is measured using the Freedom House *Annual Survey of Political Rights and Civil Liberties*. The Freedom House index generates an annual rating between 2 and 14 for every country in the world.

ties reported feeling more exploited, alienated, dependent, and powerless than their compatriots elsewhere.

The notion that societies with better integrated social networks generate superior economic outcomes is supported in other research. In a study of 121 rural water projects, Deepa Narayan found that villages in which inhabitants, on average, participated in two or more associations had far higher project performance—as well as lower levels of infant mortality, better childhood school attendance, and higher per capita income levels (Narayan 2002, 1997). Similarly, a study of the effective management of smallholder agricultural irrigation schemes—a notoriously difficult coordination challenge often involving hundreds of disparate households with incentives for diversions and free ridership—found that strength of associations is the most critical element to their success and sustainability (Ostrom 1997). Associations that set out clear rules for coordination—allocating benefits and responsibility for paying costs—and credibly commit members to a sequence of future actions are far more productive. Crafting associational rules that create incentives for reciprocity ensures ongoing investments in social capital and favors the durability of the irrigation scheme.

Implications

Countries embarking down the democratic path do not begin from the same starting point. Nations with crosscutting social networks are much better placed to quickly exchange information across a large number of people, overcome collective action disadvantages, and adopt institutions of oversight and accountability that will facilitate successful democratic transitions. Understanding the depth of horizontal networks in a society undergoing a transition, accordingly, is a priority for targeting external assistance. In societies that are starting from a strong base of societal cohesion, relatively greater emphasis can be given to strengthening the existing public institutions. In societies that lack these networks, a top priority is to create them.

Recognizing that network promotion is a medium- to long-term endeavor and something the society itself must own, external actors can encourage this process via projects that provide incentives for inter-group collaboration and redress practices of societal fragmentation. Initiatives may include national service projects that integrate youth from all segments of society, media expansion and training, social marketing and educational campaigns, external study tours to societies known for their strong social cohesion, leadership training for national leaders and youth inculcating norms of public spiritedness and inclusiveness, coalition building, and development of local chapters of membership organizations, to name a few possibilities.

This review does not suggest that democratization should wait until a society has a dense network of associations. Weak societal networks are frequently the symptom of years of autocratic governance that has purposely restricted independent voices. Societal trust will have a hard time emerging in societies where citizens fear their neighbors may be government informants. In these cases, the focus should be on creating an enabling environment for network development that reformers can seize when democratic openings emerge—as occurred in Poland or in the early days of the colored revolutions. Recognizing that democratization and network development will be iterative in these contexts should also help adjust expectations for what will likely be a long transition, subject to persistent pushback.

Initiatives to stimulate and strengthen societal networks are a strategic investment in pre-democratic societies. These networks represent a valuable resource in themselves, contributing to improved levels of well-being and social harmony. They also build the norms, skills, and organizing capacity that can challenge political monopolies and facilitate more successful democratic transi-

tions. Importantly, membership associations of many types, and not just overtly political organizations, contribute to enhancing information exchange, social organizing, and citizen self-initiative—critical ingredients for reform, particularly in societies where political activities are prohibited and the democratic process is starting from a very low point. Building social networks is also relevant for societies starting down the democratic path without a deep tradition of associational life, since these societies are more likely to experience backtracking. Investing in social networks in these contexts expands opportunities for successful democratic transitions in the short term and, perhaps more critically, for sustaining them over the long term.

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NETWORK CONCEPTS IN FIGHTING THE SPREAD OF INFECTIOUS DISEASE

by Ulrich F.W. Ernst

A tale of three brothers

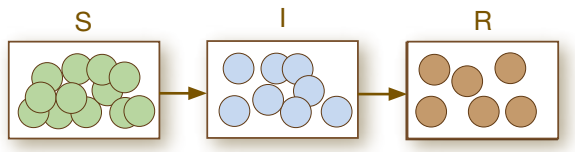
One of the few documented cases of human-to-human infection of avian influenza involved three brothers in Pakistan. Following an outbreak of the disease among chickens, one of the three participated in a large-scale bird cull. Through that work, he was infected with the H5N1 virus and became ill. He was living with his brother, who took care of him until he died. During this period, the highly pathogenic avian influenza virus made the leap from human to human, infecting the caretaker. Yet neither brother had been positively diagnosed as suffering from avian influenza. The third brother was living in New York. When the first brother died and the second fell ill, he flew to Pakistan to take care of the latter, but to no avail: the second brother died as well. The third brother buried him, and flew back to New York.

Fortunately, the surviving brother did not get infected—the receptors on the H5N1 virus do not readily attach to human lung tissue. Even so, it is frightening how close we came to a potential epidemic in a major population center. In fact, the tale of the three brothers is a perfect illustration of the "small world" phenomenon. A weak link—the third brother living in New York—connected the local disease cluster in Pakistan to a social network in the United States. And while the people in New York were spared, the consequences could have been catastrophic.

From compartmental models to contact network epidemiology

Testing out disease control strategies involves virtual experiments, partly because controlled experiments to assess the efficacy of different approaches tend to be impossible on a large scale. Mathematical modeling has therefore been a powerful tool in assessing alternative interventions to fight the spread of contagious diseases.

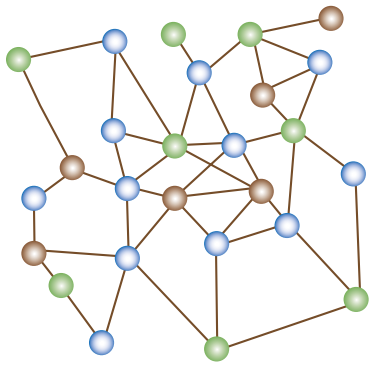
FIGURE 1. THE COMPARTMENTAL MODEL



An early approach to such analysis was the compartmental model, which linked susceptibles (S), infectives (I), and the recovered (or removed, R). The compartmental model can be sketched as shown in Figure 1. Basically, this SIR model allows only two transitions, from S to I and from I to R. In an extension of the model, there may also be a path from R to S; for example, flu and common cold viruses undergo rapid evolution enabling them to evade the immune system, such that an R almost immediately converts back into an S. Epidemiological studies (and simulations) assumed that contacts between the S and I group are random, with a given probability, according to a discrete (Poisson) distribution.

A major element in the mathematical analysis of disease spread using the compartmental model is the basic reproductive rate, R_0, which measures the number of secondary infections produced by a single infected host. If R_0 is greater than 1, an infected host will transmit the disease to at least one susceptible. Initial studies of the spread of severe acute respiratory syndrome (SARS) estimated the basic reproductive rate to be between 2.2 and 3.6. In spite of that high estimate, SARS never materialized as a global pandemic. In fact, in China alone, with an R_0 at that level, the first four months should have produced somewhere

FIGURE 2. CONTACT NETWORK



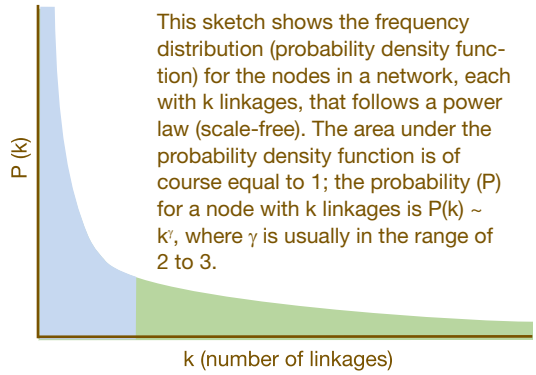
between 30,000 and 10 million cases; the country ultimately reported only 782 cases.

What went wrong with this prediction? The estimates based on the compartmental model extrapolated from the experience of a hospital and a crowded apartment building. In network parlance, they referred to local clusters. But the contact rates for the general community turned out to be much lower. The compartmental model simply did not work, and attention shifted to an epidemiological approach based on a *contact network*.

Thinking of human interactions in terms of network relations has progressed through successive stages, starting out with the basic notion that an agent (an individual, a cell, a location) constitutes a node (or vertex) linked to others in the network through linkages (or edges). The original work on networks, starting in the 1950s, focused on the behavior of typically closed or static networks with a constant number of nodes and a set probability that any two nodes are linked. However, living (in particular, human) interactions do not resemble these *random networks*. Nodes have a higher probability of connecting with nodes in their own neighborhood; for individuals, they are obviously more likely to have links to their own family (as in the tale of the three brothers) or to neighbors. In 1998, Watts and Strogatz (1998)[1] formalized these relationships: their "small-world model" combines local clusters (families, neighborhoods) through what are effectively random linkages to other clusters (one brother living in New York).

Since then, the study of living and growing networks, such as the internet, found them to be characterized by a few major *hubs* with many connections, followed by a large number of nodes with only a few linkages. The small-world model combines linkages to neighboring vertices, which are more or less predictable, with random linkages among local clusters. For the "real-world networks," the distribution of the total number of nodes according to the number of linkages follows a power law, which is described graphically in the distribution shown below. There is a high probability (frequency) of nodes with only a few linkages—the left-hand side of the distribution shown—and very few major hubs with many linkages in the long tail of the distribution. Networks that follow a power law are also referred as scale-free.

FIGURE 3. THE POWER LAW



This sketch shows the frequency distribution (probability density function) for the nodes in a network, each with k linkages, that follows a power law (scale-free). The area under the probability density function is of course equal to 1; the probability (P) for a node with k linkages is $P(k) \sim k^{\gamma}$, where γ is usually in the range of 2 to 3.

Why worry at this point about the progression from small-world models to realistic network models in the context of the spread of disease? Because understanding the pattern by which

[1] The small-world model is actually equivalent to the "great circle" model of Ball, Mollison, and Scalia-Tomba (1997), which was published a year earlier.

infectious diseases spread will help us develop strategies that keep such diseases contained.

Understanding network characteristics—the linkages between carriers and the population at risk, whether through a vector or through direct contagion—is critical in developing a strategy for disease control. At the risk of oversimplification, we can illustrate the application of network concepts to disease control by focusing on three aspects: for vectored infectious diseases, such as malaria, network-centric approaches seek to disrupt key linkages between carriers and the population at risk; for nonvectored diseases, such as SARS or sexually transmitted diseases, an understanding of network characteristics can guide the identification of hubs where intervention has a much higher potential return; and information networks matter greatly in devising and implementing effective vaccination campaigns.

How diseases spread in networks

Infectious diseases, virtually by definition, spread through networks, involving either a nonhuman carrier linking carriers of the disease to others susceptible to it, such as mosquitoes for malaria (vectored infectious diseases), or direct personal and social networks, such as cholera or AIDS (nonvectored infectious diseases). Even chronic or degenerative diseases, like obesity, may entail an element of contagion. Social proximity to obese persons, for example, has been shown to affect the likelihood of becoming obese, with significant health consequences.

At first glance, the spread of disease through a network could be thought of as the distribution of a fluid through a system of wires or pipes. But disease does not remain constant and it cannot be conserved: if you catch the flu from someone, he still has it. Nonconserved phenomena such as disease (or information or ideas, for that matter) spread from a single vertex to neighboring vertices until no further nodes remain "uninfected." In a scale-free network, featuring a large number of small components (with few linkages) and a few major hubs with many linkages, if the starting vertex for the spread of a disease is a hub, most if not all of the system will be affected. The appearance of hubs therefore dictates the pattern of dispersion.

However, in any given network, not all contacts between an infected vertex and a susceptible one result in infection. In an early model, Ball, Mollison, and Scalia-Tomba (1997) studied the spread of diseases in networks with "two levels of mixing." In epidemiological terms, the network is divided into clusters (like families) where transmission within the family is assumed to take place much more readily than among families living in different places. The model describes the kind of situation we encountered with the three Pakistani brothers. In this context, disease spread can be traced using the susceptible/infective/removed model.[2]

Ball's adoption of the network optic demonstrated that the rapid spread within local clusters (families) can lead to an epidemic outbreak in the population as a whole—even when the probability of interfamily communication is low enough that such outbreaks normally would not be possible. The weak linkages in the small-world model can become significant, since all members of infected families may have ties to the outside world, thereby pushing an otherwise nonepidemic disease to epidemic levels.

Work on the spread of diseases in small-world and scale-free networks continues. From a practical point of view, grasping the mechanics of disease spread—the interaction between such parameters as the clustering coefficient that determines the likelihood of infection among local clusters (families) and the likelihood that a susceptible picks up a contagious disease from an

[2] The "removed" category may refer to either deceased individuals (the node disappears as well), or those with (temporary) immunity to catching the disease again.

infective (which in turn can depend on the effectiveness of vaccination campaigns)—can guide disease-fighting strategies. What is the likelihood that a nonepidemic disease will make the leap to epidemic levels? Where are the hubs that need particular supervision? What are the most effective approaches to disrupting networks that transmit contagious diseases? Answering these kinds of questions will provide tangible benefits in the world of disease control. The work of Luis Amaral and his colleagues, discussed below, strikingly illustrates the power of this approach.

New explorations using network concepts continue to offer fascinating practical applications. A recent article by Goh et al. (2007)[3] in the *Proceedings of the National Academy of Sciences* analyzes the "human disease network." Nodes in this network represent disorders; these nodes are connected if they share at least one gene in which mutations are associated with both disorders. In a second network, the nodes represent disease genes and two genes are connected if they are associated with the same disorder. Juxtaposing these two networks allows us to better explain the observed differences between "normal" and disease genes. Improved understanding of network structures and processes adds a powerful tool in tackling the disease challenges we are facing.

Focusing on hubs in disease networks

In the modern world, the term airborne disease now has a double meaning. Air transportation is indirectly responsible for the propagation of diseases such as influenza (or potentially smallpox, should it ever be released) which have incubation periods that allow travelers to carry the illness aboard a plane to new destinations before they show symptoms of the disease and can be quarantined. The scare posed by SARS remains vivid. If you were traveling in the spring of 2003, you will recall the travel world and its guardians abuzz with the SARS challenge. Upon arrival in Ghana, for example, I encountered men in white coats and masks who insisted that passengers fill out a questionnaire affirming their lack of respiratory symptoms and indicating where they had sat on the plane. Alas, while the distribution of this information-gathering apparatus worked well, it is unclear whether or how that information was ever used.

Understanding the structure of the air transportation system is a precondition for developing strategies to focus vigilance and design countermeasures. As it turns out, the international air transportation system forms a scale-free network with the distribution of hubs and other nodes following a power law. Empirical research by researchers in Illinois, France, and Germany (Guimerà et al. 2005) provides strong evidence for that interpretation.

The researchers analyzed publicly available data on flights between global airports (focusing on cities) for a one-week period in November 2000. The data covered some 500,000 scheduled flights by more than 800 airlines covering 3,883 cities, and used the information to construct a network of 27,051 links. On average, it took 4.4 flights to travel between any of the 3,883 nodes of the system; the network linked 719 cities in Asia and the Middle East, for example, with an average number of flights between any city pair of 3.5 flights. The most circuitous route: Mount Pleasant in the Falkland Islands to Wasu, Papua New Guinea—a mind-boggling 15 separate flights (remember that next time you have to travel between these two places).

Joking aside, what mattered about these findings was the discovery of travel patterns that could help health experts control the spread of deadly diseases. The researchers discovered that critical air travel hubs were not necessarily based in the most logical geographical locations. Surprisingly, the nodes with more connections are not always

[3] The list of authors for this article includes the seemingly ubiquitous Albert-László Barabási.

the most central in the network. For example, Paris and Frankfurt had similar traffic levels, but Paris was a more crucial link in the network because it has more connections to different cities. Political and economic relations shape these patterns and play a role in establishing connections between different locations. Paris also ranks at the top of the list of the 25 "most connected" cities, and also tops the list of the "most central" cities in the air transportation system, characterized by a high degree of "betweenness." Similarly, both Anchorage, Alaska, and Port Moresby, Papua New Guinea, rank high in the centrality list because they serve as important gateways.

Understanding which hubs are most important could prove vital to managing the spread of disease, noted one of the researchers, Luis Amaral. "Something like SARS makes these hubs the places that you want to impose barriers," he told *New Scientist*. "Although it would depend, to an extent, on where the outbreak occurred."

Clearly, further research using up-to-date (or real-time) information is needed to complement our approach to fighting "airborne" disease. For example, our interpretations must be tempered with data on vaccination patterns. Even so, network concepts should play a central role in formulating control strategies for contagious diseases.

The role of information networks in effective vaccinations

In the 18th century, the Swiss mathematician Daniel Bernoulli, member of a highly talented family of mathematicians, developed a model that demonstrated the benefits of widespread smallpox inoculations even when there are significant risks. Vaccines ultimately eradicated smallpox in the 1970s, although isolated cases still appear.

Vaccines have also had major impact on other diseases. Yet adoption of vaccinations varies greatly. An estimated 11 million children die every year because of a lack of vaccinations.

Network concepts may offer us a way to make headway against this problem. A recent article by researchers at McKinsey & Company (Conway et al. 2008) "suggests that network analysis, which companies use to improve business outcomes by analyzing information flows and personal relationships, could speed [vaccines'] adoption." The authors examined recent or ongoing vaccine introduction in Egypt, Mauritania, Mexico, and Zambia, relying primarily on key informant interviews, including data on how frequently participants exchanged information by type, with whom, and what value they ascribed to that information. The authors used these data to construct "network maps—illustrations that identify relationships and knowledge flows among individuals and groups."

The analysis suggested that some countries do not take advantage of international knowledge. In Mauritania, for example, only local medical and research specialists, primarily in the country's National Central Hospital, were involved in the decision to introduce the hepatitis B vaccine. In contrast, Mexico relied on international disease experts to gain a better understanding of the potential impact of the rotavirus vaccine on its population. The respondents claimed that this participation helped accelerate the decision to introduce the vaccine. The informants cited the World Health Organization (WHO) (and its guidelines) and UNICEF as influential. Yet few cited cross-country gatherings, such as regional meetings of WHO's Expanded Program on Immunization, as sources of information. If the sharing of international insights and best practices helps accelerate the decision to introduce vaccines (and to administer them more effectively), additional efforts along these lines are required.

At the same time, in all four countries, finance representatives had virtually no role in the decision-making process; they were brought in after the programs were in the launch phase. Clearly, though, that involvement will be crucial to the programs' sustainability.

Conclusion

Virtually by definition, contagious diseases spread through human and surrounding networks, such as livestock systems. Understanding these networks—the nature of relationships in small clusters, like families; how those clusters are linked to others through network linkages; the impact of these contacts under different vaccination scenarios; and the focal points for enhanced vigilance—is a powerful arrow (or, rather, bunch of arrows) in the disease-fighting quiver. To take just one example, analyzing the air transportation system as a scale-free network, and distinguishing between hubs with different degrees of centrality, is a potentially important aspect of a disease-fighting strategy.

Moreover, the role of communications networks in promoting the adoption of effective vaccination strategies goes beyond the one case cited here. There is an ample literature on the power of social networks in promoting the adoption of family planning techniques, the decision to seek early intervention, the adoption of such innovations as mosquito netting, or adherence to a sometimes complex process of drug treatment. Network concepts by themselves may not be the whole answer to our public health challenges, but they should be at least a part of our strategy formulation and impact assessment.

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AUTHORS

Ioana Bouvier, a principal geospatial specialist in DAI's Geographic Information Systems (GIS) team, specializes in applying geospatial technologies to solve development problems. Her work includes developing spatial models for land optimization and land allocation; analyzing satellite images; supporting program reporting, monitoring, and evaluation; conducting training in geospatial technologies; and contributing to decision support systems for natural resources management and risk assessment.

Robert Bouvier leads DAI's GIS team. He has 15 years of international experience in relational database development, survey design, remote sensing, and GIS, applied primarily in sustainable international development, information management systems, zoonotic disease control, natural resource management, feasibility studies, and related training and capacity building.

Stijn Claessens is Professor of International Finance at the University of Amsterdam and Assistant Director of the Microfinancial Linkages Unit at the International Monetary Fund (IMF). He has worked for the World Bank in various capacities, including as Senior Advisor to the Financial and Private Sector Vice-Presidency and Lead Economist in the Financial Sector Strategy and Policy Group. Professor Claessens has advised and led World Bank missions to 23 countries, mainly helping governments develop strategies for debt restructuring and asset-liability management, and advising on financial sector reform.

Ulrich Ernst is an expert in structural reform, competitiveness, macroeconomic policy, economic and financial modeling, and privatization. Dr. Ernst is both a thought leader — he has served as technical editor for various issues of DAI's journal, *Developing Alternatives* — and an experienced development practitioner, having worked in the Middle East, Africa, Asia, Latin America, and Eastern Europe. He is currently preparing an issue of *Developing Alternatives* focused on business environment reform.

Erin Goodnough is a GIS analyst at DAI. She contributes to proposal efforts, GIS initiatives, and research related to spatial analysis applications in the development context, and she has worked on DAI projects in Indonesia, Jordan, Liberia, Malawi, and Timor-Leste. She previously worked for the Participatory Elections Project, funded by the International Organization for Migration.

Ricardo Hausmann is director of Harvard's Center for International Development and Professor of the Practice of Economic Development at the Kennedy School of Government. He previously served as the first Chief Economist of the Inter-American Development Bank. Hausmann also served as Venezuela's Minister of Planning, and has chaired the IMF-World Bank Development Committee. Hausmann's research interests include issues of growth, macroeconomic stability, international finance, and the social dimensions of development.

Cesar Hidalgo, a Fellow at the Center for International Development at Harvard's Kennedy School of Government, is currently researching the dynamic aspects of social and biological phenomena. A native of Chile, he specializes in the analysis of large data sets, using an empirically driven approach to understand the interplay between the structure and the dynamics of networks. Hidalgo's doctoral thesis in physics from the University of Notre Dame is titled "Three Empirical Studies on the Aggregate Dynamics of Humanly Driven Complex Systems."

Gary Kilmer has 40 years of international development experience, including many years as Chief of Party, leading enterprise development and agribusiness projects in Africa, Asia, the Middle East, and the former Soviet Union. He was most recently DAI's Chief of Party on the Armenia Agribusiness Small and Medium-Sized Enterprise Market Development Program, for which he also managed an avian influenza control program.

Bryanna Millis, a development economist specializing in competitiveness and business environment reform, joined DAI in 2004. She has developed and field tested tools to help governments and private sector actors increase exports, build market share, understand reform priorities, and advocate for change. Ms. Millis has provided technical direction to design, implement, and monitor market-oriented interventions, including value-chain analysis, in numerous countries and contexts.

Andrew Ross of DAI has nine years of GIS experience in developing countries and countries in crisis. He has developed and deployed GIS and information management systems in the Middle East, Southeast Asia, and Africa, leading projects through all stages of their life cycle, from needs analysis and architecture to deployment, training, and monitoring and evaluation. Highlights of his work include developing and deploying a health information system to track refugee health in Tanzania, and implementing a national internally displaced persons reporting system in Sri Lanka.

Joseph Siegle, DAI's Senior Advisor for Democratic Governance, is an expert on the political economy of development, the economic and security implications of democratization, post-conflict reconstruction, and global trends in democratic governance. He has worked in more than 25 developing countries as a practitioner, researcher, and policy analyst. Widely published, he is co-author of *The Democracy Advantage: How Democracies Promote Prosperity and Peace* (Routledge).

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