Does cooperation absorb complexity? Innovation networks and the speed and spread of complex technological innovation

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Abstract

A new technological paradigm which rewards cooperation in the innovation of complex technologies seems to have emerged in recent years. Global reach and greater innovation speed are said to be key benefits of network-based complex innovation. By bringing together multiple sources of knowledge and experience, networks of innovative firms and other organizations increasingly appear to be able to absorb the combination of spatial and temporal uncertainty. But what is the empirical evidence underpinning this new paradigm? Beyond case studies and the experience of individual researchers, what do we know about cooperation and the pace and place of complex innovations? Examination of available empirical research fails to confirm the theory that cooperation enhances either the globalization of innovation or its speed.

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“A paradigm encompassing globalization and innovation, far more than in earlier decades, seems to explain the events of the past ten years better than other conceptual constructs. If this is indeed the case, because there are limits to how far globalization and the speed of innovation can proceed, the current apparent rapid pace of structural shift cannot continue indefinitely.”—Remarks by Alan Greenspan, Federal Reserve Board Chairman, at the Conference on Bank Structure and Competition, Chicago, May 6, 2004.

The “structural shift” noted by Chairman Greenspan is characterized in his speech as a “transitional paradigm” that has “temporarily altered” the economic calculus. But many observers believe something more fundamental has taken place. They argue that the rules of competition in the marketplace have

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changed dramatically. From this perspective, high-value-added competition is now based on the innovation of technologies that are knowledge-intensive (e.g., supported by large investments in research and development), and very complex (e.g., those with many components and multiple linkages among those components). Examples include automobiles, aircraft, and telecommunications equipment. These are the technologies that underpin the major “knowledge-based” economies, provide the most prized competitive advantages, and support a host of non-economic capabilities as well (e.g., health care, national security, environmental protection). Complex technologies are innovated by equally complex innovation networks (e.g., strategic alliances, research consortia) involving firms, universities, government agencies, and other organizations [1]. High levels of innovative performance have been associated with network-based collaboration. Above all, cooperation is said to underpin the global reach of these networks and to reduce the time in which complex technologies can be innovated [2]. Thus it is asserted that network-based innovation plays the key role in the new “logic of competition” involving both the international diffusion of complex knowledge and techniques and the acceleration of the pace of global technological change [3].

On what theoretical and empirical basis are these claims based? What is the theory and evidence? And what are the implications of the evidence to date?

1. “Strong Network” theory

Not surprisingly, there is variation among the theories regarding networking and the spatial and temporal dimensions of complex technological innovation, but the dominant formulation, based on the idea that networks exert a strong influence on the reduction of innovation speed and the expansion of innovation space, begins with the idea that complex technologies are innovated by networks that self-organize. Self-organizing innovation networks demand diverse organizational members in order to create, acquire, and integrate the wide range of knowledge and skills required to bring complex technologies to the market or to apply those technologies to government missions. In other words, innovation networks are organized around constant interactive learning. Self-organization refers to the capacity these networks have for combining and recombining these learning capabilities (e.g., adding new network members, discarding old ones, altering the nature of existing relationships) without centralized managerial guidance [4].

The proliferation of self-organizing innovation networks and complex technologies may be linked to many factors, but a key one seems to be increasing globalization. Indeed, globalization and self-organizing innovation networks may be co-evolving. Globalization is most often identified with the forces that have induced cooperation among various types of innovative organizations. Globalization makes cooperation more attractive in many ways, including the intensification of competition and the increase in both the risks and benefits of complex innovation. The process of globalization also increases the value of accessing unique knowledge residing in different regions and countries around the world. Because of the need to form deep linkages and participate in networks embedded in different national systems of innovation, transnational corporations may have no choice but to conduct increasing amounts of research and development outside of their home economy [5]. And these transnational efforts focus on satisfying increasingly diverse and customized regional and global markets [6].

Less often noticed are the ways in which innovation networks appear to bring more globalization into existence. Cooperative innovation creates complex and overlapping relationships that shape global markets, provide intelligence about innovation opportunities around the world, and serve as the
organizational base for acquiring relevant knowledge and expertise wherever it is located. At least since 1990, international cooperative agreements – linking organizations from different national economies – have been the majority of total collaborative arrangements. On average, there are about two international partnerships for every domestic one [7].

Transnational strategic alliances and other forms of innovation networks appear to enhance the emergence of globalization more than traditional arrangements (e.g., mergers, acquisitions) because alliances tend to deal with uncertainty faster and with more flexibility. For example, cooperation seems to decrease the difficulties involved in predicting exactly what combinations of knowledge, skills, and know-how will be needed in complex innovation [8].

Simultaneously, the pace of technological change seems to be more rapid today. This is illustrated by, for example, research indicating that the period of time it takes to launch a new product has been gradually and significantly reduced. According to a study by the U.S. National Planning Association, in 1990 new U.S. product technologies took an average of 35.5 months to complete. By 1995, this time had been reduced to about 23 months [9]. Once having been innovated, product life cycles (i.e., the time it takes for a product technology to move from its “youthful” stage to “old age” and the beginning of efforts to develop new products and start the cycle again) appear to have become shorter too [10]. Global competitive pressures and opportunities are often identified as major factors in the reduction of cycle times. In recent years this literature has also begun to analyze specific links to complexity—to assess the direct empirical evidence on linking the complexity of an innovation and the time taken to complete the innovation [11].

What factors might be making simultaneous spatial expansion and temporal contraction possible? The dominant assertion is that network-based partnerships are at the core of the emergence of greater globalization and faster innovation. Collaboration may “absorb” the combination of spatial and temporal complexity in ways described by “Ashby’s Law of Requisite Variety.” This cybernetic principle asserts that a system cannot meet increasing variety in its environment unless it increases the range of its response repertoire. In other words, in the context of complex technological innovation “only the variety generated in collective learning processes (within and between organizations) can absorb the variety generated by environmental uncertainty [12].”

It is certain that a powerful trend in technological innovation in the past century has been the emphasis on cooperative strategies while limiting opportunism [13]. One of the first serious analyses of this tendency noted the advantages of reduced opportunistic behavior for innovative firms and other organizations:

Not all uncertainties can be eliminated by networks, but some can be greatly reduced: secondary market uncertainties, in particular those related to systems configurations and interface. From an agreed upon initial modus vivendi, mutually credible commitments are made in networks on the basis of compatible preferences and goals, which can eventually evolve into a mutual dependency and bondage resulting in positive reciprocity, the development of common language, mutual understanding, and, sometimes, trust [14].

Note the emphasis on “durable” relationships. There is recognition that to be effective, network linkages need to be more than temporary experiments. Growth in dependency, trust, and reciprocity appears to take time and to be a cumulative process [15]. Successful interactive learning commonly triggers further cooperation [16]. Organizations that succeed at networking may become not only better at learning about the technological dimensions of collaboration, but also more skilled in organizational dynamics. For
example, companies experienced in collaborative ventures frequently become better at resolving conflicts in network governance [17]. Such cooperation and trust usually rests on informal but powerful social contracts that emphasize openness, communication, foresight, and discipline [18]. Trust and reciprocity rely in part on values that place great emphasis on common interest and on the need to rely on others in uncertain, high-risk situations. This is what many students of technological innovation refer to as “strategic coordination [19].”

Trust and reciprocity seem to help innovation networks to succeed in a number of ways—including some that are extremely valuable in the new “knowledge-based economy.” For example, the diffusion of credible knowledge among network members is much more rapid and accurate when characterized by high levels of confidence in source integrity and solid faith that the knowledge transferred will be returned in kind. Thus, collaboration can lead to patterns of behavior that increase the productivity of knowledge [20].

It is no coincidence that network relationships are found mostly in complex, “high-technology” sectors [21]. These are the technologies that require the integration of the widest range of technological bases and capabilities. Keeping pace with the complexity of technological progress requires that networks repeatedly learn about, integrate, and apply a wide range of knowledge and know-how from a wide variety of locations around the world. Both direct and indirect access to knowledge is increasingly sought across national boundaries, as networks try to diversify their innovative capabilities through global collaboration. Cooperation thus has an important spatial dimension [22].

Here it must be observed that many analyses of the geographical spread of collaborative innovation find the national–global dichotomy overly simplistic. They introduce instead the concept of innovation and production taking place within multiple spatial–territorial levels, including sub-national, national, and regional—in addition to the global dimension [23]. These distinctions may be important, because amid the general fascination with the innovative advantages of globalization, some studies have indicated the significant competitive benefits that often flow from collaboration among innovating organizations located in close geographical proximity to each other. Silicon Valley and the industrial “clusters” of Northern Italy are often cited as examples. Increasingly, the various spatial dimensions are integrated in new types of networks, as in “global-city-regions [24].” This technological cluster literature tends to focus on planned collaboration and not serendipitous interactions (e.g., face-to-face exchanges of knowledge or other pathways in which knowledge spillovers are captured as a consequence of physical proximity).

As noted above, the networks that create complex technologies normally operate under intense time pressures. Faster product cycles and shrinking ability to capture the benefits of new knowledge demand sophisticated collaborative inquiry, self-reflection, and scanning capabilities. Network members are involved in an ongoing crisis that involves trying to steer innovation in a context of pervasive time pressures and uncertainties. To meet the challenge of technological acceleration, firms and other organizations must learn tacit (e.g., unwritten know-how) as well as explicit knowledge faster and more effectively because the most successful networks are also fast organizational learning systems. And cooperation often seems to enhance fast learning [25].

Ultimately, the advantage provided by self-organizing networks is that they learn in many ways. Few are easy, inexpensive, or risk-free. Yet once learning processes are established that make repeated complex innovation possible, a network may have a sustainable competitive advantage. The dynamic capabilities that result from rapid learning are difficult for competitors to replicate, precisely because they are constantly evolving and emerging. Thus among advocates of the strong network theory there is growing consensus that collaborative innovation is the “major new feature” of the modern economy [26].
2. “Weak network” theory

The more cautious interpretation notes that whatever the objectives of collaboration, the result is often failure. Success rates for strategic alliances of less than 50% are commonly reported [27]. So this theory begins with the idea that cooperation is no panacea for complex innovation. Some analysts have argued that networks are no more immune from conflicts, disputes, and lack of coordination than other organizational types. Indeed, they assert that networks may have some unique liabilities. These include inter-organizational disputes within the network, conflicts with competing network organizations, and lack of scale and infrastructure that makes networks vulnerable to competition and easily disrupted by external forces. Among these disruptive forces are the competitive actions of large integrated corporations and changes in public policy [28]. Other analysts worry that cooperation may pose excessive limits on an organization’s freedom of action, or that there is so much focus on the network that broader developments (e.g., restructuring at the industry level) may be ignored. This latter problem is sometimes called “the ties that blind” [29].

Another criticism has focused on the tendency to over-estimate the benefits of networking for all levels of technological complexity. For example, it is argued that for collaboration to be an effective business strategy, network organizational complexity should correspond to technological complexity. Innovation success may depend on the technology being appropriately complex for the network organizational arrangements [30].

Even given appropriate levels of organizational and technological complexity, cooperation does not always enhance complex innovation speed. Complexity may be a barrier to speed because the process of combining and synthesizing knowledge bases relevant to many related systems, subsystems, and components can be difficult to rapidly communicate and diffuse throughout a network. This is especially the case when much of the knowledge is tacit know-how. So the introduction of new technological products and processes may be delayed. Moreover, if a technology is perceived as too complex, potential users may be discouraged. Therefore, the time required to develop a new market can be extended [31].

Questions are raised from another vantage point regarding the ultimate payoff of efforts to speed new product development. There is some evidence, not limited to complex technologies, indicating that faster commercialization is not necessarily correlated with commercial success [32]. Such findings have triggered a general trend in recent years to pay more attention to the liabilities of innovating rapidly. For instance, time-based innovation strategies may be important in emerging or fast-changing markets, but not so significant where markets are stable [33]. Or commercial success may depend as much or more on compressing the cycle time between products as on each discrete product cycle. This is what one study calls the “new product success-to-success cycle time” [34].

Nor does complexity necessarily enhance the processes of technology-related globalization. Multinational firms have shown a greater tendency in recent years to internationalize their capabilities (e.g., moving R&D facilities abroad), but these decisions may depend on the type of technological activity (e.g., basic research, as contrasted with technological development, or incremental instead of radical innovation), rather than the level of complexity. For example, analysis of patent data suggests that the innovation of complex technologies such as biotech and advanced materials is more geographically concentrated than simple technologies like food and tobacco products [35].

Many corporations and other innovation actors may still be trying to go it alone in complex innovation—entering into few network relationships, attempting to retain their “core” technological knowledge close to home, and moving less critical knowledge bases to overseas subsidiaries [36]. Thus it may be more accurate to say that the global exploitation of complex technology (i.e., taking products
and processes to increasingly international markets) has expanded much more than its global generation (i.e., creating technology outside a multinational firm’s home country) [37].

3. Evidence on cooperation and innovation speed

Reducing the cycle time for technological innovations certainly is a major motive behind the creation of networks, and the links between enhanced innovation speed and network dynamics are often highlighted by analysts [38]. And this focus on speed is not just the perspective of the private sector. National governments seem to be coming to the conclusion that generating more rapid technological innovation may be the major reason for public sector actors to collaborate with firms and other organizations. A good example of this view is provided by a recent study conducted by the U.S. National Academy of Sciences that is explicit about the focus on speed as a reason for the federal government to network with companies. It cites “accelerating the development of new technologies from idea to market” as the central public policy objective underpinning the participation of public agencies in innovation networks [39].

A commonly mentioned example of faster innovation generated by public–private collaboration is the participation of the U.S. Defense Advanced Research Projects Agency (DARPA) in the successful semiconductor manufacturing technology consortium, Sematech. This kind of public–private collaboration is now viewed by many government organizations as enhancing the rapid transfer of innovation “best practices” (e.g., forecasting activities such as technology roadmaps) that can be incorporated into future public policies [40]. Cooperation among firms, government agencies, universities and other actors is now commonly credited with accelerating innovation in sectors like semiconductors and is now often assumed to be a major factor in achieving more rapid and sustained economic expansion [41]. The pressure to generate ever greater innovation speed thus affects a range of non-firm actors. To cite only one example, universities have invested substantial resources in efforts (e.g., the proliferation of licensing agreements with companies and government laboratories) to generate faster commercialization of their research-based innovations [42].

However, as one observer has noted, “for a hot topic, innovation speed has been the focus of surprisingly few scientific studies [43].” He is correct. Many analysts appear to simply assume ever faster innovation. The best review of the literature on time and innovation, conducted in the mid-1990s, lists about 70 studies, mostly accounts of personal experience or case studies [44]. Indeed, the association between collaboration and innovation speed is supported almost entirely by case studies and anecdotal evidence.

Much of this literature is generated by a growing innovation consultancy. A good example is the Management Roundtable, a consulting firm that highlights its expertise in “better, faster, cheaper decision-making with fast prototypes.” The organization has helped develop an extensive list of case studies, including, for example, Motorola’s rapid development of cell phones and pagers [45].

The narratives and case studies addressing innovation speed tend to be structured around one temporal model. Product and/or process cycle time is easily the dominant focus. New product development cycles are the most commonly used measures, generally defined as either the time it takes to move a new idea through various innovation stages to the market or the rate of new product introduction over time [46]. The technology cycle model posits that an industry or firm will pass through a number of distinct technological stages over time. In the first stage, most new companies or sectors are characterized by significant uncertainty about market dynamics, product design, technological constraints, etc. This “youthful” state is a fluid period of experimentation with novel designs and it typically leads to one or
more radical breakthroughs and a variety of designs offered by industry. Here technological opportunities are high and the rate of technological change accelerates.

With the emergence of a “dominant design” and well-defined markets, however, the competitive landscape changes as radical innovation gives way to incremental advance. During this “mature” phase of incremental change, technological advance in products slows down. As the product technology stabilizes and becomes standardized, there is a transition to process technological changes. Simultaneously, there is a move from competition based on higher performance to competitiveness defined in terms of lower cost. So innovation becomes faster. Eventually, the process technology becomes standardized. Now the pace of innovation is slow again. In the final stage, the “old age” of a technology features efforts to develop new designs and start the cycle again [47].

The origins of the model are important. The initial idea was focused—explain observations in a specific industry (automobiles) in a particular country (the U.S.), in a defined period (the 1970s). Most cases testing the model have also been limited to the U.S. in similar industries (e.g., typewriters, televisions). Despite these constraints, the product cycle model is widely viewed as providing a close to universal explanation for industrial and technological evolution. As one study observes, “It is hard to underestimate the influence of this theory. More than any other it has been the organizing principle around which the vast majority of theoretical and empirical work on innovation has been based during the last 20 years [48].”

A major problem is that most case studies and descriptions of expert experience using the product cycle terminology report innovation speed in ways that are not consistent with the product cycle model. As the above discussion illustrates, product cycle theory assumes a fast—slow dynamic. Even most of the critics of the model (e.g., advocates of “barrier-breakthrough” patterns or “technological discontinuities”) agree that innovation speed should be defined in pendulum language [49]. Yet almost without exception the speed of innovation is reported in terms of continuous change—as consistently faster. Thus, most of the case study literature is more supportive of a continuous change paradigm than product cycle theory.

The continuous change literature asserts that while accounts of product cycles have interested academics, these patterns are not a common experience of managers in most innovative firms. Instead, it is argued that many firms compete by changing continuously—especially in “high velocity” industries with rapidly shifting competitive landscapes. For these industries, the ability to engage in fast and “relentless” change is a crucial capability for survival [50].

The little deductive hypothesis testing that has been done is spread over several research paths (e.g., analysis of the total number of products innovated in specific stages of cycles [51], assessing fluctuations in sales within a product category [52], and analyzing the age of cited patents [53]), but surveys of expert opinion have dominated.

There are at least four studies, two based in survey research, explicitly linking strategic alliances, cooperation among producers, suppliers, and customers, or other forms of networking to the pace of innovation. Three have focused on a sector—pharmaceuticals/biotechnology characterized by fairly simple products but quite complex production technologies. The bio-pharmaceutical industry is of special interest not only because it has been made more complex by the impact of the biotechnology revolution, but because of all the major technological sectors it has been identified as having the shortest discovery-to-innovation elapsed time [54]. It is also one of the three sectors (the others are information technology and advanced materials) responsible for the vast majority of observed scientific and technological alliances [55]. Yet networking in the bio-pharma sector appears to generate a mixed set of temporal effects.
One study conducted a survey of over 130 biotechnology companies to test the proposition that a firm’s rate of new product development is a positive function of the number of strategic alliances it has entered. Instead, the relationship between strategic alliances and rapid product development was found to be nonlinear. At low levels of alliance participation, new products were introduced faster, but as the networking increased, the temporal benefits began to decline. At very high levels of alliance involvement, the costs of an additional cooperative arrangement actually outweighed the benefits. The relationship between the number of alliances and the rate of new product development turned out to be an inverted U-shape—there were diminishing temporal returns to collaboration [56].

The second analysis of pharmaceuticals found that faster “technology cycle time” (TCT, defined in terms of the median age, in years, of the U.S. patents cited on the first page of an approved patent application) was positively correlated to – among other factors – a firm’s number of strategic alliances. Yet it was also found that firms that generated new knowledge internally had significantly faster TCT than those that created new knowledge from external sources. The authors posited that fast innovators were able to combine internal learning processes with the use of alliances in areas which were not the firm’s primary area of expertise. In other words, “a broader knowledge base is better for faster technology cycle time, but this cannot come at the expense of a firm’s expertise in certain key technological areas that may be considered its core competencies [57].” In this formulation, collaboration is a way to rapidly gain access to what some have called complementary assets.

Another empirical analysis used 99 structured surveys of the company founders of research-based startup firms to determine the factors explaining time-to-market (elapsed time between the founding of the firm and the time at which the first product was available for sales) in several complex sectors (software, telecommunications, medical-related).

Unexpectedly, alliances with other firms did not significantly affect innovation speed in any of the sectors. And collaboration with universities actually led to slower product development for telecommunications and medical-related technologies (software was not affected). But the authors are quick to note that these findings should be interpreted with care. They observe that many companies entering into collaborative relationships with universities are attempting to stay at the “cutting edge” of new technologies, where highly specialized knowledge can be difficult to access [58].

A third examination of collaboration and innovation speed in the pharmaceutical industry tapped into a database constructed by a consulting firm. The sample examined included over 2000 drug development projects from 577 pharmaceutical and biotechnology companies during the period 1980–2002. The research focused on the temporal implications of alliances seen as an “innovation promoter” versus the alliance as an “impediment” to the innovation process. It was hypothesized that projects originating from “outside the boundary of the firm” (i.e., based on collaborative relationships) would shorten product development time for successful innovations, but lengthen the time for failures. When cooperation worked, innovations would be generated very quickly, but when collaboration encountered problems, it would take a long time to terminate the project. The logic was that it would be more difficult to “pull the plug” on partners involved in collaborative endeavors, than to terminate those projects conducted entirely in-house. The research confirmed both hypotheses [59].

Thus while the empirical research linking complex technological alliances with innovation speed is thin, it is nonetheless provocative. It looks as though the acceleration of complex technological innovation might be affected by the types of organizations participating in a network, the number of collaborations undertaken by a particular organization, the emergence of problems in cooperating, and the types of technological areas that are the focus of networking.
4. Evidence on cooperation and innovation spread

Research on the spatial implications of collaborative approaches to technological innovation looks a lot like the pattern regarding the assessment of the pace of innovation. Perhaps even more than with innovation speed, the spatial dimension of technological change has been the focus of national governments as well as firms and other organizations. Where innovation takes place and how technological products and processes disseminate are now major public sector issues. While many of the issues surrounding the innovation of complex technologies are inevitably international, national policy makers have a strong interest in creating nationally located companies and networks developing world-class capabilities. Despite – or maybe because of – increasing globalization, governments appear to be working hard to attract, maintain, and expand the location of innovative activities within their borders. Thus the superior performance of “national “ innovation systems seems to depend at least in part on the attraction of international flows of capital, technology, and scientific expertise, much of it embodied in strategic alliances and other kinds of networks [60].

Just as was the case with the analysis of the temporal dimension of alliance-based innovation, one analysis notes that “a review of the literature indicates that the empirical measurement of industry globalization has received little attention” and that “industry globalization has been largely subjectively measured, consisting of mostly case studies [61].” As was the situation with the analysis of collaboration and innovation speed, many of these globalization cases are generated by professional consulting companies. Forrester Research is such a firm. Forrester has developed over 270 case studies, 57 of which are categorized as focused on innovation networks. A good example is a study of the role the Santa Fe Institute has played using its unique combination of knowledge bases (ranging from particle physics to economics) to bring together researchers from around the world. These local networks have included experts from businesses such as Boeing, Cisco Systems, and Honda [62].

Unlike the analysis of the pace of innovation, studies of innovation place do not seem to have coalesced around any particular framework or model. Some spatial analyses also use the product cycle assumptions and concepts. Often these studies integrate product cycle ideas with insights from other models, such as technological discontinuities. Thus:

Spatial discontinuities may relate to specific phases in technological cycles. Technological frontiers are in operation in the RIS [regional innovation systems] that are involved in creating novel combinations and that are able to build local structures around emerging dominant designs and exploit them commercially. If those structures become too rigid in time, they cannot change as new variation emerges, beginning a new cycle of technological change. At this time, the actors at the frontier of technology may move to areas that fulfill their locational specifications. Alternatively, new technological frontiers may emerge in new areas as a result of the previous dominant design having been applied in a new context, possibly in a new region, where it becomes differentiated and may give rise to a new subtrajectory and maybe later to another novel combination beginning a new cycle with a different set of actors involved [63].

Within these various models, some deductive hypothesis testing has been undertaken. One study involved data on 145 firms and over 3500 alliances collected by an academic association, the Global Information Sector Project of the European Group for Organizational Studies. The analysis covers mostly complex technologies (i.e., telecommunications, information and data processing, semiconductor machinery, computer and electronics products) over the period between 1998 and 2000.
A “globalization hypothesis” was formulated around the idea that as the search for competitive advantages through strategic partnering increased, corporate integration across national boundaries would expand. A stable alliance structure would then emerge, consisting of a core block of networks occupied by corporations from different nations, rather than a structure characterized by nationally or regionally homogeneous blocks.

The analysis did not support the globalization hypothesis. Instead, national and sub-national regional alliance patterns emerged. For example, by 2000, Japanese companies had concentrated their alliance agreements among themselves, rather than seeking partners across national boundaries. Collaboration had led to nationally and regionally homogeneous blocks of alliances [64].

Similar results have been generated by two other empirical analyses. Both examined biotechnology firms and their patterns of collaboration, including the spatial dimension. One study developed a sample of 94 pharmaceutical biotech companies and, among other research questions, focused on identifying key characteristics of their partners. The geographic location of potential collaborators turned out to be a “strategic” factor. The most valuable partners were located in regional technological clusters organized around the capabilities necessary for the development of products. The most appropriate clusters were those that had a significant concentration of similar firms, but it was important that there not be too much competition for the cluster’s unique resources [65].

Another study focused on identifying the factors that made startup companies attractive alliance partners. It constructed a sample comprised of 325 new biotechnology firms involved in 973 strategic alliances for the innovation of drugs and diagnostics between 1973 and 1997. After public ownership, the second most important new firm characteristic was geographic location in a regional technology cluster. Established companies seemed to choose startup firms as partners not only to access the knowledge brought to the collaboration by the startup, but also to tap into the knowledge contained in the technology cluster [66].

A fourth analysis examined the degree to which strategic alliances and other cooperative relationships were a substitute for or a complement to co-location in a regional cluster. It relied on a database containing information on all firms operating in the Canadian biotechnology industry from 1991 to 2000 (675 companies in all) and used U.S. patent applications as the measure of innovation. The major finding was that location in a cluster strong in a firm’s technological specialization raised the productivity of its own R&D alliances and provided positive externalities gained from the investment in other firms’ R&D alliances. Cooperation in the form of R&D alliances was a complement to geographic location [67].

So these few empirical studies do not lend support to the idea that the major impact of cooperation is to spread complex innovation to the global level. Rather they seem to assert that the localization or regionalization of these innovations is the major result of technological collaboration. These findings seem to contradict the growing perception that the globalization of networking in complex sectors is inevitable, since even the most technologically dynamic regions (e.g., Silicon Valley, Boston’s Route 128) can no longer contain all of the requisite talent and expertise [68]. Perhaps these studies support the idea that greater globalization makes the unique capabilities that are found in local and regional space more – not less – important for innovation [69].

5. Conclusions

Surprisingly little effort has been devoted to the evaluation of the performance of innovation networks, despite a widespread and growing consensus in the scientific and technological communities around the world that these partnerships represent a powerful and important new technological phenomenon [70].
Perhaps the best evidence of the significance of collaborative innovation is that the U.S. National Science Foundation (NSF) has added a section on “technology linkages,” including data on public–private partnerships and industrial alliances to its prestigious reports on scientific and technological indicators. And in those reports, evidence of the spread of inter-organizational cooperation in technological innovation does seem to be everywhere. The NSF concludes that since the end of the 1970s there was steady growth in technological collaboration until a peak in 1989. Then, after a drop in the number of new partnerships in the early 1990s, collaboration began to increase again, reaching an all-time high of 695 alliances initiated in 2003 [71].

A small amount of empirical research, focusing a good deal on one technological sector, fails to confirm the “strong network” theory that cooperation “absorbs” spatial and temporal complexity. There is little evidence that collaboration tends to enhance the global reach of complex innovation networks. Nor does engaging in the network-based complex technologies appear to result in a pattern of faster innovation. Rather, the spread and speed of complex technological innovation seem to be much more nuanced phenomena.

These findings have many plausible interpretations. Where innovation takes place still seems to matter. But innovation space may take the form of internationalization, “triadization” (i.e., the U.S., Western Europe and Japan), regional bloc formation, local clusters, or global cities [72]. Similarly, there is no reason to suspect that even when produced, increased innovation speed is always a benefit to a network. It is more likely that faster innovation is variable and a mixed blessing, at times overwhelming the same networked organizations trying to produce it. The benefits of speed appear to be problematic when the result is often information overload and organizational fatigue more than accurate real-time decision-making capability [73].

Of course, it may turn out that all of these efforts are extremely difficult or even fruitless. It could be that each complex technology has a unique temporal and spatial dynamic, relatively independent of the level of networking. Some analysts have suggested this possibility. For example, Olinas and Malecki hypothesize that “technologies have their specific, path-dependent time geographies [74].” If so, these historically conditioned spatial–temporal interactions may be difficult to separate. Certainly many analysts continue to make the argument that globalization is as much about time—the acceleration of events and processes—as any other factor, including geography [75]. Thus, from a technological viewpoint, it may be a challenge to determine whether “the power of pace is outstripping the power of place [76].”

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