WORKING PAPER
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BANDWAGONS, BOOTLEGGING AND GRAPEVINES: STRUCTURAL AND BEHAVIORAL DYNAMICS IN THE FORMATION OF R&D COMMUNITIES

A RESEARCH AGENDA

by

Michael A. Rappa

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(revised, December 1990)
WP#3171-90-BPS

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This paper was presented at the TIMS/ORSA Joint National Meeting in Las Vegas, Neveda, May 7, 1990. The author greatly appreciates the comments of Andrew Van de Ven, Raghu Garud, and Koenraad Debackere.

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Introduction

Managerial studies of technological innovation frequently focus on the examination of individuals (researchers, inventors, or entrepreneurs) and the context in which they reside (a product development team, research laboratory, firm, or industry), as a means for understanding the process by which new technologies develop and become commercialized.

Although previous studies have made, and continue to make, substantial contributions to our knowledge of technological innovation, recent investigations of the emergence of radically new technologies suggest that it might by useful to consider an additional contextual perspective: that of the R&D community. The R&D community is defined to be that group of individuals who become committed to reducing an interrelated set of technical ideas to practice--with no regard *a priori* to their organizational or geographical location--and who communicate in some manner with each other. Thus, a community may consist of a number of scientific and technical people, who are dispersed across a wide variety of organizations and in any number of countries around the world.

While the notion of focusing on a community as a unit of analysis is not new in the context of those who study the sociology of science (hence, the term "scientific community"), only recently that has it become of interest to those who study technology. Traditionally, technological development has been seen as an activity that is for the most part within the domain of industry. Therefore, to understand technological development, the critical focal point for study has been logically within the firm, or among a collection of firms within an industry. This follows a line of reasoning which tends to view technology in the tangible sense as hardware, which is produced by firms in order to make a profit. In this sense, technological development is a proprietary, highly secretive, intra-firm activity--and far from being "communal" in any sense one may wish to apply the term.

Why study R&D communities?

Given this tradition, why study R&D communities? The reason for the burgeoning interest in investigating the role of R&D communities in technological development is manifold, but can be summarized in the following manner.

First, it is not unusual to find that the emergence of a new technology is not limited to a particular firm or industry. Rather it can involve a number of firms, whose product/market definition is not consistent with a single industry. Typically an industry is defined in terms of the final product output, and therefore does not take into account customers, suppliers and other firms who might use the same technology but apply it to very different products. Indeed, new technologies can make new firms and new industries, but this is likely to happen on the tail-end of the process of emergence, when the technology is nearly commercialized.

What is more, it is not uncommon to see a number of non-industrial organizations (universities and government laboratories) play a role in a technology's development. Although important in itself, this role may not be limited simply to training technical personnel, but also, as more and more people have come to recognize, as a hotbed from which new technologies emerge.

Investments in university-based technology parks have grown dramatically for precisely this reason. But the importance of non-industrial organizations to technological development is nothing new, nor particularly surprising: the freedom of investigation in academic institutions permits radically new ideas to flourish, if not to fully develop them in a commercial sense.

In a related manner, many radically new technologies have very close connections to basic and applied research activities conducted by scientists. This runs contrary to the established notion that science and technology are of "two worlds" that run in parallel with each other, but seldom actually work in tandem. Clearly, the relationship between science and technology is not obvious, nor is it easily understood. But progress toward understanding the relationship is frequently inhibited by conceptual definitions that do not keep up with changing times. Recently, the view that both science and technology are fundamentally social processes that yield new knowledge, lends credence to the idea of treating science and technology as a unified system. By taking a community perspective, the "two worlds" issue is largely avoided because the focal point is the set of ideas that people hold in common, and not by the scientific or technical character of their activities.

A community perspective also takes into account the contribution of various organizations without regard to the ultimate success or failure of their efforts in developing the technology. The positive role of failure in technological innovation is easily underestimated because retrospective analyses tend to ignore, overlook, or otherwise cannot investigate efforts which did not bear fruit. It could be argued that technological development is in many ways a process of learning by doing, and sometimes (perhaps more often than not) the efforts of a particular organization are unsuccessful. But some organizations may succeed where others fail, and it is the efforts of those who fail that can provide a substantive (albeit indirect, at times) contribution to those who eventually succeed. Examining both success and failure in an integral manner appears to be called for in order to understand a technology's emergence.

Lastly, the need for a global perspective is now well-recognized, and by focusing on the R&D community, the international dimension of technological development is dealt with explicitly. In most instances, R&D communities are global in their scope.

This emphasis on the importance of the R&D community is a decidedly technology-push orientation: in essence, the R&D community perspective asks "who is doing all the pushing and why are they pushing so hard?" The basic premise of this perspective is that radically new technologies emerge because some individuals become undeterred in their commitment to solve certain problems in order to make an idea practical. This is not to dimish the relevance the longstanding debate between technology-push and market-pull factors. There is a need to understand both sides of the equation. However, from the point of view of the R&D community, the issue becomes one of understanding how the market is perceived by researchers and, given their perception, how it subsequently influences their behavior.

In summary, rather than focusing on a single organization or industry, investigation of the community provides a broader perspective which captures the contributions (no matter how successful in the ultimate commercial sense, and with no regard to the scientific or technical orientation of the work) of as many relevant organizations as possible, in whatever industry or sector or country they might reside. To examine the R&D community is to focus on the people who develop technology, their ideas, their interactions with each other, and the organizational context in which they work, as the process unravels over time.

Structure and Behavior of R&D Communities

While the relevance of embracing the R&D community as a unit of analysis in the study of emerging technologies seems sensible, the obvious question is "What are the most important characteristics of the community to study?" In order to answer this question, it is useful to think in terms of the body of knowledge that has been developed in the field of industrial organization(IO). In their quest to understand the performance of industries, economists have created a framework for delineating the "structural" and "behavioral" characteristics of an industry. It is possible to investigate the structure and behavior of an R&D community much in the same manner, and such analyses may provide a useful starting point for studying the functioning of communities.

For example, IO research seeks to characterize an industry in terms of its growth rate and size (sales volume), its level of concentration (the distribution of sales across firms), its entry/exit behavior (of firms), among other things, in an attempt to draw relationships between such variables and industry performance.

Similarly, it is possible to examine a number of structural and behavioral characteristics of R&D communities, and hypothesize about their relationship with community performance (e.g., rate of technical progress). Important variables include, but are not limited to: the community's growth rate over time, in terms of the number of researchers; the organizational distribution of researchers, or the community's level of concentration; the sectoral distribution of researchers (between public and private); the international distribution of researchers; researcher entry/exit patterns into and out of the community; the formation of a core group researchers who remain in the community year after year; organizational entry/exit patterns; researcher mobility between organizations; the average scale of R&D effort, or minimum efficient size; inter-organizational collaboration networks and the flow of information between organizations; and the degree of technological specialization or integration (material-component-system).

This list is not intended to be exhaustive, but rather simply to provide an initial route for thinking about community structure and behavior. Undoubtedly, a tremendous amount of work will be required to fully understand all of the most important characteristics of communities and the relationship these variables have to overall performance. Nevertheless, preliminary research on a number of R&D communities has begun to yield insight into the process of technological development, and enables a rudimentary life-cycle model of R&D communities to be proposed.

Life-Cycle Model of R&D Community

Life-cycle models are commonly used devices that have proven useful for understanding certain time-dependent phenomenon, such as with product or industry life-cycles, and R&D communities are no different in this respect.

Investigations of twelve different R&D communities suggest that a life-cycle model of community growth may be equally relevant in describing some of the major structural and behavioral dynamics of the R&D community.

To begin, three characteristic phases can be distinguished in the evolution of the R&D community over time. Before describing the phases, it is important to recognize that while each phase may have certain dominant characteristics, the boundaries between phases are likely to be fuzzy. Furthermore, although a sequential ordering of phases is given, the causal linkages between them, if any, is not discussed.

Using one dimension of an R&D community, that of the level of researcher participation, an illustration of the life-cycle model is provided in Figure 1. The first phase is characterized by a very low level of researcher participation in the community. During this time, the community can be fairly concentrated in a few organizations, each with just a few researchers, whose efforts are directed at experimenting, building prototypes, and isolating the challenging problems which confront them. The activities of these organizations typically occurs in isolation of each other.

The ideas that these researchers dedicate themselves to developing are decidedly not mainstream in the sense that others share in their enthusiasm or belief that such ideas can have widespread, practical implications. Indeed, a fair amount of tension may arise between community members and their peers who pursue more traditional research topics. To their mainstream peers, they may be nothing more than second-rate researchers with misguided passions and poor judgment. But in their own mind, they are likely to fashion themselves as technological visionaries, highly committed to seeing their ideas through.

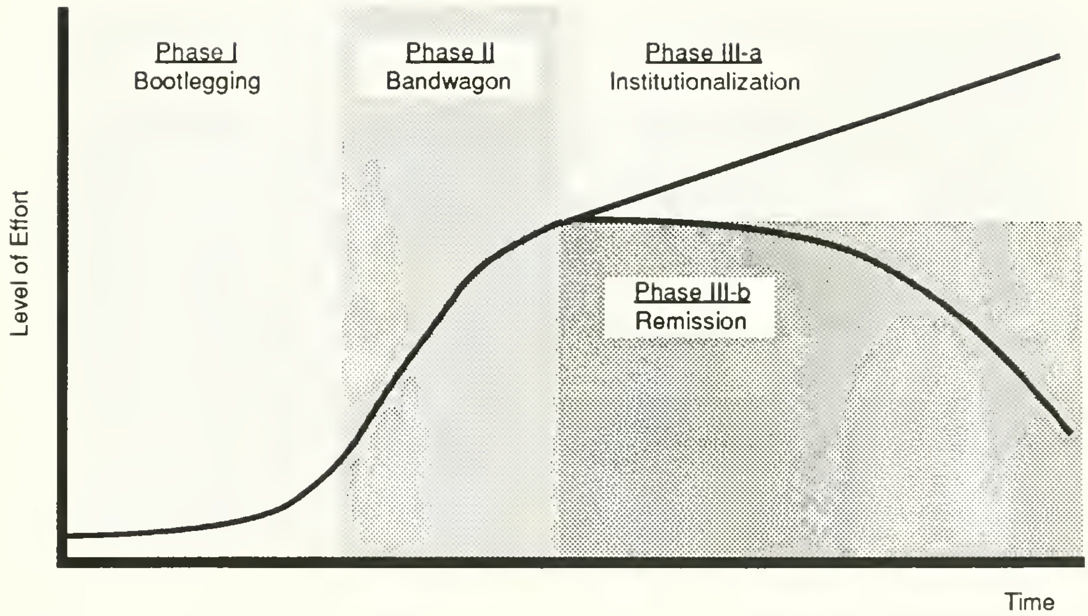

FIGURE 1: PHASE MODEL OF R&D COMMUNITY

Because of the fringe nature of their work, community members find it is difficult to secure funding, and sometimes resort to what is commonly termed "bootlegging" or "moonlighting" in order to underwrite the costs of Figure 1 their research. Not only does bootlegging spare researchers the scrutiny of accountants and funding agencies, but also protects them from the intense criticism of mainstream researchers who are likely to be competing for the same resources.

In a practical sense, there is no obvious market for the technology being developed by the community. While the scientific value of researchers work may be uncertain, the commercial value of their work is extremely difficult to see. Thus, researchers tend to have little pecuniary motivation in pursuing their line of work.

The last important characteristic of this phase is the proliferation of a variety of different technical concepts and approaches that are generated by the community. This variety may lead to a certain amount of factionalism within the community, as researchers begin to pursue distinctly different technical paths and vigorously compete against each other in the race to be the first to succeed. This last point deserves added emphasis, since it is important to recognize that researchers within a community can be intensely competitive--the norm of communal behavior notwithstanding.

The transition between the first and second phase is sharp and easily noticeable. The dominant characteristic during the second phase is the very rapid increase in the number of researchers working in the community in a relatively short period of time. This phenomenon is sometimes referred to as a "bandwagon." Putting aside the important question of why bandwagons occur and what might fuel them, it is worth recognizing simply that researchers are influenced by each other's judgments in such a way that there is a certain element of "fashion" in research.

As the community grows it typically becomes more widely distributed across organizations and geographically. This dispersion of researchers has both positive and negative effects on the functionality of the community. It is positive in that the emergence of numerous groups working independently and in competition with one another will enhance the underlying probability for solving the problems that confront them: i.e., more groups pursuing different avenues improves the likehood that problems will be solved. However, the organizational and geographic dispersion of researcher also means that the flow of communication among researchers becomes more difficult logistically--not so much because of the limitations of communication technologies, as it is because a researcher can no longer have colleagial relationships the multitude of others working in the field. When the community consists of a few dozen researchers, everyone knows each other (for better or worse) and thus the sharing of information is a manageable process. This changes dramatically when the community consists of several hundreds of researchers, the great majority of whom are new to the field and not yet socially integrated.

This is not to say that information stops flowing. As the community grows, researchers move among organizations in their capacity as students, visitors, employees, and this movement lends itself to the establishment of a network (or "grapevine") of people who know one another well enough to share information. The importance of the grapevine is not because it is the source of communal knowledge (*that* eventually gets transcribed in papers and books), but because it is the well of all communal understanding, both useful and useless. In trying to solve problems one needs to know both.

As the community grows, the competitiveness among researchers also intensifies, as does the controversy between the community and its mainstream detractors. The controversy is stirred, in part, by the tendency for some researchers to make exaggerated claims regarding the potential of the technology, or by underestimating the magnitude of the obstacles that lie ahead and the time it will take to overcome them. The situation is almost always made worse by media reports that highlight the potential impact and applications of the technology without adequately conveying the difficult problems that will still have to be solved before such events can be realized.

During this phase potential markets for the technology begin to materialize, although they are usually small niches that are dwarfed by the large markets existing for the established technologies with which it might ultimately compete. Within these niches, the emerging technology is relatively well insulated from competition, since users want the technology because it uniquely satisfies their particular requirements. Nonetheless, the commercial value of the technology is still largely uncertain.

As the bandwagon progresses, the community begins to enter a third phase. At this point one of two distinctly different paths can emerge: (a) if researchers continue to make progress in solving the problems confronting them, the community will begin to institutionalize itself, or (b) if progress begins to slow down such that researchers become discouraged, the community will begin to contract and return to the conditions prevailing in the first phase.

Under scenario (a), success is at hand: the scientific and commercial value of the technology becomes increasingly apparent, markets begin to expand, funding sources are secured, and the community begins to institutionalize. The growth rate of participation in the community will begin to stabilize at a lower level. Recruitment becomes more formalized as universities develop standard curricula and graduate programs by which students can specialize in the field. New university research centers dedicated to the field are formed, as are new firms which specialize in the development and application of the technology. Moreover, specialized journals, conferences, and professional societies are established that facilitate communication among researchers. Standards begins to emerge, easing the way for market development. In sum, what once had been a fringe group, now begins to establish itself within the academic and industrial mainstream. As it does, the role of the community in the technology's development begins to subside in favor of corporate interests.

The alternative scenario (b), illustrates a community in which progress does not meet researchers' expectations, markets do not develop, and the institutionalization process does not take hold. Under these circumstances, researchers begin to filter out of the community in favor of other more promising research topics. Recruitment of new researchers suffers, and funding sources begin to run dry. The result is for the community to revert back to phase-one conditions. This implies that over longer periods of time, communities may undergo several cyclical fluctuations before successfully institutionalizing itself.

Conclusion

This paper suggests the potential usefulness of studying R&D communities as a means of understanding the emergence of radically new technologies. A parallel is drawn between economic models of industrial structure, behavior and performance, and the study of R&D communities. Finally, a proposal is made for adopting a life-cycle model of R&D communities, which consists of three distinct phases.

A number of studies are now being conducted on various R&D communities. Results from this research should give us a better idea of how R&D communities function and what role specific structural and behavioral dynamics might play in influencing their performance.