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The Evolution of Knowledge Networks in Akron and Rochester

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Abstract

Two opposing forces reshaped knowledge networks in 'rust belt' communities over the course of the 1980s and 1990s. On the one hand, large industrial companies which for generations had stood at these places' economic, social and intellectual cores attempted to reinvigorate their own innovation processes by reaching out beyond the parochial boundaries of locales in which they resided to tap into what was seen as a richer set of conversations taking place in Europe, Asia and in the coastal regions of the U.S. But for the communities they inhabited, these actions posed a significant threat. Already stung by massive job losses, the notion that their core companies might also move processes of innovation elsewhere as well threatened not only to undermine economic wellbeing, but of the cities' identities as well. In response, community leaders developed strategies—often linked local universities—designed to reinvigorate the quality of conversations taking place in locals.

This paper analyses the experiences of two well-matched places that were simultaneously subjected to these forces. Until the 1980s, Akron, Ohio was the "tire capital of the world." Today, not a single tire is today produced in the city. Yet, many of the companies—or at least parts of them—remain located there and have shifted emphasis to advanced polymers, the general class of materials which include synthetic rubber, fibers and engineered plastics. Economic development efforts in the city have been based around attempts to build a new community of innovation around these technologies. Rochester, New York was home to several internationally prominent companies in optical-electronics. In the 1980s, these companies moved significant parts of the production process elsewhere and shifted investments in an effort to diversify portfolios. Similarly, they have also made an attempt to transition from a dependence on mass produced consumer opto-electronics to higher technology areas including lasers, semi-conductors and photonics.

Drawing on both historical matched-pairs comparison and a unique network analysis of co-authored scientific papers, this paper explores the particular trajectories knowledge networks in the cities have taken and how the particular actions of local have had concrete impacts on outcomes. In doing so, the paper sheds light on how communities can influence the trajectory of economic change through concerted attention to organizing and relationship building.

1. Introduction

Two opposite forces were acting within "rust belt" communities to reshape local knowledge networks in the 1980s and 1990s. On the one hand, companies were pushing outward in order to tap into global flows of information and knowledge; a goal which meant distancing themselves from the narrow set of parochial relationships in which they had been embedded up until that point (Bluestone and Harrison 1986). On the other, communities were attempting to maintain their place as nodes in the global network of knowledge, ideas and people associated with what one might call "the creative class" (Castells 2000; Florida 2000; Cooke 1991). To do so, community leaders sought to enact policies that would build on existing pools of knowledge and localized networks in order to facilitate and reinvigorate the quality of conversations taking place within their own borders (Asheim 1996; Morgan 1997; Storper 1995).

The two forces implied very different trajectories for knowledge networks within communities. One would expect the effect of the companies' actions to lead to a thinning out of local relationships. While companies located in the same place may draw from a common pool of employees and specialized services, but in terms of trading relationships and, most importantly in terms of their intellectual and creative relationships, their most important partners should be found elsewhere on the global scene and certainly, at least, outside of any one particular region (Markusen 1999). On the other hand, there are in fact only a limited number of places in which the most exciting and most important conversations can take place and these are places where companies congregate in order to tap into vibrant knowledge networks. Thus, in communities that are particularly successful at developing the right milieu should find the quality and density of local ties increasing over time rather than thinning out (Castells 2000).

This paper analyzes the experiences of two places that were simultaneously subjected to these opposing forces in the 1980s: Akron, Ohio and Rochester, New York. Beginning in the 1970s, companies with which these cities had become closely identified in the 20th century began reaching outside of their home community to find sources of innovative ideas. But in doing so, the companies' actions posed a threat to their home communities. In particular, communities feared they would lose further ground to places in the "subelt" and on the coasts that were quickly gaining reputations as host to more interesting, more innovative conversations

(Bluestone and Harrison 1982). Community leaders in both places responded to this threat by enacting a set of policy interventions which were designed at a minimum to maintain the knowledge base that had been built up over several generations. More ambitiously, they aimed to reinvigorate the quality of conversations among firms in ways that might approximate (or recapture) the creative cacophony that prevailed in the emerging 'high-tech' hotspots.

The bulk of these efforts were based around building partnerships between industry and local universities. By channeling access to research and development seed funds through universities, states hoped to build on universities' strong reputations in the community and their apparent pools of innovation-oriented resources to help upgrade innovation processes in these communities. However, *how* universities may or may not play in doing so is not necessarily clear. Universities have been identified as organizations whose actions and interactions can help to create "institutional thickness" (Amin and Thrift 1992; 1994) and "institutional capacity" (Phelps and Tewdwr-Jones 1998). As such they may be thought of as increasing overall stocks of "social capital" or social connectedness (Portes 1998; Portes and Sensenbrenner 1993**;** Woolcock 2000) with the university acting mainly as a catalyst and facilitator, but not necessarily a primary "hub." On the other hand, universities may be in a position to act as a bridge filling the structural holes that exist among disconnected actors in communities (Burt 1992) and, in doing so, help to efficiently channel the kinds of tacit knowledge necessary for innovation.

Twenty years later, it is possible both to assess the impact of these opposing forces on communities and of the particular role universities may or may not have played within them by analyzing and comparing how patterns of conversations have evolved in these two places. To do so, this paper draws on a unique source of empirical data: networks of co-authored scientific papers. Many science-based companies have found it in their interest to encourage employees to publish findings in scientific journals. Indeed, the best and brightest potential employees actually pay a premium in terms of wages in order to do so because of the prestige and satisfaction associated having one's work appreciated by one's peers (Stern, 1998). Publications can also result from collaborations across companies whether through informal interactions or the result of formal partnerships. This is likely to be particularly true when collaborations involve university partners for whom publications are, of course, the coin of the realm. Many universities, in fact, make the potential for such publications a prerequisite for engaging in collaborations in the first place.

By analyzing the evolving patterns of collaboration in these two well matched cities over this critical period of time, it becomes possible to gain insight into several important questions. The first is simply: What has been the balance achieved between the opposing impulses of outward looking companies and the attempts of localities to invigorate the local scene? Interestingly, two different answers emerge from this investigation. Today, Akron's major companies are far less parochial than they once were, but their new found cosmopolitanism has come mainly as a result of large companies engaging in conversations well outside the region. In Rochester, the overall proportion of conversations taking place within the region itself has actually increased. Rochester's major industrial companies are more likely today than in the past to collaborate with local organizational actors—particularly local universities. Local universities, in turn, are today more likely to be engaged in conversations with small, entrepreneurial companies. Despite the fact that the large local firms have reached out to establish ties elsewhere (famously so, in the case of Xerox and its Palo Alto Research Center), the city's networks have become far more vibrant than they were in the past.

Because the cases were selected in such a way as to facilitate comparison, we can probe further into both the cases and the consequences of these different trajectories to shed light on several other questions as well. First, to the extent that one thinks of the pattern and quality of relationships in a community as reflecting is stock of "social capital" (Putnam 1993; Portes and Sensenbrenner 1993**;** Woolcock 1998) then these data provide evidence to correlate this concept with concrete, socially beneficial, outcomes. Indeed, the data make it possible to see how social capital has had an impact on one important outcome in particular: levels of entrepreneurship in the two communities. Specifically, because the universities took approaches to engaging industry that essentially conform to the two ways in which theory suggests—that is, institutional and "social capital" building versus structural holes bridging—the data actually help us to understand *how* community and state actions help shape outcomes. In doing so, the longitudinal and qualitative nature of the research allow for insight into how state actions can (and possible should) contribute to building social capital (Evans 1996).

The paper proceeds as follows. The next section provides a (relatively lengthy) discussion of the methods. The second section establishes the context with a brief history of the two cities' industries and of the technologies with which they are identified. The network analysis follows in the third section with data on the evolution of knowledge networks in the two places. The fourth section discusses the impact these changes have had on how innovations are produced in the cities. The paper concludes with some tentative insights that emerge from this analysis on processes of institutional change.

2. Methods

Following Markusen (1999), the principal assumption of this research is that organizations' strategies create the character of regional economies hosting them, not the other way around. However, it is also assumed that these strategies emerge from a negotiated order in which any one organization's strategies necessarily emerge and evolve in relationship to the strategies of the organizations with which they interact (Nelson and Winter 1983). In seeking to understand how knowledge networks have evolved it is necessary both to gain a sense of the unique perspectives and constraints organizational actors bring to the process of crafting strategies and of the environment in their sense making takes place (Weick 1973).

To do so, this research combines two methodological approaches which, although complementary, have only been rarely used in conjunction with each other. The first is historical-comparison based on the method of similarity (Skocpol and Somers 1980). Under ideal conditions, the method of similarity compares two contexts that are similar with respect to all potential explanations except for (a) the variable one is trying to explain and (b) the proposed explanation for those outcomes. In reality, of course, it is never possible to achieve an exact match. Many mitigating circumstances inevitably muddy the water. Nevertheless, comparative approach is not intended necessarily to "prove" a given finding. Rather it is simply to present cases in such a way as to allow insights to emerge; the approach strikes a middle ground between richly detailed, but non-generalizable case methods and sterile, thought apparently more rigorous 'big n' analysis. The key is careful case selection and a full accounting of the similarities and differences between cases. The first part of this section therefore establishes the basis on which the cases are to be compared. The section that follows then describes the methods used in collecting historical and interviews-based data on the recent experiences of these two places.

The second methodological approach employed is network analysis.[1] An assumption that underlies this research is that conversations matter in the process of innovation. Furthermore, it is assumed that it is not only the quantity or even the quality of conversations that matters; their also, vitally, the pattern and structure as well. The degree to which one comes into contact with information that is different from what one already knows is determined, in part, not only by the conversations one has, but also by the conversations one's interlocutors have as well (Granovetter 1973). Moreover, one's positions within the overall structure of conversations in a community can carry both responsibilities and opportunities depending, for instance, on whether that position allows one to play a "brokerage" role potentially linking two pools of knowledge and language that are otherwise disconnected (Fernandez and Gould 1994). Network analysis is ideally suited to gaining the overarching view of the pattern of conversations within a community one needs in order to ask and answer questions about the quality, quantity and structure of conversations in a community. To do so, this paper draws on a unique data source in doing so: co-authored scientific papers. The second part of this section describes these data and the techniques used to analyze them in more detail.

2.A Case Selection and Comparability

There are three relevant dimensions on which the claim of comparability in this research is based: (1) the industrial composition and organizational infrastructure of innovation; (2) the comparability of the cities' core technologies; and, (3) demographic, geographic and social comparability of the cities more broadly. A fourth section describes data gathered from interviews among relevant actors in the two cities.

- **Industrial Composition and the Institutional Infrastructure of Innovation in 1980**

The primary dimension on which the selection was made concerns the concentration and industrial organization of the local economies. What stands out immediately about the two places is the fact that each has historically been home to technology-based mass production industries in which a troika of major industrial companies took predominate roles. In Akron, that industry was tires. As home to four of the five leading American tire makers, it was known as the 'tire capital of the world.' Rochester was identified with its three major companies,

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[1] On network methods generally, see Wasserman and Faust (1994)

Kodak, Xerox and Bausch and Lomb, all of which shared a common technology base around optoelectronics. In both cities, a broader set of organizations and institutions developed in relationship to their core industries including cadres of small niche producers, suppliers, equipment manufacturers, universities, professional associations and unions.

Table 1 contains data showing the relative size and distribution of companies in the two cities into three categories: major industrial firms, small and medium sized technology-based companies and finally small and medium sized companies with a low to medium technology base. Companies with over $1.5 billion in revenues in 1980 were included in the category of major industrial firms. Companies were assigned to the first of the two categories of smaller firms are based on whether they were included in one of two corporate research and development directories: the 1986 CorpTek (first available) and Bowker's Directory of American Research and Technology for 1982. Remaining companies were assigned to the last category. The table shows that both cities had approximately equivalent structures in 1980. Together, Akron' four major tire companies – Goodrich, Goodyear, Firestone and General Tire – contributed $X billion in revenues to the city's economy in 1980.[2] Rochester's three major opto-electronics companies – Eastman Kodak, Xerox and Bausch and Lomb – contributed approximately $ X billion that same year.[3]

Both cities, moreover, had a relatively robust group of smaller technology firms which are fairly comparable in terms of numbers. However, they differ somewhat with respect to size. Akron's smaller players were relatively larger companies in 1980 than Rochester's (FILL IN…).

It proved difficult to gain an accurate representation of the third and last category in Table 1: smaller, low- to medium-technology companies which in both places in the 1980s. The data presented were gathered from a variety of sources including counting the number of companies that exist today that were founded before 1980, data gathered from a few local industrial histories of the cities and finally web and lexis-nexus searches which produces a few companies

[2] A fifth major industrial firm, Babcock and Wilcox, was headquartered within the Akron metropolitan statistical area as well but was not included because its primary and secondary industries were not directly related to polymers, but rather to the manufacture of power generation equipment. However, as will become apparent later, possibly because it was not related to the other firms with respect to their core technologies Babcock and Wilcox was an important node in the city's knowledge network.

[3] FINANCIAL DATA ON THESE COMPANIES IN THE 80s IS LAST PIECE OF INFORMATION I NEED TO GET! THIS SECTION IS THEREFORE SOMEWHAT INCOMPLETE. NEED TO CONSULT MOODYS.

not otherwise found through other means appearing on resumes posted on line and in obituaries. These data are therefore incomplete. However, they at least give an indication of the magnitude and comparability of low-tech producers. While the number of such firms is relatively larger in Akron, both places were clearly home to significant clusters of companies in these two technologies.

Also, since local universities are a potential determinant of the trajectory of these places, Table 2 presents data comparing the major research universities and polytechnics in the two cities including data on departments within each that specialize in the technologies with which the cities are identified. The data indicate several similarities and differences. The University of Rochester is more comprehensive than its counterpart, the University of Akron. In addition both of Rochester's universities are private institutions whereas their counterparts in Akron are public. Nevertheless, the universities' capabilities with respect to the core technologies addressed in this research are quite similar as measured by levels of funding from industry, patenting, rates of scientific publication and independent national rankings.[4] Mitigating the public-private issue is the fact that both universities have benefited from (and been constrained by) state and federal policymakers efforts to channel innovation-oriented economic development efforts through university-sponsored programs—Rochester's universities are in no way independent from the state's influence. At the same time, the universities' pertinent industry-related research departments maintained long standing relationships to local industry that were both philanthropic and intellectual with relatively few distinctions drawn from the public or private nature of their parent institutions. Thus, given the goals of this research, one can safely conclude that the similarities of the two universities outweigh their differences.

- **Comparability of the Regions' "Core Technologies."**

A second point of comparison concerns the technologies themselves. On first glance, the comparison of these two places may seem questionable given the differences in the technologies involved. However, on closer inspection, it becomes clear that, while certainly there are differences between them, the technologies are not as different as one might initially assume. Table 3 ranks the research intensity of twenty-four major industries in the United States as

[4] In addition, it should be noted here that I made an explicit decision to exclude organizations with primary headquarters in the Cleveland metropolitan statistical area from all data pertaining to the comparison of these two cities. This decision is motivated out of the desire to keep the comparison as straightforward as possible. Nevertheless, the choice leaves out several important pieces of that city's economy. The important role that Cleveland based Case Western Reserve University, a private comprehensive research university that perhaps more on a part the University of Rochester with respect to the breadth of its programs, is one of them.

indicated by the ratio of research and development spending to revenues. The data show that the two categories into which the cities' industries fall—for Rochester, 'other computer and electronic products' and for Akron, 'resin, synthetic rubber and fibers'—the industries are about as well matched as one could hope with 5.9% of revenues spent on R&D in the case opto-electronics and 5.6% spend in the polymers industry. Graphs 1.a and 1.b present data on the number and geographic distribution of patenting activity in the two industry in five year intervals since the mid-1970s providing further evidence of the technology's comparability. At the outset of this period, significantly more polymers patents were being produced when compared to optoelectronics. But by 2000, the two industries were producing approximately the same number of patents at around 15,000 issues per year (or 75,000 every five years).

The figures also give an indication of the place the two cities maintain in the global patterns of knowledge and innovation with respect to these technologies. Between 1976 and 1980, Akron inventors accounted for approximately 7% of all polymers patents and, in recently years are responsible for approximately 5%. Rochester companies contributed 12% of optoelectronics patents around 1980 and today account for about 9% globally. Thus, in both cases, the cities have lost some ground in the last two decades but nevertheless remain important locales of innovation.

- **Demographic, geographic and social comparability**

Independent of their respective industrial bases, the cities themselves are also quite comparable. Table 4 presents some basic indicators of the city's demographic composition. They show that Rochester is a slightly larger city at about 1,000,000 residents compared to Akron's nearly 700,000. However, when one includes adjacent metropolitan areas, it becomes clear that Akron is in fact located in close proximity to a larger extended metropolitan area that is home to nearly 4,000,000 residents compared to Rochester's extended region of around 3,000,000 inhabitants. As indicated in Figure 1, Akron is located just 40 miles south of Cleveland and is, in fact, fairly well integrated into a consolidated regional economy encompassing Northeast Ohio in which Cleveland is the primary city. Rochester's closest neighbor is Buffalo which, like Cleveland, has a fairly large and diversified manufacturing, finance and services based economy. Significant linkages between the two Western New York cities exist. But they are not quite as closely intertwined as is the case between Akron and Cleveland. Nevertheless, as the map presented in

Figure 1 also shows, the cities are situated in similar proximity to many of the major industrial centers of the northeastern U.S. within the Great Lakes basin.

Finally, Table 5 provides some base line indicators of the cities "innovative capacity" which are drawn from an assortment of measures that have been advanced by a variety of researchers in the last several years. The first two measures show data relating to the concept of "job sprawl"—the notion that people and employment have moved out central business districts in recent decades and in to relatively disbursed suburbs (Glaeser and Kahn 2001). This might affect innovative capacity to the extent that proximity encourages interactions that might lead to innovative new ideas and new approaches. Both cities score in the top quartile of larger metropolitan areas in the U.S. in this respect with 27% and 33% of jobs located within three miles of the city's central business districts in Akron and Rochester respectively; both of which are above the average for cities in the Northeastern United States. Furthermore, in Rochester, nearly 82% of jobs are located within ten miles of the central city which is significantly higher than other cities. Thus, in both cities, jobs are concentrated proximally in ways that would at least not preclude interaction.

Two indicators of social structure are presented next. The first shows the percent of local religious adherents who worship in the Catholic Church. Some cultural theories of innovation have attributed a lack of innovativeness within societies to hierarchical cultural structures with the primary example of such a structure being the highly bureaucratic Roman Catholic Church **(CITE)**. In both places, Catholics represent the largest single religious denomination as indicated by the relatively strong concentrations of Catholic adherents. The second is a measure of gay and lesbian households taken from a recent question included in the U.S. Census. Florida (2002) and his students have argued that this figure represents a measure of the openness and tolerance within communities to differences of lifestyle and opinion—traits that they assert are vital to the innovation process. The data show that Rochester has a relatively higher population of gay and lesbian-headed households although both are well within the standard deviation from the mean which is 0.25.

2.B Data Collection: Archival and Interviews-Based Data

Having established the basis on which the cases were selected, this part of the paper describes the historical and qualitative methods that provide a sense both of the context and of the particular actions and interventions undertaken in the two places in the last 20 years.

Interviews were conducted among individuals likely to be knowledgeable about how knowledge networks in the two cities and how it had changed. Since networks were the "dependent variable", so to speak, I conscientiously avoided using industry association lists and university-suggested contacts as a means of selecting potential interview participants since these sources of information were likely to lead to only certain parts of the networks. Interviewees were therefore identified by compiling a list representing the universe of organizations in the two cities with capabilities in the cities' core technologies. Companies were categorized according to size and "innovative capabilities" as determined by mentions in relevant directories as well as the number of patents and publications. Companies were initially identified from a concordance of both Dun and Bradstreet data[5] and an exhaustive search of yellow-pages directories[6]. In addition, smaller entrepreneurial companies identified from databases containing the names and addresses of SBIR award winners[7] as well as from companies that had received venture capital funds.[8] Web searches[9] and a search of newspaper articles on lexis-nexus[10] were conducted in an effort to find firms going back in time that were mentioned either in industrial histories, reports or, in a few cases, obituaries. Historical data on private research and development laboratories came from various years of the Directory of American Research and Technology (Jacque Catell Press 1965, 1974, 1983, 1992, 2001) as well as CorpTech (1985 and 2002).

Among large industrial companies, interviewees included two CEOs, several Vice President for Research and Development as well as primary liaisons for University-Industry Relations. Among smaller companies, interviews were almost always conducted with company presidents or marketing specialists. At the universities, interviews included in university Presidents as well as members of their external relations teams as well as the Dean or a prominent faculty member associated with relevant research departments. An effort was also made to identify key informants among "third party" organizations including labor market intermediaries, one self-described "research

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[5] Available online at www.hoovers.com (subscription required for full access)
[6] Available online at www.referenceusa.com (subscription required)
[7] Available online at www.zyn.com/sbir/
[8] Available online at www.ventureeconomics.com/ (subscription required)
[9] Available online at www.goggle.com
[10] Available online at www.lexis-nexis.com (subscription required)

commercialization catalyst," the leaders of industry associations and the leaders of important professional associations. In total, 45 interviews were conducted (see Appendix A for a list of interviewees). Comprehensive notes were taken at each interview and most were recorded and transcribed. Interviews typically lasted about one and a half hours. While all of the interviews were open-ended (Piore 1979), a consistent theme among interviews involved identifying various kinds of organizational crises—the loss of major customers, technological discontinuities, changes in supplier relationships, regulatory changes—to understand how organizations reacted to those crises and how their reactions affected or were affected by the organizations' relationships to other organizations both in inside and outside the district. In particular, crises that affected similar companies were probed through further questioning.

Wherever possible, secondary data from newspaper interviews, analysts' reports, published accounts, data services and company websites were used to corroborate and extend information gathered in the interviews. These were perused to provide an overall impression of the trajectories these companies have taken in the last thirty years as a check on the generality of trajectory of companies that chosen for interviews. To gain a sense of innovative output, data on patenting and scientific publications were gathered from US Patent Office Data[11] and from the Science Citation Index[12].

2.C Network Analysis Methods

The similarity of the industries, technologies and histories of these two places combined with the simultaneity and comparability of the problems they faced in the 1980s provides a unique opportunity for comparative analysis. One particularly interesting aspect of what has unfolded in these communities concerns what happened to the pattern of conversations taking place among companies. Network analysis provides a set of techniques for describing and analyzing these patterns. In combination with the comparative historical and interview data, these techniques give an overall sense of how these patterns have evolved and the forces that shaped their evolution.

The data for this analysis were collected on co-authored publications appearing in peer reviewed scientific journals. Many companies engaged in science-based industries have found it in their interest to encourage employees to publish findings in scientific journals. Indeed, the best and brightest potential employees actually pay a premium in terms of wages in order to do so (Stern, 1998). Publications can also result from collaborations across companies whether through informal

[11] Available online at www.uspto.gov
[12] Available online at http://isi2.isiknowledge.com/portal.cgi/wos (subscription required)

interactions or the result of formal partnerships. This is likely to be particularly true when collaborations involve university partners for whom publications are, of course, the coin of the realm. Many universities make the potential for such publications a prerequisite for engaging in collaborations in the first place.

Most conversations among innovators—indeed, probably the vast majority of them—are never recorded let a lone published. But, the ones that are published are likely to involve a large portion of the newest and best ideas. These ideas, moreover, are ones that emerge through the structured process of collaborative research and writing; a process that embodies the kinds of collaborative, creative conversations this paper seeks to observe. Given the goals of this research, the pattern that emerges from these collaborations is therefore likely to give fairly accurate indication of just the kinds of conversations one would be most interested in seeing unfold.

Data were colleted over three year intervals at two points in time: 1980-1982 and 2000-2002. The same database on which interviews were selected was used to indicate the universe of innovative companies in both cities at those two periods of time. Web of science searches on these companies were conducted and data on authors' names and organizational affiliations for each publication on which at least two names appeared. A slightly different approach was used to gather data from universities. Rather than search for all co-authored publications in the relevant disciplines—which would have produced an overwhelming number of potentially irrelevant ties—data were collected only for those faculty and students who showed up as having collaborated with local co-author in industry. Individual searches were then conducted on each university-based co-author which revealed any companies—inside or outside the region—with which they had also co-authored papers. This procedure, therefore, provides a good indication of what role they may be playing in "brokering" or "bridging" information.

With this data in hand, authors/organizations [m] were arranged on one axis and publications [n] on the other creating an [n x m] matrix. This matrix was then transformed to produce an [m x m] matrix [MM'] in which each cell represented the number of papers on which a given pair of authors appeared together on the same paper. This procedure produced a complete affiliation network. It is an affiliation network in the sense that it takes its data from joint participation in a common event, the assumption of which is that the participants have some kind of a relationship either before or after the event. It is complete in the sense that it produces information not only the ties do exist among individuals in a network, but also one which ties *do not* exist as well (see Wasserman and Faust 1994)

The data are presented in two different formats. The first is a graphical representation of ties in the network. This network map was produced by submitting the data to Pajek, a software program designed for large network datasets which contains several different protocols for arranging the various nodes and arcs of the network in meaningful ways. The data presented here subjected to a Fruchterman-Reingold 3d protocol in which the nodes and arcs are arranged in such a way as to make it possible to see the overall pattern of ties. The data are arranged mainly to allow for an analysis of the overall pattern of relationships among all of the nodes taken together and does not necessarily provide an objective assessment of how "close" they might be or of the "strength" of ties. The data in these maps are presented on the highest level of aggregation that the data allowed—full organizations. Data were collected at the sub-organizational and, of course, individual level as well. However, presenting those data in graphical form would not have been meaningful with the tools and space limitations of this particular project.

The second way in which the data are presented is through a block model of ties. This procedure categorizes organizations into several buckets or "blocks" and then analyzes the density of ties within and among these blocks. This procedure allows one to compare the structure of relationships both across cities and over time. The significance of differences among the data contained in the block models were tested by means of chi-square contingency tables. However, because most of the ties for any given organization—and therefore any given block of organizations—are primarily sent and received within one's own organization, these data were badly skewed—a violation of the assumptions of chi-square procedures. To reduce some of the skew, the data were transformed by means of taking the natural log. This however was also problematic since it produced numbers that were, generally, too small to work according to chi-square assumptions. The data were therefore transformed once again by multiplying them by ten. Two degrees of freedom were taken away as a result of these transformations.

Having established the ground on which the comparison is to be made and the methods used to analyze them, the next section provides a brief introduction to the cities and the emergence and decline of the industries that came to define them in the 20th century as well as the actions undertaken by organizations in response.

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3. The Context: Akron and Rochester in Historical Perspective

The Silicon Valleys of the Second Industrial Revolution had names like Akron, Detroit, Pittsburgh and Rochester. In the late 1800s, would-be entrepreneurs from around the world flocked to these places in order to tap into the excitement—and riches—that came form making one's name in emerging technologies and industries. Successful companies that would go on to become industrial giants in the 20^{th} century emerged from the cacophony that prevailed in these cities around the turn of the century.

Akron was known for much of its history as the "tire capital of the world." In 1870, Dr. Benjamin Franklin Goodrich, a New Yorker who had earned his medical degree in Cleveland a decade earlier, emigrated there with the intention of establishing the first American rubber company west of the Appalachian Mountains. By the turn of the century, Goodrich's company had grown into a large establishment supplying rubber tires to the U.S. Army for its new fleet of airplanes. At least twenty other small and medium sized rubber-producing companies emerged in the city over the intervening period as well. Among them were several firms that would go on to join Goodrich as internationally prominent industrial companies in the 20^{th} century including the Goodyear and Firestone Tire and Rubber Companies; each of which grew to prominence as suppliers of tires to the automobile industry.

In Rochester, Bausch and Lomb emerged out of the immigrant enclave of skilled German lens makers as the country's first mass-producer of eye-glasses, goggles and microscopes. It was partially out of this cluster, as well, that Eastman Kodak would eventually emerge on its way to becoming the world's leading producer of cameras and photographic film. Finally, in 1906, the Haloid Corporation was established as a maker of specialty photographic paper filling a niche that had been neglected by Kodak. By the 1960s, Haloid had transformed itself into Xerox, the world's leading producer of photocopiers.

As is briefly sketched below, all of these companies stumbled badly in the 1970 and 1980s as they started facing stiff foreign competition setting off a series of reactions among different kinds of actors. Companies, firstly, began to distance themselves from their place at the very center of civic, economic, political and economic life in these two cities. The most wrenching impact of this distancing was felt in the loss of thousands of jobs among production workers. Between 1977 and 1982, manufacturing employment declined by over 29% in Akron while

Rochester lost over 17% of its manufacturing jobs between 1982 and 1987.[13] These were among the over 3.6 million manufacturing jobs lost in the eight states that border North America's Great Lakes—a region that collectively became known as the 'rust belt' over this decade of time (Harrison and Bluestone 1982).

To stem further decline, government and business leaders in these and other mature industrial cities resolved to partner with companies in order to support their restructuring efforts. But they had an ulterior motive in doing so; they hoped to influence these companies in ways that would ensure they maintained high-end scientific and engineering jobs in place. Among the policy interventions that emerged from these efforts, communities encourage research universities to take on a more significant role in addressing these companies' needs. In large part, these efforts were directed at upgrading the skills of the population in order to meet the skill requirements of increasingly demanding employers. But at the same time, it was hoped that universities could somehow help to reinvigorate companies' innovation process as well. Their goal in doing so was to encourage companies to move toward high technology—high value added—products; although, in general, states left it up to the universities and their potential industry partners to define exactly how this arrangement would work in practice.

This section provides a brief sketch of the events that led to the crisis in the 1980s and of the ways in which key actors responded.

3.A The Challenge to the Industrial Paradigm in the 1970s and 1980s and the Responses of Firms: Akron

Over the course of the 20th century, Akron's tire companies posted tremendous profits by faithfully producing incremental improvements in tire designs based on what was learned during the War effort.[14] Unfortunately, the tire makers devoted most of their attention to domestic automakers' requirements for new car models coming out of Detroit—a part of their business that accounted for only about 40% of sales. The remaining 60% of the companies' tire business consisted of the retail replacement market sold directly to consumers through a network of retail establishments. When the French company Michelin launched a frontal assault on the U.S. replacement tire market in the 1970s, Akron's tire companies were caught short. Investing in

[13] U.S. Bureau of the Census, City and County Data Books, 1988 and 1994.
[14] On Akron's industrial history, see Love and Giffels (1999); Blackford (1996); Nelson (1988). This section draws heavily on Sull (1998; 2001).

excess of $100 million in five new factories, Michelin introduced its radial tire in 1972 which was an improvement on Akron's dominant cross-ply bias tire design providing a longer lifespan and lower fuel consumption.

The major American tire producers had ignored the threat and continued to focus on Detroit (Sull 1998). Unfortunately, the automakers also stumbled as the OPEC oil crisis abruptly shifted demand toward smaller cars with less fuel consumption. Customers began purchasing radial tire as replacements and Akron's tire makers suddenly felt the looming threat. The industry finally reached a crossroads in 1976 when the United Rubber Workers struck American tire companies, en masse, for 106 days. Michelin, Italian producer Pirelli and Britain's Dunlop were each able to take advantage of the opening and to make significant inroads into the American tire market.

Akron's tire companies responded to these events by moving in three directions simultaneously: diversification, investment and reorganization. The companies' diversification led them to acquire unrelated companies in industries market steady, stable demand such as utilities, communications. The addition of these firms to the tire companies' portfolios was intended to create a buffer against market cyclicality which had become a more significant problem as tire prices came down and the market began to take on properties of a commodity. At the same time, however, the companies began to invest more heavily in developing new, fast growing applications of their existing technologies by extending them into new markets such as aerospace, building materials as well as faster growing technologies including advanced polymers and commodity and specialty chemicals.

All of the companies pursued these two strategies to one degree or another. Nevertheless, two different camps emerged with respect to which one was emphasized. Goodyear and Firestone made the strategic decision to maintain their identities as tire companies first and aerospace and chemicals companies second. With 24% of the American market in tires, Goodyear in particular had decided to face its foreign competition head on by reinvesting in the innovation process and also by counterattacking foreign producers in their home markets. It signaled its approach by investing $75 million to refurbish a large tire factory in Akron as its new corporate headquarters and home to its primary corporate R&D labs. In addition, the company announced that would spend $125 million to establish a second Technical and Research Center in Luxembourg, Michelin's back yard.

Goodrich and General Tire took the opposite tack and decided to distance themselves from the tire business. Goodrich doubled its investment the production of polyvinyl chloride (PVC), a plastic resin that was just then gaining popularity as a material in building and construction supplies. At the same time, it moved in the direction of transforming itself primarily into a chemicals company. General Tire, on the other hand, embarked on a series of acquisitions, the capstone of which was its purchase of a California-based aerospace company.

Perhaps not surprisingly, the two camps also differed in their approach to the reorganization of production. Goodyear and Firestone invested heavily in new equipment and processes that would allow them to compete more effectively with foreign competitors. To do so, they built new facilities in regions of the country where cheap labor was available rather than investing in renovating existing factories in the North. At Goodrich and General Tire, investment in tires production simply began to lag as they shifted investment to more lucrative areas of their business. Both companies eventually sold their tire businesses to foreign competitors who quickly consolidate their holdings by shutting down virtually all of the companies' Northern production facilities.

Regardless of the particular strategy, the impact on Akron's large population of rubber workers was the same. Between 1975 and 1980, Akron's tire companies closed 20 cross-ply tire plants throwing nearly 40,000 workers onto unemployment lines. Twenty-five thousand of those works came from Akron. By 1985—just 15 years after the first Michelin radial tires landed at an America port—the city of Akron had stopped producing tires intended for passenger automobiles. A massive wave of consolidation in the industry ensued. Goodrich sold its tire holdings to U.S. Rubber in 1987 in order to focus on its chemical and aerospace businesses. U.S. Rubber, in turn, sold its own tire business—including the former Goodrich holdings—to Michelin in 1990. In 1989, Bridgestone of Japan acquired Firestone and moved its American headquarters to the Southern state of North Carolina. General Tire changed its name to GenCorp in 1984 and sold its tire plants to Continental Tire soon after. GenCorp remained headquartered in Akron and moved heavily into polymers, auto-parts manufacturing, chemicals, communication, energy and aerospace. In 1998, the company spun-off its polymers related-operations (which remained in Akron) and moved its headquarters to California. Thus, by the mid-1990s, Goodyear was the only major tire company still headquartered in Akron.

3.B The Challenge to the Industrial Paradigm in the 1970s and 1980s and the Responses of Firms: Rochester

In 1965, Kodak's share of the world consumer film market was in excess of 90%, Xerox sold 75% of the world's copiers and Bausch and Lomb produced 40% of the world's eyeglasses. These stratospheric market shares, however, were challenged beginning in the 1970s and then dramatically so in the 1980s. The first challenge to Kodak came from a domestic competitor—the Polaroid Corporation's instant camera first produced in 19XX. Soon, however, the company faced a more significant threat from Japan's Fuji Film Company. Unlike the threat that faced the tire companies from Michelin's radial tire, Fuji's innovation was not technological—its advantage was cost. Having established a strong distribution network in the United States, it began chipping away at Kodak's dominance abroad and eventually in domestic markets as well. Xerox also came under competitive pressure including major threats when, in the 1980s, both Kodak and IBM both started to produce a high-end copier system for use in large office setting. A more significant threat emerged from the Japanese company Cannon, which made headway into the more profitable lower end of the copier market.[15]

Like Akron's tire companies, Rochester's large industrial companies sought to buffer against these shocks by diversify their holdings. And, like Akron, the different companies did so in very different ways. Kodak distributed resources among what were seen as a more stable set of industries including chemicals and pharmaceuticals. At the same time, the company attempted to move its research efforts into fast growth areas both by concentrating on creating advances in their core products—cameras and film—and by moving aggressively into new areas such as LCD displays and semi-conductors. In doing so, however, they never considered abandoning their core identity as maker of film and related equipment. Xerox, on the other hand, was more ambitious. Though it faced some competition – both from its homegrown neighbors Kodak and IBM which both produced high-end copiers and from the Japanese company Cannon at the low end – it enjoyed steady strong demand for its copiers. It sought to build on this steady income stream by diversifying into more lucrative technological areas. In the 1970s Xerox bought printer, plotter, and disk drive businesses, as well as record carrier Western Union. It also embarked on a plan to into the computer business and signaled its commitment by building

[15] See generally, McKelvey (1993); Buttino (1984); Swasy (1997); Collins (1990); Howe (2002); Hitzik (1999); Kearns and Nadler (1992)

a major new research arm in Palo Alto, California.[16] In the early 1980s, the company moved its headquarters to Connecticut. It nevertheless kept production, headquarters and R&D of its office products division—which included copiers—located in Rochester.

3.C Companies' Efforts to Shift to Science-Oriented Economic Base: Akron and Rochester in the 1980s

As touched on above, one of the three pillars on which industrial companies based their strategies in the 1970s was to diversify resources by investing in potential high-growth areas associated with their core technologies. In Akron, that technology was polymers chemistry which is the science of long molecules that give rise to materials ranging from basic the plastic resins that make food wrapping to more sophisticated materials such a crystals (which, for instance, make flat screen displays possible) and the advanced materials necessary for extreme conditions such as space flight. Rubber is a naturally occurring polymer. But, to make it useful for most commercial applications requires a surprising amount of sophisticated processing. With the onset of the Second World War the Japanese gained a stranglehold on the supply of natural rubber which was located on vast plantations—owned and operated by American tire makers—in the South Pacific. Companies in the United States were forced to accelerate the search for a synthetic replacement leading to an expansion in the technological capabilities of the companies. Already tied into the flow of raw materials, this proved to be a catalyst toward the development of sophisticated polymers capabilities among the tire companies which would prove to the basis on which the city's economic future has come to rely.

All of Akron's tire companies had built significant commodity plastics businesses by the 1970s with BF Goodrich and Firestone becoming increasingly dependent on these divisions as sources of revenue. The tire companies joined the ranks of several other nearby firms that were significant commodity producers of plastic resins including Ferro Corporation, headquartered twenty miles north in Cleveland as well as several smaller local custom resin compounding companies including M.A. Hanna and A. Schulman.

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[16] Xerox's Palo Alto laboratories became a prodigious contributor of many important innovations including the laser printer, the computer mouse and the Ethernet. However, none of these innovations were ultimately commercialized by Xerox.

Figure 2.a shows the structure of the polymers industry and the place Akron has assumed within it. The supply chain in polymers begins with the producers of raw materials, a multi-billion dollar segment of the chain dominated by large petroleum and chemicals companies such as ExxonMobil, Monsanto and DuPont. Materials are then channeled to compounders which mix the materials in various combinations to produce specific resins. Some of these materials—like PVC and polyurethane—are standard and produced in very large batches which are then sold for processing by producers ranging from small scale plastics injection molders to large industrial users such as automotive and appliance makers.

In Rochester, the shift toward optical electronics followed a similar pattern. Figure 2.b shows the structure of the optical-electronics supply chain. The emergence of the three large industrial companies in Rochester was preceded by the establishment of a small cluster of optical lens makers in the nineteenth century. Initially intended mainly for eyeglasses, the city's large consumer-oriented industrial companies would eventually provide a market for more sophisticated optical components. As the large companies diversified into computer technology, instrumentation and satellite applications in the 1970s, they demanded even more sophistication. The troubles the large companies faced in the 1980s led to disruptions for local suppliers. These companies were forced to look outside the region for customers and opportunities as a result.

3.D University-Industry Partnerships

The competitive challenge and the dramatic declines in production employment that followed sparked crises in both cities. As the large companies shifted resources to faster growing industries—which were increasingly being located in places other than Akron and Rochester—civic, government, and business leaders grew fearful that their cities would follow the same "hollowing out" path their "rust-belt" neighbors had begun to experience. They called on the local universities—particularly the major research universities located in the cities—to take a more active role in supporting companies' innovation efforts.

In fulfilling this mandate, however, the universities in the two cities took significantly different approaches. As this section explains, in Akron, the approach most closely resembles Burt's (1992) notion of bridging structural holes, in this case, between the research taking place inside university labs and the research and development laboratories of companies. In Rochester, the approach can be characterized as coming closer to building 'institutional thickness' (Amin and Thrift 1994) and 'social capital' (Portes 1992).

- **The University of Akron**

The history of the University of Akron's interactions with the polymers industry stretch back to the 1930s when Professor Frank Knight began holding an evening class at which scientists and engineers from the city's rubber companies would gather for seminars.[17] The Second World War brought a more formal arrangement as the University became a significant node in the U.S. federal government's effort to build a domestic synthetic rubber industry as a substitute for the natural rubber supplies which had been cut off by Japanese expansion into the South Pacific. That history laid the groundwork for a transition to the development of a top-notch research department in materials science. In the 1950s, researchers at the University started to work with cutting edge technologies associated with long molecule polymers. By the 1970s, the University was rated among the top four Ph.D. programs in polymers science along with MIT, the University of Massachusetts, Amherst and Case Western Reserve in nearby Cleveland.

From the University's perspective, however, these calls were not immediately seen in a positive light. As one prominent informant put it, the university got "dragged kicking and screaming into economic development." University leaders eventually assessed their capabilities and their values as an institution and decided that it was in a position to do two things to assist the community's economic development efforts. The first, was to continue doing what it had already been doing for decades: turning out highly qualified scientists and engineers. Many of those workers remained in the region to start families and, in doing so, became a significant locally embedded resource to support companies' efforts. The second, was to add a set of capabilities that could help address the problem solving needs of local industry.

- *The Edison Polymers Innovation Corporation*

In 1983, a consortium of university and corporate leaders approached the State of Ohio to apply for a grant under the state's Thomas Edison technology partnership program. Like several other industrial states in the Northeast, the State of Ohio hoped to encourage innovation by making

[17] For a history of the University of Akron, see Auburn (1970). For a history of the University's polymer department see Morton (1989; 1976). On the University's economic development initiatives, see Worthy (1990) and Kelley (1984).

public funds more readily available for research and development. To receive the funds, however, project proposals were required to be submitted by a coalition of actors with a home at a research university. The focus of the Edison Polymers Innovation Center was on polymers—an industry that had little identity as an *industry*, despite the large concentration of companies in the region that drew on polymers as a major source of their revenues. Most polymers companies had begun as parts of companies—such as the tire makers—and were therefore mainly associated with the projects those companies ultimately produced such as vacuum cleaners and the automobile industry. The University and EPIC were immediately were confronted with the issue of having to establish an identity among companies in the industry.

The initial model required companies to make a significant investment—up to $50 million—in the program. In return, they were afforded a "window on technology" and first rights to intellectual property that was coming out of the university's labs.

- **The University of Rochester**

As in Akron, fears of significant restructuring from its largest and most prominent companies led the city's business, civic and political leaders to search for ways of building a more robust—and more innovative—economic base within the region. The city's two major universities—the University of Rochester and the Rochester Institute of Technology—were called on to play more active roles in transforming existing capabilities in ways that would to retain knowledge and facilitate learning among local firms. Several university-based initiatives were key: the Laboratory for Laser Energetics and the New York State Center for Advanced Technology in Electronic Imaging Systems (CAT-EIS).

- *Center for Optical Manufacturing*

In 1989, the head of the University of Rochester's Institute of Optics and representatives of Eastman Kodak joined forces to lobby for U.S. Army funds in order to set up a Center for Optics Manufacturing housed at the University's Laboratory for Laser Energetics. The goal was to learn how to process glass using computer control. Until this point, skilled craftsmen—many of whom could be found among the scattered optical shops in the Rochester area—made all but the simplest optical lenses by hand. By the late 1980s, however, many of those capabilities had moved off shore.

Kodak loaned a prominent researcher, Henry Pellicove, to the project. Pellicove had previously worked on one of the company's major innovative initiatives, the disc camera. While the disc camera ultimately turned out not to be a significant commercial success, it had required a number of technical advances including the mass production of an asphyrical lens which made the camera's thin profile possible. Manufacturing the lens with existing technology turned out to be problematic. The Optical Manufacturing Center set out to build a consortium of companies interested in developing computer aided optical manufacturing technologies. Twenty companies became involved in the effort.

- *Center for Advanced Technology in Electronic Imaging Systems*

The second university-based initiative, CAT-EIS, was initially intended to provide large companies with seed capital and access to resources in support of imaging technologies. When it was created in 1989, the program was designed to channel funds from the State of New York to major companies in order to support innovation and basic research. Later in the decade, however, the program shifted its emphasis toward developing entrepreneurial businesses and providing assistance to small businesses. Its primary function remains transferring funds although today those funds are more directly accountable to the goal of creating jobs.

4. The Evolution of Intellectual Networks in Akron and Rochester

Three important facts emerge that from the preceding discussion of what has happened in Akron and Rochester in the last twenty years. First, in both places, clusters of industry emerged around core technology at the end of the 19^{th} century which grew and prospered in the 20^{th} century. In both cases, a troika of major international firms emerged around these technologies. Second, by the 1980s, these companies had run into competitiveness issues related which stemmed, in part, to their apparent inability to innovate. Companies in both places took actions designed to address this concern including acquiring portfolio companies, building new research capabilities in different areas of technology and moving some innovation activities to places thought to be more cutting edge. Finally, community leaders in both places engaged in very similar interventions designed to use local universities as a base from which to engage companies in an effort to improve innovative capabilities in place. This section seeks to understand what happened to the structure and pattern of knowledge networks in the two cities once these forces were set in motion.

Importantly, the universities developed different perspectives on how to proceed; perspectives that coincide, quite neatly in fact, with the two theories of university involvement. Akron's "windows on technology" approach resembles Burt's (1992) notion of bridging structural holes. By brokering its position between the cutting edge research coming out of its labs and, potentially, translating what was coming out elsewhere, the university hoped to parley its unique structural (and repuational) position within the city to propel both it and the city's economic fortunes forward. The University of Rochester's approach, on the other hand, more closely resembles the notions of Amin and Thrift (1992; 1994) concerning building institutional capacity within the community toward developing greater stocks of "social capital" or relational density within it.

As described in the methods section (section 2), the data for this analysis are drawn from co-authored scientific papers published by individuals in local companies and their collaborators. The data were collected over three year intervals at two points in time: 1980-1982 and 2000-2002. In this section, we will first consider the similarities and differences between the two cities in the early 1980s. Doing so both contributes one more dimension on which to base the comparison of the two cities while, at the same time, providing the base line on which to evaluate the degree and nature of the changes that have taken place. The second part of this section presents data on what the networks look like today and draws some conclusions about the degree and nature of the changes that have taken place. The third part, finally, discusses how the two networks have evolved through block modeling techniques which allow one to make direct comparisons both within and among the networks over time.

4.A Knowledge Networks: Akron and Rochester: 1980-1982

Table 6 presents basic descriptive statistics on the four networks that emerged from the data indicating their relative sizes, densities and centralization scores. The number of organizations represents the size of the M x M matrix which is created by matching co-authors (and their home organizations) to each other. Focusing on data from the early 1980s, the data indicate that Rochester's network was slightly larger than Akron's at 104 and 85 organizations, respectively. The measure in the next row indicates the total number of publications found in each interval of time. Akron has a larger number of publications in the early 1980s, though only slightly so at 236 compared to Rochester's 198. On average, each of those publications in Akron had 2.8 authors compared to nearly 4 in Rochester.[18] In total, the number of author-publication pairs was 661 in Akron compared to 764 in Rochester. Several authors appear on more than one publication. The number of "unique" authors, that is, the number of authors when one counts an author only once in each data set, is almost exactly the same between the two cities in the early 1980s at 463 in Akron and 465 in Rochester.

Of course, these numbers provide little indication of differentiation within the network among actors that may be more or less important. In fact, a few organizations produce the majority of publications in the network as indicated by comparing the mean number of authors per organization in the network as a whole to the figure one gets when one weights this figure by organization. In Akron, the mean number of authors per organization is 22.59 compared to the overall network figure of 7.8. The spread in Rochester is almost exactly the same at 22.67 versus 7.3. However, the overall skew of the network is revealed by analyzing the standard deviations on the mean number of authors per organization. Although Akron and Rochester are relatively similar in terms of value, the standard deviation in Rochester is much greater.

The information contained in Table 7 gives some indication of the degree to which particular organizations are responsible for this skew. The data show that in Akron, for instance, the network's most prolific organization the 1980s was B.F. Goodrich with 180 authors, followed by the University of Akron with 64. In Rochester, Xerox was the most prolific at 183 with the University of Rochester coming in second at 172.

At this point, what these data indicate is that the networks of these two places were fairly similar in the early 1980s in terms of size and the composition of its actors. This similarity is confirmed in the graphical representations of the two networks presented in Figures 3.a and 3.b. The placement of nodes on these "maps" is neither geographic nor based on the "strength" or "weakness" of ties. Rather, the map is simply meant to show the overall pattern of relationships throughout the network as a whole; it shows the paths through which information must flow to get from one point to another. The overall sizes of the networks are similar as are the number of nodes that seem to be significant contributors. However, what also jumps out is the apparent

[18] Keeping in mind that sole authored papers were excluded from the dataset.

differences in the density of the two networks. In Rochester, companies seem somewhat more connected to each other through multiple paths (though it is interesting to note from this data that there are no direct ties between Rochester's two major companies, Kodak and Xerox). In Akron, on the other hand, the network is more linear with the major axis of information passing from the university on one end to B.F. Goodrich on the other passing through Goodyear and Babcock and Wilcox (with a major 'spur' branching off to Firestone) in between.

The data in Table 8 provide further indication of the structures of the two networks. Mean distances between actors are fairly similar between the two cities at 1.7 ties (or, "degrees of separation") and 1.8 in Akron and Rochester respectively. The standard deviations, however, provide some indication of the differences with Akron organizations falling into a narrower range of ties than compared to Rochester. This is confirmed by the maximum distances between the two networks. The longest possible path in Akron was 6 in Akron and 10 in Rochester.

The University of Akron's position on one end of this network is interesting when compared to the place of the University of Rochester; it is positioned in between the two major corporate actors. The concept of 'centrality' provides a way of describing this difference objectively. The second measure presented in Table 7 is an index of centrality derived from summing the number of shortest paths through passing through a given actor in the network. A path is defined as the string of ties connecting one actor in the network to another. The shortest path is the one that passes through the fewest number of nodes from one end to the other. Summing the number of shortest paths that runs through a given actor provides a measure of the centrality of that actor within the network. One interesting fact to note is that the largest actor (in terms of authorships in this case) is not necessarily the most central. In Akron, the central actor in the early 1980s was actually a surprise; Babcock and Wilcox is a locally based company that produces power generators and is therefore not directly related to local industry. And yet, it was among the organizations most collaborated with among the region's core rubber and plastics companies at that time. In Rochester, the most central actor is Eastman Kodak which came in third in that year in terms of the number of authors.

The overall impression to take away from these data is that, while the networks were of fairly similar in size and contained actors who were fairly similar along a number of important dimensions, one can see that the networks were at least somewhat different in terms of their structures with Akron being less densely interconnected.

4.B Knowledge Networks: Akron and Rochester: 2000-2002

Having established the similarity of these two networks we can now turn to how the structure of the networks looks today. Returning to Table 6, the first thing that becomes apparent is the relative sizes of the networks has changed. Akron's has grown but only a little from 85 organizations in the 1980s to 100 today. In Rochester, the number of organizations in the network doubled to 516. In terms of the number of publications, the differences are even more striking with only 166 publications and 377 unique authors in Akron – a decline from the 1980s – compared to 516 papers and 795 unique authors in Rochester. In general, the number of authors per organization stayed about the same in Akron at 22.59 (though the standard deviation on this measure increased significantly) compared to Rochester where it doubled. Publications, clearly, became a more important medium of "conversing" in Rochester over these twenty years.

Looking at how particular actors' publishing trajectories changed provides some indication of what is going on. In Rochester, Eastman Kodak shot to the top among the network's producers of scientific publications with 543. This was followed relatively closely by the University of Rochester which has 438 publications in the network. In Akron, the top producers of papers are the region's two prominent universities: the University of Akron and nearby Case Western Reserve located in Cleveland (again, here it is interesting to note that these two universities have no actual joint publications between them—at least not among faculty who are collaborating with local industry).

The data are helpful in that they give us a sense of magnitude. But the differences between Akron and Rochester today come alive in the graphical representations, presented in Figures 3.c and 3.d. Despite the radical industrial restructuring that has taken place over the intervening 20 years, Akron's network looks little changed from how it looked from the early 1980s. While there is more density in terms of interconnections among prominent actors, they network remains relatively sparse and disjointed. Rochester, on the other hand, seems to have exploded with conversations scattered throughout. The range of actors and the complexity of inter-relationships have grown in Rochester whereas, in Akron, the conversations have remained disciplined and well ordered. If these were networks represented graduate student parties, there's no question which one seems likely to be the livelier and more interesting of the two.

4.C Evolution of the Networks: 1980-2002

These data provide a good sense of how networks have evolved in the two cities over time. While they started off relatively similar, Rochester's network has undergone what seems to be a radical transformation both in terms of size and composition. However, the data so far do not give a good sense of exactly *how* they have changed except in the broadest possible terms. Nor do they give us a detailed understanding of what roles actors play within the network or what the particular patterns mean. This section presents the data in an alternative form which allows us to make more detailed comparisons and to draw some conclusions about how the differences in the networks might relate to specific outcomes.

The data in this section are presented in the form of block models (Tables 9 a-d) which aggregate the data into several categories. Three categories of companies were identified, as described in the methods section above: multinational firms, small and medium sized technology companies and universities. The data were furthermore divided into three geographical categories: local (defined as firms located in the cities' respective metropolitan statistical areas), national (which includes all multinationals regardless of where their headquarters are located) and international. The block models therefore reduce each of the four M x M, organization-based matrices to 8 x 8 categorical matrices. For our purposes, however, only the connections emanating from within the local region are meaningful, therefore, the matrices are presented as 3 x 8 tables showing the percent of ties sent from each of the three local categories of actors to others in the network. Each cell shows the percent of ties sent from the category on the left to the category on the top, totaling 100% across each row. The total number of ties for each row is presented in the second to last column.

Finally, to get a sense of the significance of differences both over time and between the two networks in the 1980 (T_0, so to speak) the data were subjected to Chi-square tests in which each row of the model was tested against the corresponding rows in the other tables. These were treated as contingency tables, thus significance indicates a result that is significantly different from what one would otherwise expect given all of the other values in the row weighted by the total number of ties in that category, city and year.

- **1980-1982**

The first thing that jumps out of the Table 9a, which shows Akron's ties in the early 1980s, is the degree to which the city's multinationals were speaking almost exclusively with each other at that point in history. From the network map in Figure 3a, it is clear that they are not actually speaking to each other, but rather each company is mainly speaking to itself. This provides concrete evidence of the pattern described by Don Sull and colleagues have written on (Sull 1998; 2001): Akron's tire companies though direct competitors, spoke mainly into an echo chamber which might help explain the subsequent upheaval in the industry. But the data indicate that they were not alone in this; 78% of the University's ties were to itself with the next major category being other universities outside the area. Worse still were Akron's small to medium sized technology firms where 95% of ties were internally directed. Tellingly, there were *no* ties between smaller tech firms and city's universities at this time and extremely few ties between the multi-nationals and local universities (9.5% of large companies' ties were to universities outside the region compared to just 0.4% of ties locally) or to local technology companies. In short, Akron's local network in the 1980s was remarkably insular and yet, at the same time, remarkably disconnected.

Rochester's networks at the time were slightly better, but not by much. Sixty-six percent (66%) of multinational's ties were internally directed in 1980 while the figure for the universities is essentially identical to that of Akron with 77% of its authors finding co-authors locally. One significant difference between the two places, however, is in the ties between local tech companies and other organizations. Local technology firms directed 8.5% of their ties to the local multinationals. But, in a very similar pattern to Akron, none of their co-authored papers were sent to local universities at the time although 21% were directed toward universities outside the region.

- **2000-2002**

Jumping forward in time, one can see important changes in the structure of the networks. The Akron of 2002 resembles the network that existed in Rochester in 1982. The major companies are far less insular than they once were. However, those ties have not necessarily been re-distributed locally. Rather, for the most part, they are spread out among all of the categories of companies outside the region including a significant increase in collaborations among non-US based technology firms. There are no ties between large local companies and smaller ones, although ties to local universities have increased somewhat (however, the difference is not statistically significantly).

As one might expect, the data tell as different story in Rochester. It is interesting to note comparing across time in the two cities that the total percent of local ties (indicated in the first Group Total cell in each table) decreased in Akron over this period from 86 to 74%. It went in precisely the opposite direction in Rochester increasing from 74 to 81%. In doing so, however, what is striking is that almost all of the local increase is <u>due to increased collaborations among local organizations</u> including significant increases in between local multinationals and universities, among local tech firms and between tech firms and local universities.

5. Explaining the Divergent Trajectories

The story that emerges from the network data is one of divergence. In Akron, despite the decline of the tires industry gave way to a group of smaller, more focused companies with a higher technology-base. In doing so, the region retained this very important set of local actors and certainly has been successful in parlaying its inherited stock of capability to build a new industry "on the ashes" so to speak of the old. However, what seems not to have been overcome entirely is the inability of local companies to talk effectively; firms within the city remain largely walled off from each other.   In Rochester, the major companies remained more or less intact over time. They did nevertheless, reach out in order to tap into conversations taking place elsewhere (Xerox and its Palo Alto Research Center is only one example). But clearly something happened along the way; something has allowed companies in Rochester to engage *each other* in significant ways. This section of the paper explores both the how and the "so what". The first part of the section discusses the role of the universities emerges as an important factor in explaining the divergence.   The second part asks what impact these differences have had on one important aspect of the city's innovation system: entrepreneurship.

5.A The Role of the Universities in Affecting Change

Rochester emerges from these cases as exceptional with its proliferation of local ties and the surprising increase in the local nature of conversations taking place within it. In the early 1980s, ties between the city's large industrial firms, universities and tech companies were relatively disjointed. Today, however, the university has emerged as probably the most critical player having increased its connections among both local companies both large and small. Looking more closely at the actual pattern that has emerged in Rochester in combination with the targeted interviews that were conducted as part of this research provides an indication of what explains this difference.

The key element of Rochester's relative success was the willingness of companies to engage the university—and subsequently, local firms—around substantive, creative and intellectual ideas. The university's approach – particularly its emphasized facilitating interactions among firms – was an important factor in making this possible. Through the creation of consortia and the encouragement of joint work between university and industry researchers, the university built relationships among local actors that generated a higher level of trust. This trust, in turn, led companies to interact with local organizations not just as suppliers—as had been the case in earlier eras—but around ideas as well. Akron's approach, which centered on generating new ideas and knowledgeable people with the goal of injecting these into the local economy, failed to achieve its intended result. Industry, it turned out, already had ideas and the university was already doing a good job of producing highly capable engineers and scientists. What they lacked was the forum for interaction among companies which the university—as was the case in Rochester—were uniquely situated to provide.

- **The University of Akron's "Window on Technology Approach"**

What became apparent in Akron was that many of these companies already had very sophisticated—indeed, world class—research and development operations of their own and these labs were dedicated to the search for utilizable discoveries, not the long-range forward thinking projects that were coming out of the universities. With time, it became clear that very little output commercial value had emerged from collaboration with the University. So, from the industry's perspective, the model failed. There were experts at the University in specific fields and companies used their labs for very specialized tests. But companies weren't able—or interested—in taking advantage of their inventions. Indeed, many of the largest companies had begun crafting very sophisticated strategies for interacting with universities that involved developing targeted research collaborations wherever the best research was taking place, not just with the local departments. As one company official put it, "our interest is more or less community influenced. Staying involved locally will have spin-off effects. The quality of the education and the students available will improve. Because of the climate, I would like to get an innovative climate that would increase our talent base."

However, around this time, the economics of the polymers industry began to shift. As the large industrial tire companies spun off their commodities plastic businesses, those businesses suddenly found themselves without the financial cushion that a large conglomerate or industrial firm could provide. Tied to cyclical commodities prices, the new polymers companies sought out more stable, and more profitably, income streams.

The thinking adopted by virtually all of the large-scale commodity plastics companies in Akron was that, to be successful, they needed to bring in more technology and more people and become very agile. They did this either by pursuing relationships—and eventually acquisitions—of specialized, custom and engineered compounding services firms that allowed companies to invest in developing specialized polymer resins that met particular customer needs. In the 1990s, this custom segment of the industry grew and many of the commodities plastics producers made the decision to pursue mergers with the custom compounders as a way of building a more stable income stream.

- *Ohio Polymer Enterprise Corporation*

By 1995, no one was happy with EPIC. Large plastic resin compounders saw little value in the university relationships. Small producers felt their interests were inadequately addressed. The University felt pulled in too many directions. The decision was made to put the program on stasis until a new model emerged to make it work. The arrival of a new University President, Luis Proezna, marked the beginning of a second round of thinking how to better utilize the resources of the university in the service of building innovative capacity into the region's polymers industry. Unlike the EPIC model's emphasis on technology transfer, the new scheme—coordinated through a new organization known as the Ohio Polymer Enterprise Development Corporation or OPED—emerged based on the logic of bridging among disconnected parts of the community. It is too soon to tell whether these efforts will be successful. But it is interesting, and reassuring, to note that the general approach being taken by the university today resembles, in several ways, the more facilitative, conversation driven, approach that has emerged in Rochester.

- **The University of Rochester's Approach**

The University of Rochester took a different approach. The first of Rochester's two major university-industry partnerships was the Laboratory for Laser Energetics which set out, initially, to form collaborations among local firms which sought to develop long range technologies in the field of lasers. Housed in an academic department with significant funding from the U.S. Government, the project was committed to openly publishing findings and, broadly, to engaging companies in forward looking conversations. They succeeded in producing a technology that could build aspherical senses using computer-controlled machines. However, German and Japanese companies picked up the technology quickly after publication. As one member of the team put it "our job was to introduce the technology to the U.S. first. If they didn't jump, it's not our fault. We move on." In 1992, an entrepreneur from New York City traveled to Belarus and met with a group of scientists at the Lukiv institute. They had been working on large "Star Wars" like lasers—designed to compete with the U.S.'s Reagan era initiative to blast incoming nuclear warheads out of the sky with satellite mounted laser systems—when the UUSR fell. However, as part of the effort, the scientists had found a fluid technology that could polish glass—including asphyrical lenses.

Scientists from the University of Rochester then visited team leader William Kordonski in the Byelorussian capital of Minsk. They were impressed and when they retuned to Rochester, they set about to bring the technology back to the United States and, this time, to ensure that the technology would be taken advantage of by a U.S.—and Rochester based—company. To do so, they set up a research collaboration involving several high-tech companies in the Rochester area. They also brought Kordonski's team to the U.S. The result was three patents and the introduction of a commercializable polishing technology—magnetorheological finishing (MRF) which magnetically manipulates the viscosity of fluid while it is in contact with a portion of the glass. That creates "a subaperture polishing lap" that conforms to the optical surface. The technology has three primary advantages: the MRF "polishing tool" never dulls; because it is a compliant fluid, it adapts to complex shapes; and removal rates are very high, resulting in short processing times.

The second of these—its ability to adapt to complex shapes—is particularly important. Working with the U.S. Department of Defense's Advanced Research Projects Agency (DARPA) and researchers from the University, a consortium of companies has developed a system to automate the manufacture of unusually shaped lenses known as aspheres—the first one of its kind. Typically, it costs up to $4,000 aspherical lenses which limits their commercial use. Nevertheless, aspherical lenses have the ability to deliver much better optical performance and image quality than traditional spherical ones since an aspherical lens or mirror focuses incoming rays to a single point, while spherical lenses can cause blurring. The machine will push costs down to as little as $25 to $100 per lens.

Byelocorp and the University of Rochester's Center for Optics Manufacturing jointly licensed the technology to QED Technologies, a company founded late in 1996 with several University of Rochester faculty and Kordonski on the payroll, to develop enabling technologies for precision finishing. The company has assembled a consortium consisting of the University, Moore Incorporated, Byelocorp Scientific, Raytheon TI Systems, Eastman Kodak, Opkor, Lockheed Martin, and OptiPro Systems, and funded partly by DARPA to make the MRF systems.

The second of Rochester's partnership efforts, the CAT-EIS initiative, focused building ties between companies and university faculty. Initially, at least, this was meant to provide companies with a source what substantially amounted to subsidized consulting provided by university professors and graduate students. With time, though, the priorities of the state sponsors have shifted toward promoting entrepreneurship. As a result, over time, the university has made an effort to develop ties to smaller firms. In doing so, however, the university certainly has not lost its ties to the large companies. Nevertheless they have been able to parley their relationships on both sides into concrete outcomes.

An example of the how this has happened is Pixel Physics. Pixel Physics, was founded by researchers from RIT, designs and markets imaging systems for remote sensing and precision applications. The company maintains a test and evaluation laboratory that serves both their own internal development as well as offering testing services on a contract basis. The company targets the areas of aerial imaging, biomedical optics, and precision metrology markets with application-specific systems based on their own internally developed technology.

Pixel Physics employs engineers and scientists who are experienced in building complex embedded systems using a variety of host architectures and real-time operating systems. Pixel Physics corporate strategy is designed to cultivate scientific advisors and university faculty affiliates with long-standing business and academic relationships in the Rochester area. They draw on the region's talent pool to gain insight and develop solutions to address clients' needs. In partnership with another local firm—Sine Patterns—Pixel Physics has developed a suite of test target standards that go beyond ISO requirements. The companies have developed test protocols to measure noise, non-uniformity, yield and sensitivity parameters associated with the introduction of a new image sensor technology—Complementary Metal Oxide Semiconductor—developed by Kodak.

Pixel Physics recently announced their first product, an integrated imaging system that has been designed for airborne imaging. Employing a technology developed—but not commercialized—at Kodak the company's new product TerraPix has a 16 million pixel sensor that provides greatly increased area coverage without compromising resolution. In combination with software under development in cooperation with RIT, the technology can be used, for instance, in analyzing and modeling wildfires.

5.B Knowledge Networks and Entrepreneurship

These anecdotes suggest that one of the ways in which shifts in the structure of networks has concrete impacts on the ground is on entrepreneurship. The data bear this out. Table 10 shows several indicators of entrepreneurial activity in the two cities since the 1980s. Rochester's optoelectronics companies have won significantly greater numbers of SBIR[19] awards than Akron polymers-related companies. At the same time, they have garnered a significantly greater share of the pool of venture-oriented venture capital funds. These numbers are true both in absolute terms and in terms of the percentage of awards and funds granted in those technologies overall.

These differences are the result of the different strategies companies in the regions took in restructuring their innovation processes in the 1990s. Large commodities polymer companies spinning-off in the 1990s were determined to acquire customization capabilities. However, rather than develop relationships with small, entrepreneurial companies as the means of achieving these capabilities—a path that their counterparts in the pharmaceutical industry have taken—the companies instead integrate those capabilities—primarily though acquisitions. In Rochester, the large industrial companies started to reconsolidate their research capabilities into

[19] The SBIR award program is a federal government program that awards seed grants to entrepreneurial companies based on a rigorous—peer reviewed—selection process. See Audretsch (2003) for a description.

the region in the 1990s. By the end of the decade, they had also started to warm to the notion of outsourcing a more significant portion of their research and development activities.

Differences in the rate of new company startups in the two cities can be attributed to the different ways in which the universities interacted with industry. In Akron, despite the technology boom, very few high-technology companies emerged. Rochester, on the other hand, saw a new crop of high-technology photonics companies emerge. Their business model is built around providing intellectual technology development related services to the large companies—a departure from predecessor start-ups whose focus was on particular technologies. By providing intellectual services to the large companies, these companies are building the physical, human and social capital necessary to develop their own products and successfully commercialize them. While Akron's Universities have recently turned their attention toward facilitating small company start-ups, these companies lack this built in relationship to large companies and their distribution channels. Significant resources must therefore be devoted to establishing those linkages through a concerted—and costly—effort.

6. Conclusions

The findings of this research contribute to our understanding of how technologies and institutions of mature or "rust-belt" regions can be adapted to make them more innovative (Cooke 1995; Gertler 1993; Hudson 1998; Morgan 1997). Research on industrial districts had drawn attention to the key role of untraded interdependencies between local firms and other organizations (Stoper 1995), involving informal inter-firm networking (Yeung 1994) and processes of "collective learning" (Lorenz, 1992, Lazaric and Lorenz 1997). Proponents of the related concepts of "learning regions" (Asheim 1996; Morgan 1997; Florida 1996) and "local innovation systems" (Cooke, Boekolt and Todtling 1998; Cooke, Uranga and Etxebarria 1998; Cooke and Morgan 1998) have argued that what mature regions lack are institutions that can help bridge among isolated actors in communities. Utilizing the embeddedness of so-called "third-party" organizations including government, training organizations, unions, development agencies and universities are seen as key factors in the ability of regions to adapt and compete effectively.

To the degree that the approach struck by Akron resembled a "structural holes" perspective, the data indicate this strategy failed. This may have been the case for several reasons. First, it may be that the key contribution made by the University of Rochester to entrepreneurship in the Region was not to bridge the holes between university researchers and companies, but rather to bridge them between small companies and large ones or, as seemed to be the case with respect to Byelocorp, between actors inside the region and others outside it. Possibly a more interesting argument, however, comes out of the distinctions between different kinds of brokerage roles made by Fernandez and Gould (1994). It may be that universities should primarily see themselves in a liaison position, rather than a representative one. Akron's problem may have been that it asserted itself too forcefully in the process when compared to Rochester's more sotto voce approach. Thus, in this sense, the research sheds light on *how* the state's embeddedness (Evans 1996) can best be wielded: that is, by acting behind the scenes as facilitators of conversations rather than drivers of process.

Most importantly, what this research shows is that communities can affect the tenor and trajectory of regional economies through a concerted, organized, *organizing* approach. Communities—even one's stuck in the 'rust belt'—need not be captives to economic fate and inevitability. Through strategic action they can and should take stewardship of its path.

References

Amin, A. and N. Thrift. 1992. "Neo-Marshallian Nodes in Global Networks." *International Journal of Urban and Regional Research* 16: 571-587

_____. 1994. "Globalization and Regional-Development" *Ponte* 50(7-8): 41-66

Asheim, B.T. 1996. "Industrial Districts as ‚Learning Regions: a Condition for Prosperity." *European Planning Studies* 4(4S):379-400

Blackford, M. 1996. *BFGoodrich: Tradition and Transformation 1870-1995*. Columbus: Ohio St Univ. Press.

Burt, R. 1992. *Structural Holes*. Chicago: University of Chicago Press.

Camagni. R. 1991. "Local 'Milieu", Uncertainty and Innovation Networks: Towards a New Dynamic Theory of Economic Space" in R. Camagni (ed.) *Innovation Networks: Spatial Perspectives*. Belhaven Press

Castells, M. 2000. "The Space of Flows" in *Cities and Social Theory*. Malden, MA: Blackwell Publishers.

CorpTech Directory of Tchnology Companies. 1985 and 2002. Woburn, MA: Corporate Technology Information Services.

Cooke, P (ed.). 1995. *The Rise of the Rustbelt*. London: UCL Press

Cooke, P. and K. Morgan. 1998. *The Associational Economy*. New York: Oxford University Press

Cooke, P., P. Boekolt and F. Tödtling. 1998. *The Governance of Innovation in Europe*. London: Pinter

Cooke, P., M.G.Uranga and G. Etxebarria. 1997. "Regional innovation systems: Institutional and organisational dimensions" *Research Policy* 26 (4-5): 475-491

Evans, P. 1995. *Embedded Autonomy: States and Industrial Transformation*. Princeton: Princeton University Press.

Fernandez, Roberto and Roger V. Gould. 1994. "A dilemma of state power: brokerage and influence in the national health policy domain." American Journal of Sociology 99: 1455-1491

Florida, R. 1996. "Toward the Learning Region." *Futures* 27 (5): 527-536

_______. 2002. *The Rise of the Creative Class*. New York: Basic Books

Gertler, M.S. 1993. "Implementing Advanced Manufacturing Technologies in Mature Industrial Regions: Towards a Social Model of Technology Production." *Regional Studies* 27: 655-680

Glaeser, E. and M Kahn. 2001. "Decentralized Employment and the Transformation of the American City" Cambridge: NBER Working Paper 8117

Granovetter, M. 1973. "The Strength of Weak Ties." *American Journal of Sociology* 78(6): 1360-1380

Hitzik, M. 1999. *Dealers of Lightning: Xerox PARC and the Dawn of the Computer Age*. New York: Harper Books

Howe, R. 2002. *The Fall of Xerox at the Turn of the Millennium: A System Dynamics Approach*. Ph.D. Diss., Massachusetts Institute of Technology

Hudson, R. 1998. "Regional Futures: Industrial Restructuring, New High Volume Production Concepts and Spatial Development Strategies in the New Europe." *Regional Studies* 31 (5): 467-478

Jacque Catell Press. 1965, 1974, 1983, 1992, 2001. *Directory of American Research and Technology*. New York: Bowker

Kearns, D., and D. Nadler. 1992. *Prophets in the Dark: how Xerox Reinvented Itself and Beat Back the Japanese*. New York: Harper Business Books.

Kelley, F. 1984. "Polymer Science and Engineering Partnerships with Industry at the University of Akron." Ohio Journal of Science 84 (2): 97

Lazaric, N. and E. Lorenz. 1997. "Trust and Organizational Learning During Inter-Firm Cooperation" in N. Lazaric and E. Lorenz (eds.) *The Economics of Trust and Learning.* Cheltenham: Edward Elgar.

Lorenz, E. H. 1992. "Trust, Community, and Cooperation." In M. Storper & A. J. Scott (eds.), *Pathways to Industrialization and Regional Development.* London: Routledge,

Love, S. and D. Giffels. 1999. *Wheels of Fortune: the Story of Rubber in Akron.* Akron: University of Akron Press.

Markusen, A. 1999. "Fuzzy Concepts, Scanty Evidence, Policy Distance: The Case for Rigor and Policy Relevance in Critical Regional Studies." *Regional Studies, 9*: 869-884.

Morgan, K. 1997. "The Learning Region: Institutions, Innovation and Regional Renewal." *Regional Studies* 31: 491-503

Morton, M. 1976. "Scientific Contributions of the Institute of Polymer Science at Akron." Abstracts and Papers of the American Chemical Society S:15

_____. 1989. "From Rubber Chemistry to Polymers – A history of Polymer Science at the University of Akron" Rubber Chemistry and Technology 62 (1): G19-G37

Nelson, D. 1988. *American Rubber Workers & Organized Labor, 1900-1941*. Princeton: Princeton University Press.

Nelson, R. and S. Winter. 1983. *An Evolutionary Theory of Economic Change.* Cambridge: Harvard University Press

Phelps, N.A. and M. Tewdwr-Jones. 1998. "Institutional Capacity Building in a Strategic Policy Vacuum: the Case of the LG in South Wales." *Environment and Planning A* 30: 1603-1624

Piore, M.J. 1979. "Qualitative research techniques in economics.'" *Administrative Science Quarterly* 24: 560-569.

Portes, A. 1998. "Social Capital: Its Origins and Applications in Modern Sociology" *Annual Review of Sociology* 24: 1-24

Portes, A and J. Sensenbrenner. 1993. "Embeddedness and Immigration – Notes on the Social Determinants of Economic Action."

Putnam, R.D. 1993. "The Prosperous Community." *The American Prospect* 4 (13)

Skocpol, T. and M. Somers. 1980. "The Uses of Comparative History in Macrosocial Inquiry" *Comparative Studies in Society and History.* 22 (2): 174-197

Stern, S. 1999. "Do Scientists Pay to be Scientists?" Camrbidge, MA: NBER Working Paper 7419

Sull, Don. 2001. "From Community of Innovation to Community of Inertia: The Rise and Fall of the Akron Tire Cluster." *The Academy of Management Best Paper Proceedings* Summer 2001

Swasey, Alecia. 1997. *Changing Focus: Kodak and the Battle to Save a Great American Company.* New York: Times Business

Storper, M. 1995. "The Resurgence of Regional Economies, Ten Years Later: the Region as a Nexus of Untraded Interdependencies." *European Urban and Regional Studies* 2: 191-221.

Wasserman, S. and K. Faust. 1994. *Social Network Analysis: Methods and Applications.* New York: Cambridge University Press.

Weick, K. 1979. *The Social Psychology of Organizing.* Reading, MA: Addison-Wesley Publishing

Woolcock, M. 1998. "Social Capital and Economic Development: Toward a Theoretical Synthesis and Policy Framework." *Theory and Society* 27 (2): 151-208

TABLES

Table 1. Industrial Organization of Companies, Akron and Rochester, 2003

	Polymers Companies in Akron	Opto-Electronics Companies in Rochester
Large Multinational Firms		
Number	4	3
Average Age	99 years	122 years
Average Local Employment	1,304	16,650
Revenues	$3,000 Million	$9,500 Million
Local Patents (Since 1976)	3440	21,999
Total Patents (Since 1976)	6,445	30,595
% Local HQd	25%	66%
Small to Medium Sized Technology-Based Firms		
Number	15	33
Average Age	54 years	25 years
Average Local Employment	540	77
Average Revenues	$950 Million	$673 Million
Local Patents (Since 1976)	80	154
Total Patents (Since 1976)		1244
% Local HQd	45%	41%
Low-Technology Suppliers and "Job Shops"		
Number	190	89
Average Age	25 years	24 years
Average Employment	40	55
Average Revenues	$1.3 Million	$4.7 Million
Patents (Since 1976)	Less than 1	157
% Local	85%	94%

Sources: Data from www.hoovers.com (based on Dun and Brastreet data) and from www.referenceusa.com

Table 2. Universities in Comparative Perspective

	Year Founded	Faculty	Grads and Post Docs	Pubs '93-'03	Patents	Industry Funded R&D (rank)	Total R&D (rank)
University of Rochester	1850	1,010	3,895	18,935	248	$7.7M (30)	$197.0M (23)
• Institute of Optics	1929	25	103	749			
• Laboratory for Laser Energetics	1970	n/a	n/a	653			
• Center for Optics Manufacturing		n/a	n/a	n/a			
• Theory Center for Optical Science and Engineering	1995	8	19	n/a			
Rochester Institute of Technology	1891	605	2,400	1,437	9	n/a	$4.7M (292)
• Chester Carlson Center for Imaging Science	1955	36	n/a	244			
University of Akron	1870	777	3,973	3,582	191	$4.9M (144)	$19.4m (197)
• Maurice Morton Institute of Polymer Science	1956	21	150	498			
• Department of Polymer Science	1967	n/a	86	542			
• Department of Polymer Engineering	1982	n/a	n/a	642			
Kent State University	1910	144	n/a	2,986	48	n/a	10.8M (229)
• Center for Advanced Liquid Crystal Display	1965	12	38	553			

Sources: Publications: Science Citation Index; Patents, USPTO; R&D Spending: National Science Foundation and personal correspondence

Table 3. Research Intensity by Major Industrial Categories, 2000

	millions of dollars		
	R&D Spending	Net Sales	As a percent of Sales
All Industries	177,270	5,249,573	3.4%
Manufacturing	120,500	3,405,208	3.5%
Medical equipment	3,041	28,588	10.6%
Aerospace	14,742	141,548	10.4%
Navigational equipment	12,179	126,421	9.6%
Computers and electronic products	38,307	501,999	7.6%
Computers and peripherals	5,162	79,199	6.5%
Semiconductors and electrical components	10,909	172,363	6.3%
Communications equipment	7,381	116,792	6.3%
Other computer and electronic products	*427*	*7,224*	*5.9%*
Resin, synthetic rubber, fibers	*2,852*	*50,637*	*5.6%*
Chemicals	19,156	353,926	5.4%
Transportation equipment	32,458	749,851	4.3%
Machinery	6,082	170,276	3.6%
Basic chemicals	2,574	87,728	2.9%
Plastics and rubber products	1,670	91,243	1.8%
Appliances and components	2,434	164,385	1.5%
Fabricated metal	1,754	118,452	1.5%
Nonmetallic mineral products	651	46,002	1.4%
Textiles and apparel	370	35,137	1.1%
Beverage and tabacco	416	56,005	0.7%
Furniture	246	36,544	0.7%
Primary metals	695	122,752	0.6%
Wood products	65	13,527	0.5%
Food	1,227	310,802	0.4%
Petroleum and coal	1,005	353,210	0.3%

Source: National Science Foundation

Table 4. General Descriptive Statistics, Akron and Rochester, 2003

	Akron		Rochester	
	1980	2000	1980	2000
Population (Percent of U.S)	660,334 (0.29%)	695,954 (0.25%)	1,032,224 (0.45%)	1,098,821 (0.39%)
Total Non-Farm Employment (Percent of U.S.)	299,410 (0.27%)	399,218 (0.24%)	507,978 (0.46%)	653,571 (0.40%)
Population including adjacent MSAs† (Percent of U.S.)	3,986,959 (1.75%)	3,986,959 (1.40%)	2,996,215 (1.32%)	3,000,240 (1.06%)
Per Capita Income (U.S. Average)	$10,233 ($10,183)	$31,091 ($29,760)	$10,769 (105.4%)	$33,950 ($29,760)
Annual Per Capita Tax		$273		$369
Population with Bachelor's Degrees				
Percent of Population Holding PhDs		6%		7%

Source: Bureau of the Census, State and Metropolitan Area Data Book
† Adjacent PMSAs: For Akron: Cleveland, Canton-Massillon, and Youngstown-Warren; for Rochester: Buffalo-Niagara Falls and Syracuse.

Table 5. Measures of Innovative Capacity

	Akron	Rochester	Northeast US Average
Percent of Employment Located within 3 miles of City Center	27.6%	33.7%	25.0%
Percent of Employment Located within 10 miles of City Center	66.3%	81.6%	66.3%
Catholics as a Percent of All Religious Adherents	29%	33%	
Gay and Lesbian Households as a Percent of all Households	0.78%	0.91%	0.85%
Locally Based Venture Capital Funds	3	12	

Sources: Catholic: Lilly Endowment American Religion Archive (www.thearda.com). Gay Couples: www.gaydemographics.org/. Venture capital fund: Thompson Financial. Proximity: Glaeser, Kahn and Chu (2001). Demographics: U.S. Bureau of the Census, State and Metropolitan Area Data Book

Table 6. Network Descriptive Statistics

	Akron		Rochester	
	1980-82	2000-02	1980-82	2000-02
Number of Organizations	85	100	104	249
Number of Publications	236	166	198	516
Number of Authors†	661	668	764	2131
Number of Unique Authors	463	377	465	795
Authors per Publication	2.8	4.0	3.9	4.1
Authors per Organization	7.8	6.7	7.3	8.5
Unique Authors per Organization	5.4	3.8	4.5	3.2

† An author is counted once for each paper on which his or her name appears.

Table 7. Selected Organizations Akron and Rochester, 1980-82 and 2000-02: Total Number of Authors (with Rank) in order of "Betweenness" Centrality Index Scores

Akron			Rochester		
	'80-'82			'80-'82	
	Authors	Centrality		Authors	Centrality
Babcock & Wilcox	54 (4)	40.1	Eastman Kodak	88 (3)	50.8
U. of Akron	64 (2)	34.2	Xerox Corp	183 (1)	40.7
BF Goodrich	180 (1)	31.3	U. of Rochester	172 (2)	19.7
US Navy	10 (6)	18.8	U. of Wisconsin	19 (4)	12.2
Goodyear	61 (3)	12.2	Bausch & Lomb	17 (6)	7.8
	'00-'02			'00-'02	
	Authors	Centrality		Authors	Centrality
U. of Akron	113 (2)	33.2	Eastman Kodak	543 (1)	63.5
Goodyear	50 (4)	27.8	U. of Rochester	438 (2)	23.3
B.F. Goodrich	59 (3)		Xerox Corp	142 (3)	13.2
Case Western Reserve	117 (1)	23.6	Bausch & Lomb	105 (4)	8.2
Bridgestone/Firestone	16 (7)	22.6	RIT	33 (5)	4.9

Table 8: Network Measures

	Akron		Rochester	
	1980-82	2000-02	1980-82	2000-02
Mean Distance Between Nodes (St. Dev)†	1.725 (0.37)	1.49 (0.54)	1.82 (0.76)	1.50 (0.61)
Maximum Distance	6	7	10	22
Mean Authors Per Organization (St. Dev)‡	22.59 (63.55)	26.14 (108.93)	22.67 (107.23)	41.89 (214.12)
Maximum Number of Authors per Organization	506 (Goodrich)	599 (U. Akron)	1286 (Kodak)	2118 (Kodak)

† The algorithm finds the # of edges in the strongest path between each pair of nodes. The strength of a path is equal to the strength of its weakest link.

Table 9.a **Akron 1980-1982: Truncated Block Model**

	Local Multinational	Local Tech Firms	Local Universities and Labs	Non-Local Multinational	U.S. Tech Firms	U.S. Universities and Labs	Non-U.S. Tech Firms	Non-U.S. Universities and Labs	n	_^{2} d.f.
Local Multinationals	86.1% _	0.1%	0.4%	0.8%	2.5%	9.5%	0.2%	0.5%	1277	5
Local Tech Firms	1.7%	95.0% _				3.3%			60	5
Local Univs and Labs	2.4%		77.6%	1.0% _	2.4% _	8.1%	1.0%	7.6%	210	5
Category Total	71.4% _	3.7% _	10.9% _	2.4% ‡	9.0% _	0.3% _	0.3% _	1.5%	1547	5
Group Total		86.0% _			12.2%		1.7%			2

_ — significantly different from Rochester

Table 9.b **Akron 2000-2002: Truncated Block Model**

	Local Multinational	Local Tech Firms	Local Universities and Labs	Non-Local Multinational	U.S. Tech Firms	U.S. Universities and Labs	Non-U.S. Tech Firms	Non-U.S. Universities and Labs	n	_^{2} d.f.
Local Multinationals	62.3% ‡		3.7%	5.2%	8.1%	10.6%	3.1% _‡	7.1%	621	5
Local Tech Firms		64.8% _‡	6.0%	3.8% _	3.3% _	17.3% _		4.9%	369	5
Local Univs and Labs	2.1%	2.0% _‡	77.1%	5.3% _‡	3.5%	6.2%	0.5% _	3.2%	1091	5
Category Total	19.7% _‡	12.5% _‡	42.6% _‡	5.0% _‡	4.8% _‡	9.5%	1.2% _‡	4.7%	2081	5
Group Total		74.8% _‡			19.3% _‡		5.9% _‡			2

‡ — significant change from 1980-1982
_ — significantly different from Rochester

Table 9.c **Rochester 1980-1982: Truncated Block Model**

	Local Multinational	Local Tech Firms	Local Universities and Labs	Non-Local Multinational	U.S. Tech Firms	U.S. Universities and Labs	Non-U.S. Tech Firms	Non-U.S. Universities and Labs	n	_ ^{2} d.f.
Local Multinationals	66.7% _	0.3%	2.8%	1.6%	2.4%	21.8%	0.1% _	0.1%	1359	5
Local Tech Firms	8.5% _	57.4% _		6.4%	6.4%	21.3%			47	5
Local Univs and Labs	2.9%		77.1%	1.6% _	0.1% _	15.5%		2.8%	1310	5
Category Total	34.9% _	1.1% _	38.6% _	1.7%	1.3% _	18.7% _	>0.1% _	3.5%	1547	5
Group Total		74.7%			21.8%		3.6%			2

_ — significantly different from Akron

Table 9.d **Rochester 2000-2002: Truncated Block Model**

	Local Multinational	Local Tech Firms	Local Universities and Labs	Non-Local Multinational	U.S. Tech Firms	U.S. Universities and Labs	Non-U.S. Tech Firms	Non-U.S. Universities and Labs	n	_ ^{2} d.f.
Local Multinationals	68.2%	1.3%	7.6%	1.3%	2.1%	11.3%	0.3% ‡	7.8%	2847	5
Local Tech Firms	7.0% _	62.3% _	8.0% ‡	0.6% _	0.8% _	16.1%	1.1% _	4.2%	528	5
Local Univs and Labs	8.3%	1.6% _‡	77.7%	1.2%	1.1% ‡	5.1% ‡	1.1% _‡	3.8%	2575	5
Category Total	36.9% _	6.9% _‡	37.9% _	1.2% _	1.5% _	9.1% ‡	0.7% _‡	5.7% ‡	5950	5
Group Total		81.7% _‡			11.8% _‡		6.5% ‡			2

‡ — significant change from 1980-1982
_ — significantly different from Akron

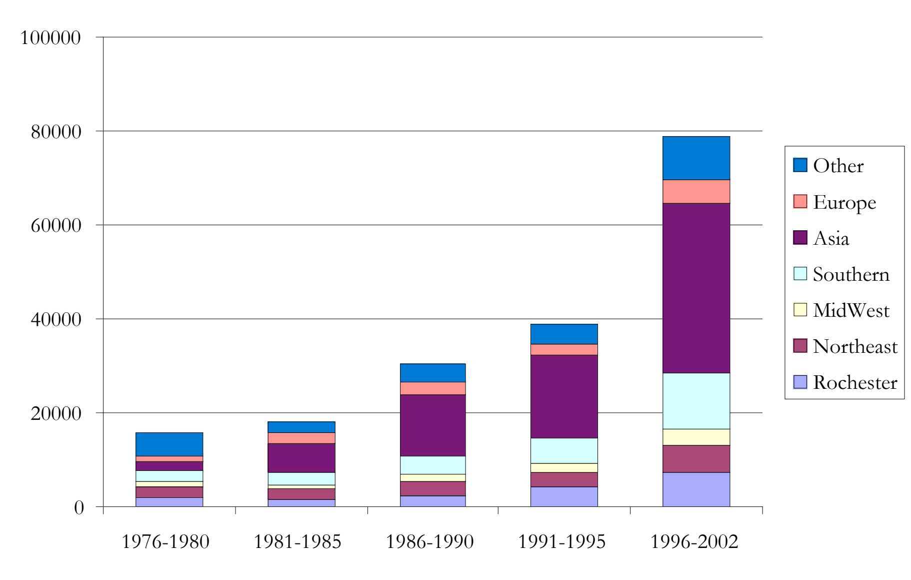
Table 10. Indicators of Entrepreneurship

	Polymers, Specialty Chemicals and Advanced Materials		Optics, Photonics and Lasers	
	Akron	Total Polymers	Rochester	Total Optics
SBIR/STTR Awards, 1983-2003				
Number	9	1796	45	6241
Percent of Total	0.5%		0.7%	
New Venture Oriented Venture Capital, 1973-2002				
Amount ($000s)	$ 122,063	$ 2,505,730	$ 103,440	$ 1,066,303
Percent of Total	4.9%		9.7%	

Sources: SBIR: U.S. Department of Commerce; Venture Capital: Thompson Financial.

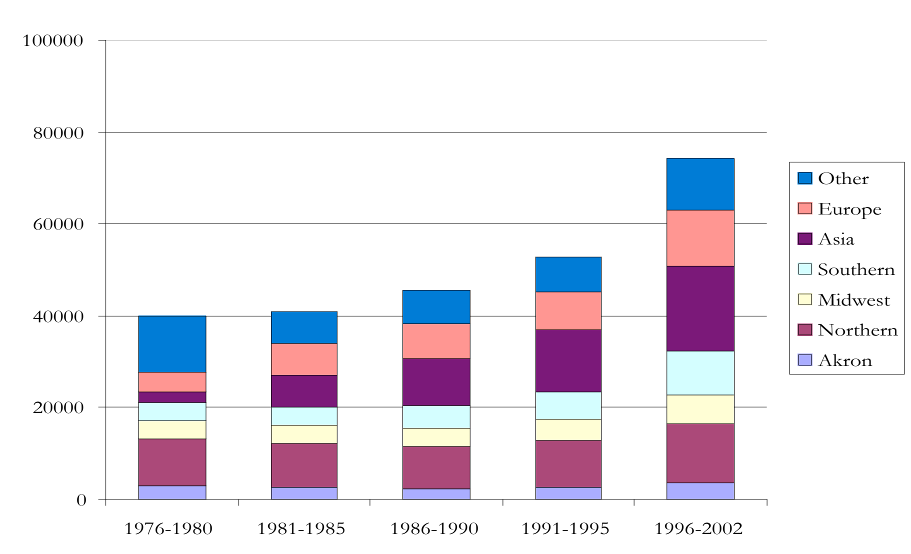
GRAPHS

Graph 1a. Geographic distribution optics patent inventors, 1976-2002



Source: USPTO. Optical electronics are defined as the following patent series: 347, Incremental printing of symbolic information, 351-359, optics, 382, image analysis, 385, optical waveguides, 396, photography, and 399 Electrophotography. Data reflect inventors of patents whose addresses are in the given geographic areas.

Graph 1b. Number and Geographic Distribution of Polymers Patents, 1976-2002



Source: USPTO. Polymers are defined as the following patent series: 156, Adhesive Bonding and Miscellaneous, 264, Plastic and Nonmetallic Shaping, 265 Plastic Article Shaping, 427 Coating Processes and 521-528 Synthetic Resins or Natural Rubbers. Data reflect inventors of patents whose addresses are in the given geographic areas.

FIGURES

Figure 1. Northeast United States Highlighting Akron and Rochester

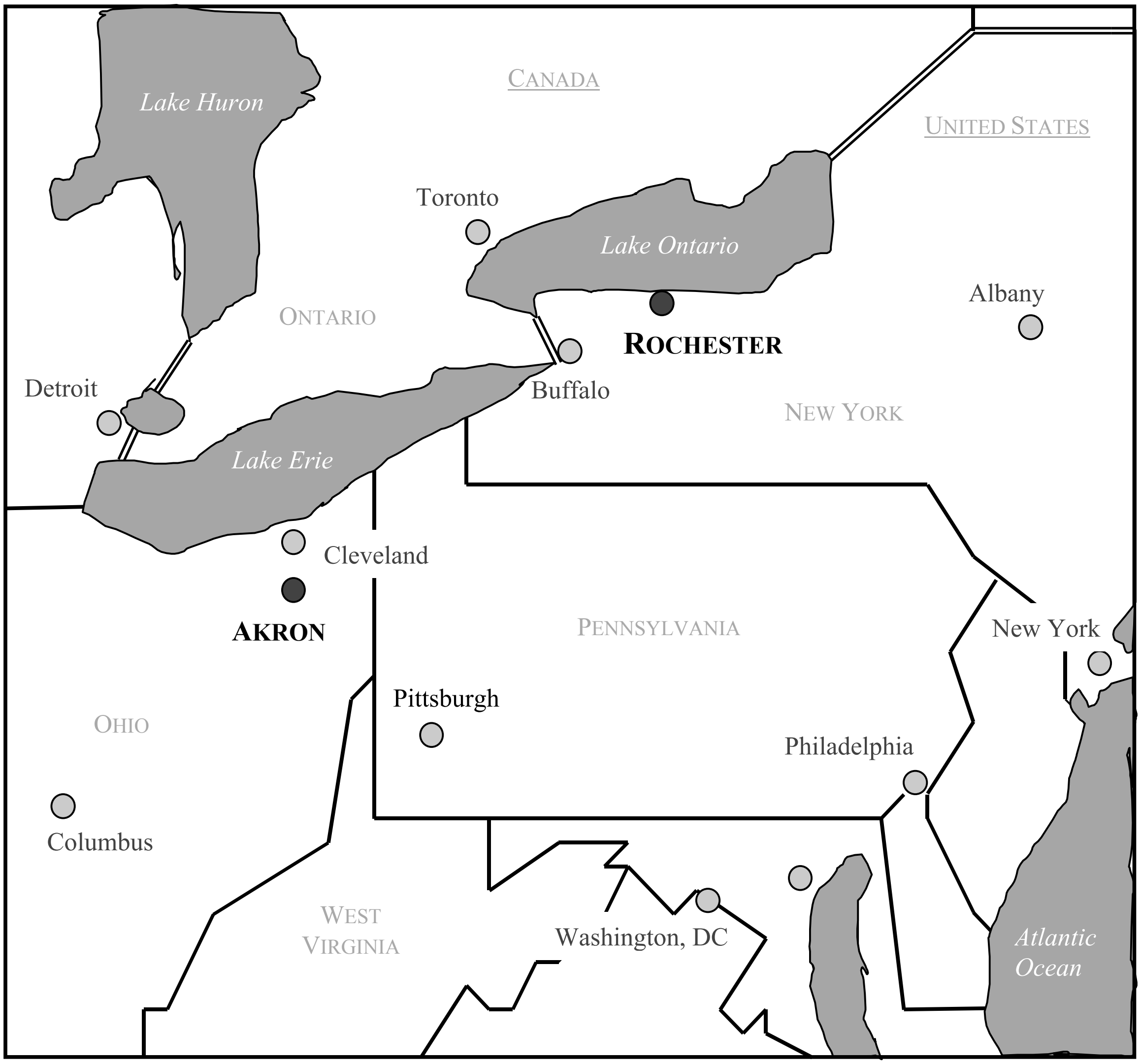


Figure 2. Polymers Industry Supply Chain

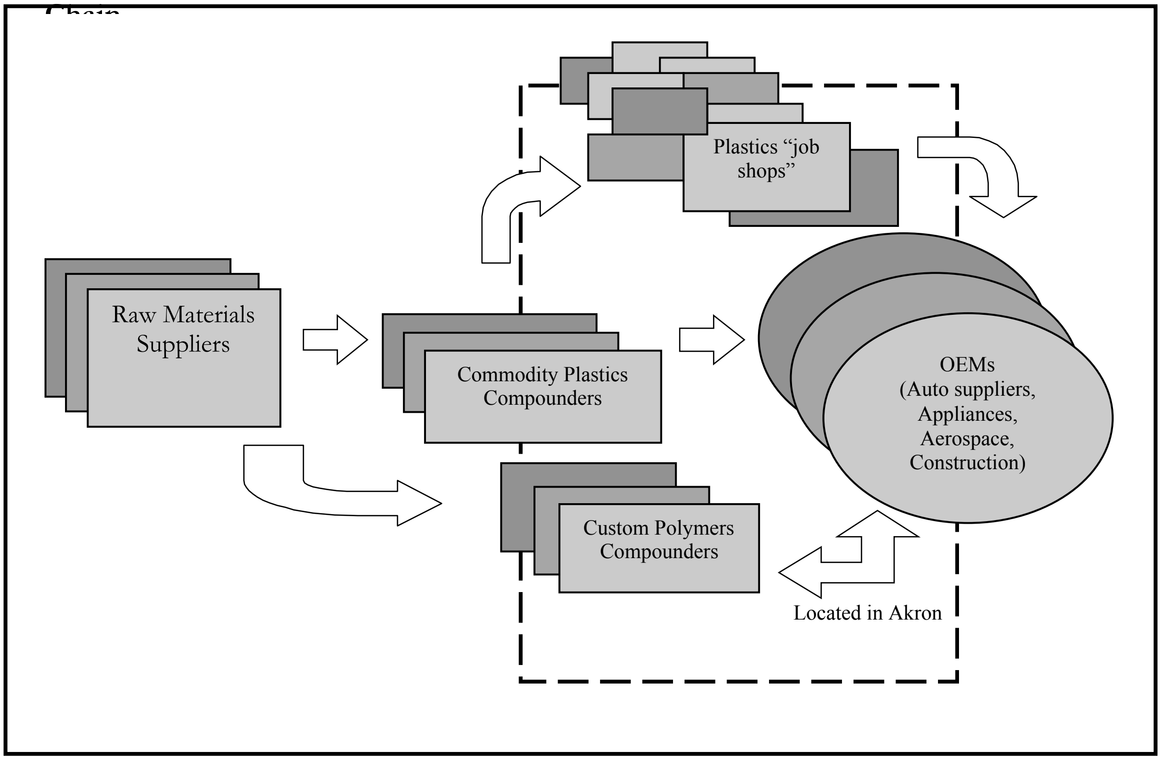
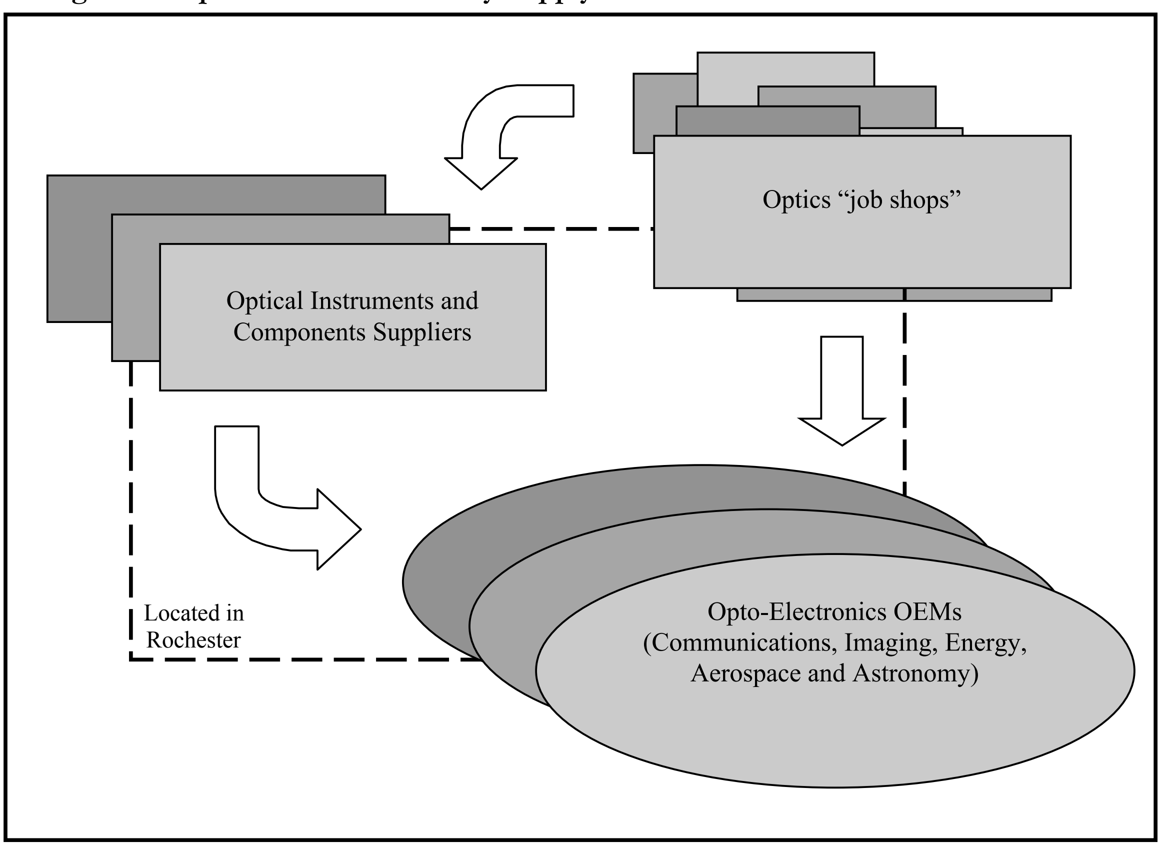


Figure 3. Optoelectronics Industry Supply Chain



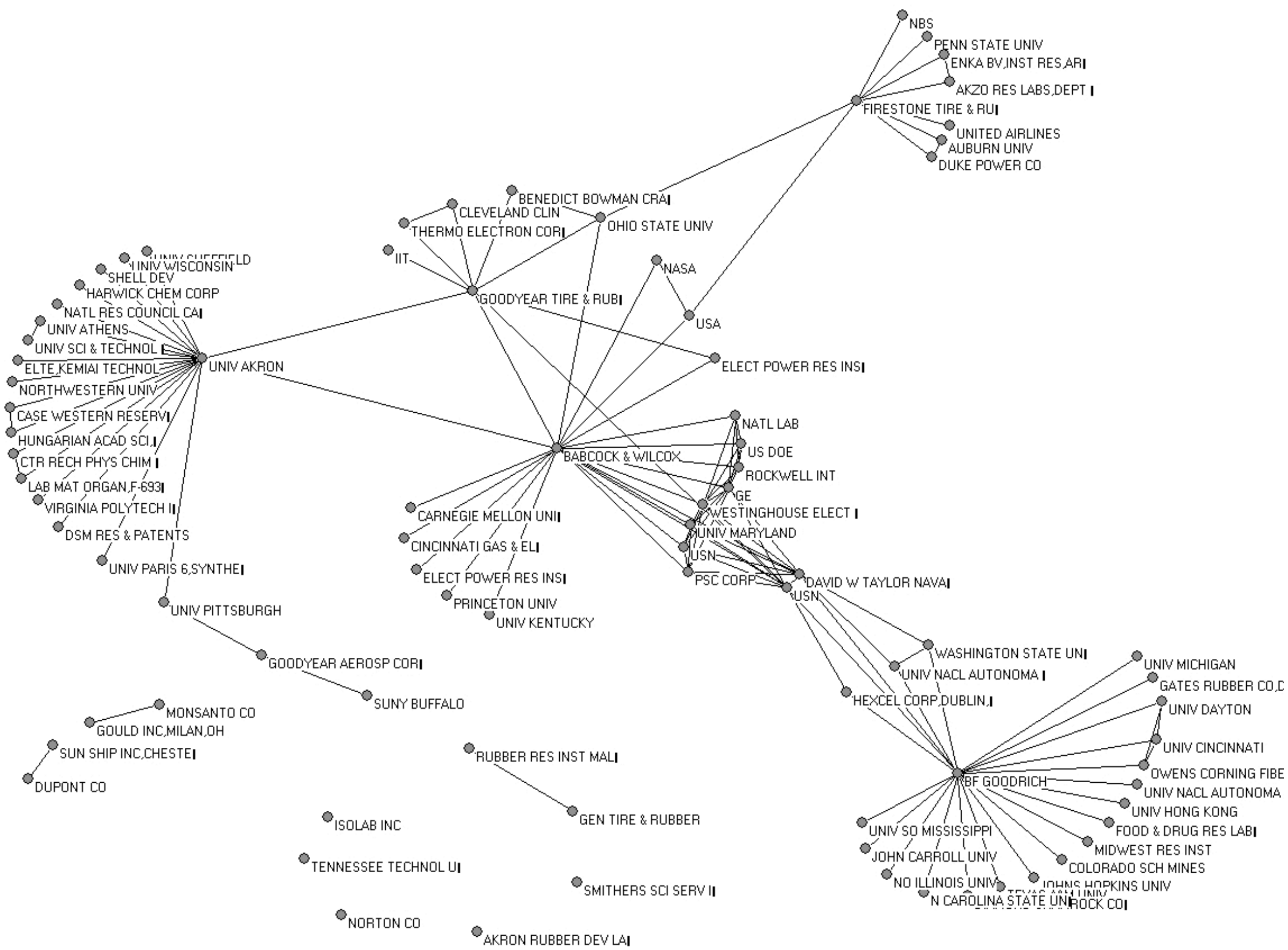


Figure 3.a Akron's Knowledge Network 1980-1982

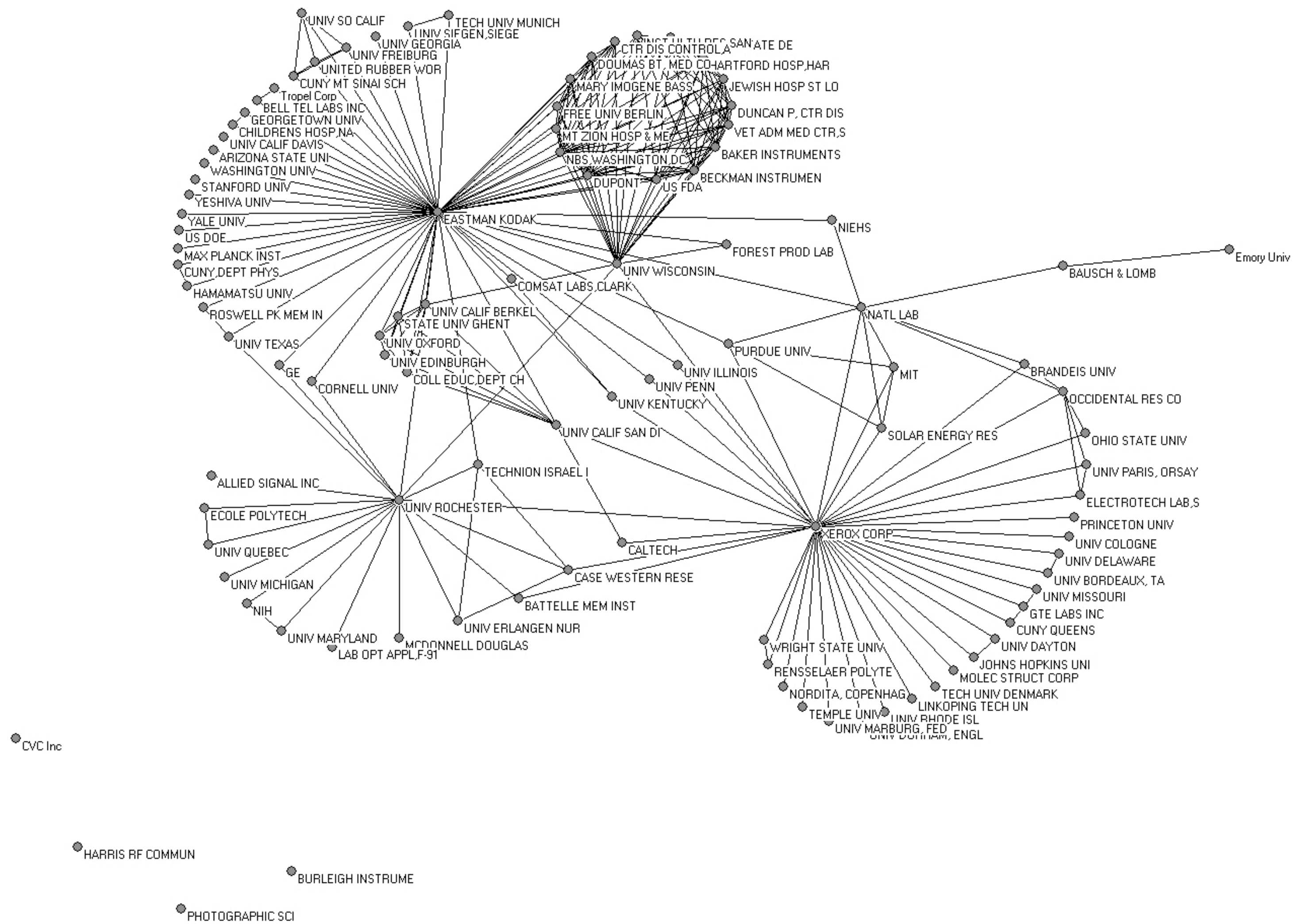


Figure 3.b Rochester's Knowledge Network 1980-1982

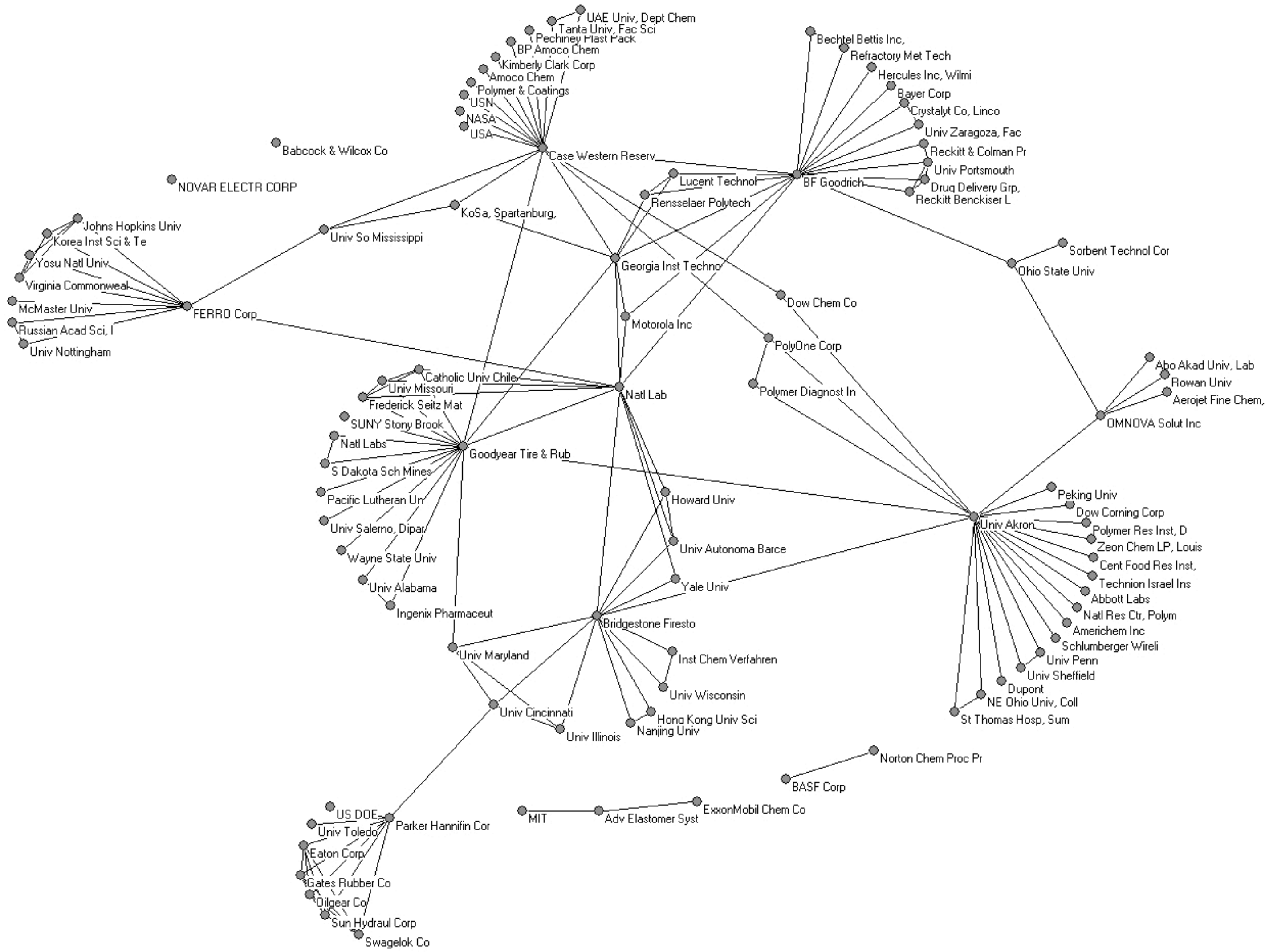


Figure 3.c Akron's Knowledge Network 2000-2002

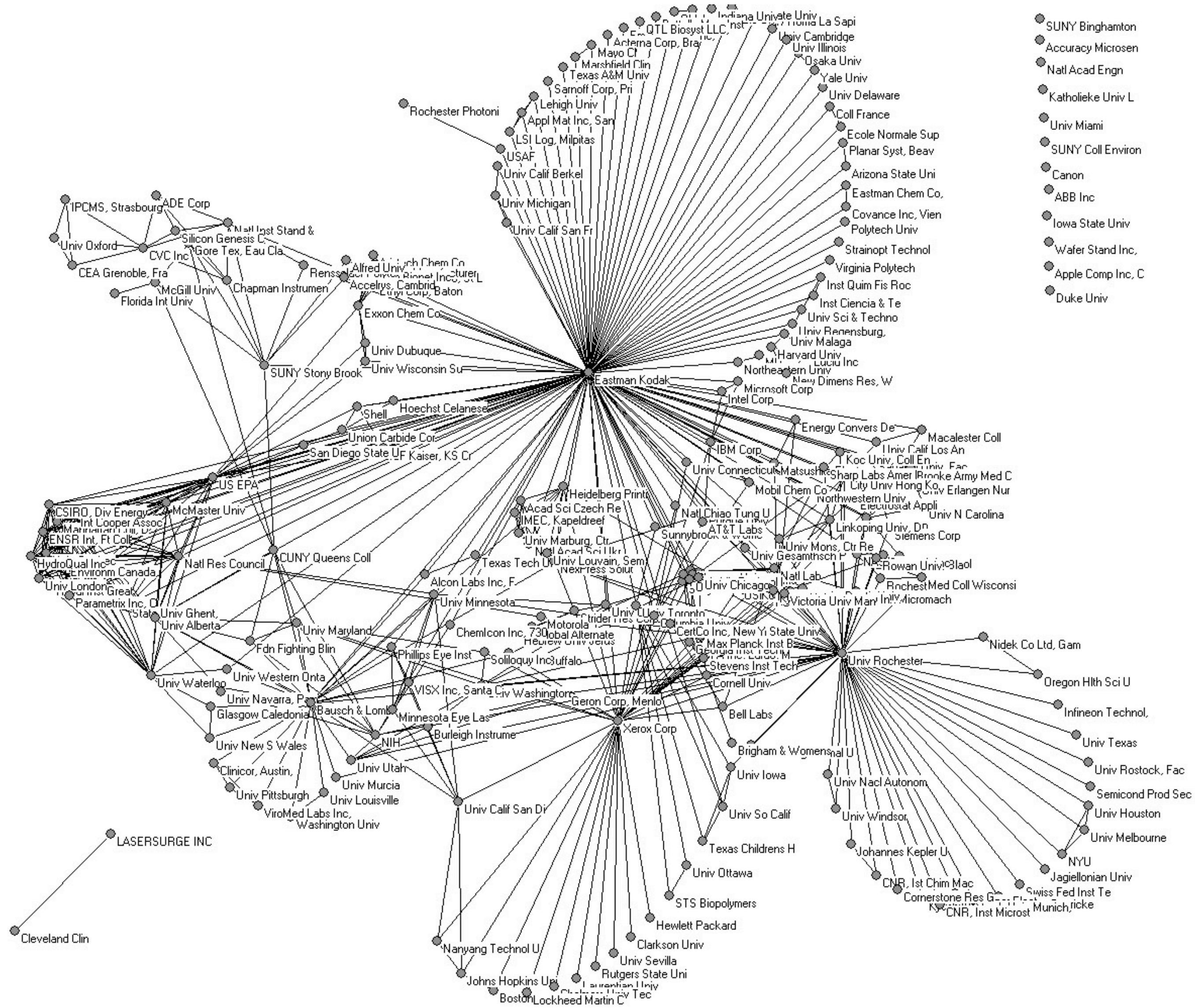


Figure 3.d Rochester's Knowledge Network 2000-2002