Specialization Versus Diversity in Local Economies: The Implications for Innovative Private-Sector Behavior

Bennett Harrison
Harvard University[1]

Maryellen R. Kelley
Massachusetts Institute of Technology

Jon Gant
Carnegie Mellon University

Abstract

Regional economists, planners, and geographers have for many years drawn a useful distinction in characterizing the properties of spatial agglomerations or growth centers. However, they are just now providing evidence for the hypothesis of Jane Jacobs: that urbanization is at least as relevant as localization in explaining spatial patterns of innovation and economic growth. The results of our research, conducted at the level of individual companies and plants rather than on the aggregate economies of cities and regions, also corroborate Jacobs' theory. Across a national size-stratified random cross-section of almost 1,000 manufacturing establishments, the likelihood that managers will adopt new technology is significantly related to the types of counties in which their factories are situated, and less strongly to the proximity or density of clusters of similar businesses. In short, in manufacturing—and probably even more so in services—urbanization definitely matters, while the case for localization is less strong.

Over the past decade, economists, sociologists, political scientists, and theorists of business strategy have rediscovered industrial geography. For some (Arthur, 1989; Enright, 1993, 1994a, 1994b; Glaeser et al., 1992; Henderson, 1988, 1994; Krugman, 1991; Porter, 1990; Romer, 1986), the principal research question is to determine why economic activity in so many industries tends not to be evenly distributed among cities and regions but rather to be relatively concentrated in a few "signature" locations, such as microelectronics in Silicon Valley, optics in Rochester, and clothing and jewelry in New York City. In other words: Why do firms commonly cluster together in economic space—especially in an era with an apparent ubiquity of basic services, a decline in the relative importance of heavy-to-move raw materials, and vast improvements in the technical and organizational means of interregional/international production and distribution coordination? For most economists, and also for some geographers (notably Scott [1990, 1994]), the answer lies in theories about the nature and functioning of external agglomeration economies in particular and, more generally, of internal and external increasing returns to scale.

Given that spatial clustering occurs in so many industries, one research question—associated with revived interest in the sources of long-run ("Schumpeterian") economic growth throughout the social sciences—is how and to what extent agglomeration promotes technological learning. All models of the diffusion of an innovation assume the existence of some social process for interorganizational learning. Differences among locales in the provision of opportunities for one organization to learn from others constitute an important field for the study of such processes.

In the view of sociologists, geographic proximity may enhance social proximity by allowing frequent face-to-face interactions and the subsequent creation of trust among key individuals in various firms (Park and Burgess, 1967; Perrow, 1992; Sabel, 1992; Sako, 1992; Simmel, 1971). This proximity may create an environment in which skilled workers, engineers, and managers are more likely to communicate with nearby individuals in the same or related industries who are facing similar production problems. The intent of such communication (when it is not simply serendipitous) is to learn what those in similar organizational settings are doing and to acquire information about new technological and product developments in the industry. Reliable information from trustworthy individuals and organizations is thought to be an important ingredient in the acceptability of an innovation and in the willingness of followers to adopt it.[2]

In the hands of theorists of industrial economics and business strategy, transactions cost economics also provides a number of hypotheses about the reason why location within clusters may facilitate interorganizational learning (Enright, 1993).[3] Thus proximity may reduce the cost of negotiating and monitoring contracts, in the same manner that locally embedded social relationships reinforce implicit "handshake agreements." Whether socially embedded or not, by increasing the likelihood of familiarity, proximity may reduce the incidence of opportunistic behavior by suppliers, customers, and even competitors. For example, the availability of many alternative local suppliers or customers may provide a firm with insurance against opportunistic behavior by existing partners, thereby reducing asset specificity (that is, dependence on transaction partners whose possession of or control over unique resources, competencies, or information gives them extra bargaining power). Economic geographers, planners, and social scientists have combined these approaches to craft a rich body of work on the formation and reproduction of so-called *industrial districts* (Best, 1990; Enright, 1994a; Perrow, 1992; Piore and Sabel, 1984; Saxenian, 1994; Scott, 1988, 1990; Storper and Scott, 1989; Storper, 1993).

Industrial districts are collections of information about geographically bounded, mostly small- and medium-sized enterprises (SMEs), alternately competing and cooperating with one another and specializing in particular aspects or stages of production that are coordinated (governed) at the level of the region (district) as a whole rather than within a particular firm. A lively debate has ensued, in which critics question the importance of local division of labor among the SMEs vis-à-vis the system-shaping role of large public and private organizations. Others are reexamining the very stability of the better known districts, from Toyota City and Silicon Valley to the clusters that make up the so-called

"Third Italy" (Florida and Kenney, 1990; Glasmeier, 1991; Harrison, 1994a, 1994b; Martinelli and Schoenberger, 1991). Central to this debate are concerns about how and to what extent technological learning is enhanced by the proximity in the districts of those involved: business firms and a mosaic of social and government organizations.[4]

This interest in the agglomeration-innovation nexus has spread to the realm of public policy. One element of new U.S. policies (at both the Federal and State levels) designed to modernize manufacturing is a concern with more effective dissemination of information that will lead SMEs, in particular, to retool production facilities with modern computer-controlled equipment (Kelley and Arora, 1996; Kelley and Watkins, 1995; Shapira, 1994; U.S. Congress, Office of Technology Assessment, 1990). Another element is a desire on the part of policymakers to encourage the explicit creation of consortia of companies and local governments that are aimed at creating new—or reinforcing existing—growth poles and growth centers organized around particular sectors and technologies, such as the electric car (Scott and Bergman, 1993). That was an explicit objective of the (unfortunately short-lived) Regional Technology Alliance (RTA) component of the Federal Government's Technology Reinvestment Project (TRP). Still other policy experiments are aimed at creating and nurturing industrial districts on the Italian model, complete with a matrix of supporting local public services (Bosworth and Rosenfeld, 1993; Rosenfeld, 1992; Sabel, 1992).

Both the theoretical debates and the policy issues form the context for this article. Specifically, we ask how the characteristics of location distinguish those who adopt one especially important manufacturing technology—computer programmable automation (PA)—from nonadopters. PA is considered by managers and engineers to be a technology that is generally superior and more flexible, because it makes it possible to change a specific tool configuration (to accommodate changes in production requirements) by rewriting the software rather than by physically substituting one piece of equipment for another. PA tools also permit machinists to achieve the finer tolerances required by exacting jobs, such as the shaping of fan blades in aircraft engines, to reduce materials wastage (Edquist and Jacobsson, 1988).

We also consider the way external economies of urbanization and localization, as well as leading firms from the same sector—the components of agglomeration—give rise to the generation and acceptance of information that might influence a "focal" business (the unit of analysis) to adopt a new technology after controlling for the influence of intraorganizational (but not explicitly geographic) factors. In the language of urban economic theory, we seek to detect the presence of dynamic agglomeration economies (Glaeser et al., 1992; Henderson, 1988).[5]

More specifically, we examine the extent to which the decision to adopt new technology can be attributed to learning effects associated with the size and centrality of the prospective adopter's local milieu in the national system of such places and of the density of the local industrial sector to which the focal firm belongs. The likelihood of an establishment learning from others may be enhanced by the presence of experienced users and leading firms from the same industry or sector; from firms in other industries; or from trade associations, universities, laboratories, and other specialized information sources located in the proximity. The establishment's learning—and the ability to act on that information—will also vary by level of organizational resources, scale of production processes, appropriateness of the new technology to the establishment's core production processes, and sources of information that have nothing to do with geography in itself. For example, an establishment may learn as much from its non-local parent firm and the parent's network as from nearby institutions.

In nearly all research in economic geography, models predicting growth or change of individual firms or entire locales lack appropriate data with which to account adequately for the organizational and technical properties of the firms and industries in question. As a result, previous estimates of the effects of local milieu on a firm's performance are likely to have been exaggerated. As Annalee Saxenian observes in her article in this volume, proximity may or may not be necessary to firm learning; it is surely not sufficient. The institutional nature of how and whether firms themselves are internally organized to be disposed to cooperate will matter.

The Locational Context for Firms Learning About New Technologies

Certain kinds of information about the ease or difficulty of implementing a technical change may be highly localized. Learning about these aspects of an innovation will depend on direct observation of early adopters, word-of-mouth, or other informal mechanisms. Hence more rapid or more complete diffusion is more likely to occur in places where a relatively densely packed community of organizations shares an interest in a particular innovation than in less institutionally rich or less densely packed locales. Contagion models of innovation diffusion—in which early adoption and further development of a new technology occur locally before spreading to other places—are based on the assumption that certain crucial kinds of information are "sticky" (that is, impacted or embedded within particular organizations) (Case, 1992; Jaffe, Trajtenberg, and Henderson, 1993; Porter and Brantley, 1992; von Hippel, 1988).

The learning process is critical to reducing uncertainties associated with adoption of new technology. Although there are many definitions of learning, "an entity learns if, through its processing of information, the range of its potential behaviors is changed." (Huber, 1991.) As an organization increases its knowledge base through learning, it will update prior beliefs about adopting the technology and will adjust its expectations about the potential returns to adoption (Thirtle and Ruttan, 1987).

Some organizations learn by turning to external sources that allow them to tap knowledge accumulated from the experience of others. Firms seek out interorganizational linkages in order to reduce uncertainty related to the lack of information about new or existing technologies, thereby enhancing the possibility of successful adoption. From interaction with these external knowledge sources, organizations are able to gain access to a body of accumulated knowledge related to advances in science and technology, competitors, and the marketplace. Kelley and Brooks (1991) argue that information linkages to external knowledge sources are crucial to the adoption of advanced manufacturing technologies, especially for small firms. Through sources such as professional meetings, trade associations, equipment manufacturers, and special-order customers, an organization learns about the properties of a technology and the kinds of adaptations of existing organizational routines—formal and informal operating procedures—needed to exploit its capabilities fully (Leonard-Barton, 1988).

One body of theory suggests that for learning to take place, the parties must have developed a degree of mutual trust. In a world of bounded rationality (that is, limited human capacity to absorb and parse information pertinent to making choices), trust reduces the complexity of evaluating information and proximity may promote a sense of trust (Lorenz, 1988; Sabel, 1992; Sako, 1992). Whatever the relevance of trust, any learning process requires that an organization initiate and maintain an internal and external search for new information and screen the information based on its relevance to the organization

(Cyert and March, 1963). The geographer Hagerstrand (1967), like the economist Griliches (1960) before him, studied the diffusion of innovations in agricultural technology from one farm to another. Hagerstrand's models of Sweden suggest that even the widespread availability of information about an innovation will not, by itself, lead to rapid adoption and diffusion. Individual firms are endowed with an unevenly distributed array of economic, organizational, and psychological "delaying mechanisms" that interfere with the potential for instantaneous acceptance by an entire population. Differences within and among the firms affect their ability to acquire, understand, and use the information needed to decide whether or not to adopt an innovation. Consequently, a pattern emerges in which some entities are very likely to adopt an innovation, others hesitate, and still others may never adopt it. In Hagerstrand's models, this pattern is a function of location and adopter characteristics.

Although Hagerstrand was unable to find strong evidence for his theory of unevenly distributed receptiveness to information about new technology, this idea has motivated some of the subsequent research in geography. For example Ormrod (1990) hypothesizes that localities differ in their perception of the relevance of a particular innovation to their industries and conditions, in the resources they can muster to make the requisite investment, and in the extent to which the innovation is likely to be viable in that place. Ormrod's examples are residential air conditioning and home food freezers. He concludes that both the communication of information about new technology from initiator to potential adopter and the receptiveness of the potential adopter, in the sense just defined, are necessary elements of a valid theory of diffusion. By itself, the widespread diffusion of information about technology is a necessary but insufficient condition for actual adoption. Consistent with these geographic and economic theories is Nelson's (forthcoming) observation that some new technologies will never be taken up by certain firms, however relevant they may be. In other words, some firms will not "learn," and many of those will decline or will be replaced by younger firms with production and work organizations built around the new technological paradigm.

Within the field of economics, Cyert and March's (1963) interest in the differential capacity of firms to absorb and make good use of new technical information has been revived. According to more recent treatments, differences in internal expertise, access to financial resources, and heterogeneity of organizational routines affect each firm's expected profitability (that is, the incremental returns to investing in the new technology). Since investment is ultimately a function of expected profitability, these sources of heterogeneity give rise to the observed uneven pattern of adoption (Cohen and Levinthal, 1990; Dosi, 1988; Malerba, 1992; Nelson and Winter, 1982). Nothing in these models of heterogeneous "absorption capacity" speaks to locational considerations except insofar as there may be a tendency for the more adept, flexible firms either to colocate or to exert a demonstration effect on their neighbors, which inspires the latter to institute changes in their own organizations that increase their capacity to adopt the new technology.

In contrast to these less direct (if not necessarily arm's-length) forms of intercompany communication of information pertinent to the adoption of innovative techniques of production, some establishments are part of a centrally managed firm in which administrative decisions about the uses of technology are imposed on the member establishments. The branches or divisions of multiple-site firms are connected to intraorganizational knowledge sources distributed among many locations outside the focal establishment's particular place of doing business. Producing at multiple, diverse locations instead of in one or a few localized complexes may even be the outcome of a conscious strategy on the part of the firm. For example Caves (1989) and Scherer et al. (1975) suggest that, to the extent that a firm has difficulty selling its intangible assets, such as know-how, it will instead invest directly in disparate cities, regions, and countries by expanding itself in the form of branches or divisions and then by directly transferring information developed in one location to others within the multisite firm.

Moreover some—perhaps a growing number of—establishments are developing collaborative relationships to their parent companies, principal customers, subcontractors, and technology vendors that are ongoing, external, and often only implicitly contractual. As these network relationships evolve, the geographic scope of information sources available to the focal establishment increasingly transcends its immediate locale (Badaracco, 1991; Gerlach, 1992; Harrison, 1994b; Kelley, 1993; Kelley and Brooks, 1991; Kelley, Harrison and McGrath, 1994; Kelley and Watkins, 1995; Lincoln, et al., 1992; Mowery, 1988; Powell, 1990; Scott, 1994; Storper, 1993; Storper and Harrison, 1991).

The implication of these theories is that, exactly as Saxenian asserts, while clustering may promote interfirm learning about technologies, it is unlikely to be sufficient—and may even be relatively less important than had been thought—once characteristics of the individual firm's relationship to its more complex organizational environment are taken into account. This question can be explored only by simultaneously studying the impacts of technology, business organization, and location on innovative firm behavior.

Local Milieu and the Adoption of Innovations: Urbanization and Localization Revisited

Following a distinction originally developed by Hoover in his 1930s case studies of the leather shoe industry, which were subsequently incorporated into standard texts in the field (Hoover, 1971; Isard, 1956), both static (with given technology) and dynamic spatial externalities are now conventionally classified as entailing *localization* or *urbanization* economies. Chinitz (1961) argues that the contrast among places that is most relevant to the generating of such externalities as technological spillovers is the difference in the composition and structure of a particular industry among locales of the same size (that is, holding population size constant). Therefore, from the perspective of the focal establishment, technological spillovers may derive from either urbanization or localization economies, or from both.

Urbanization economies reflect externalities associated with the simultaneous presence of firms from various industries, extensive infrastructure, or a large pool of labor in a given location. Because denser places are more likely to contain a more finely grained, occupationally diverse division of labor, institutions that generate new knowledge, and a more specialized infrastructure, advantages accrue from the massing of economic activity within a location. As the size of the urbanized locale increases, there is an accompanying increase in the diversity and specialization of goods, services, and labor force.

The diverse industry mix in an urbanized locale stems from the functional separation of establishment in *heterogeneous* industries whose close proximity and spatial interdependence generate benefits and costs for everyone in the region (Scott, 1990). This diversity improves the opportunity to interact with others in the same or different industries, making it easier to copy a practice being used by industry peers and to modify a practice from an outside industry. Furthermore, the diverse economy offers a labor force with a broader mix of skills, including new skills conducive to working with emerging production technologies. Local diversity as a key source of agglomeration economies forms the main theme of Jacobs' (1967) well-known theory of urban growth. Beyond local industrial structure, per se, many theorists also posit the importance of diversity to the production of urbanization economies in general and to the diffusion of technical information spillovers—particularly of supportive specialized public and private services, distribution networks, and supply arrangements—

within the cluster or district (Bianchi and Bellini, 1991; Enright, 1994a; Porter, 1990; Saxenian, 1994; Scott, 1988, 1990, 1994; Storper, 1993; Storper and Scott, 1989). This principle of collective services is common to all industrial parks, shopping centers or malls, and warehousing districts. The potential benefits are again attributable to the realization of economies of scale in the provision of services.

By contrast, localization economies are externalities associated with the presence in the locality of a mass of other producers in the *same* industry or sector. Since these producers use common technologies or face similar problems, they are more likely to pay attention to one another. Perhaps the most important source of localization is the possibility that a large concentration of similar firms in a given place will lead to the realization of economies of scale in the production of shared inputs, such as labor, equipment, and types of infrastructure (Hoover, 1971; Krugman, 1991; Marshall, 1920). To the extent that these savings in average production costs are passed along from suppliers to customers/users, the latter will derive a benefit not available to them in less highly localized settings.

When one or more leading firms are located in a particular place, the opportunity is enhanced for the emergence of asymmetric relations of power and diffusion of new technology among establishments within the locality (Chinitz, 1961; Perroux, 1955).[6] Nevertheless, the local presence of a lead firm—typically, but not invariably, a large branch plant or enterprise—may promote the diffusion of technical information, because it is likely to be using state-of-the-art technology itself and exerting a significant influence on nearby firms through backward linkages, such as subcontracts, or technology agreements (Angel, 1994; Hoover, 1971; Kelley and Harrison, 1990; Saxenian, 1994).

In sum, the capacity of an organization to learn from external sources is a function of many structural factors, of which locational context is only one. Indeed for certain types of organizations, such as the branches of a multilocational corporation or production network, the characteristics of the local business environment may be largely irrelevant or of only minor importance to the external learning process. Only by comparing the probability of adoption of a new technology among businesses having the same capabilities and resources but different locational contexts can we hope to attribute causal significance intrinsically to location. Such is the explicit objective of the empirical modelling to which we now turn.

The Data

A common criticism of earlier geographic studies is that "the tendency . . . is to use highly disaggregated geographic units and highly aggregated industry units"(Enright, 1993), typically at the 2-digit level of the U.S. Standard Industrial Classification (S.I.C.) scheme. We are able to overcome many of the limitations of earlier research in distinguishing the capabilities of organizations from the attributes of the locales in which they are situated, using a unique data set that provides detailed information on the technical and organizational characteristics of a large sample of establishments sharing a common production process, each of whose locations can be identified. We then match our data to information on the properties of the locales obtained from the Center for Economic Studies (CES) of the U.S. Bureau of the Census.

The organizational data were drawn from the Kelley-Brooks 1987 survey of manufacturing establishments in the U.S. metalworking sector. The data include information on the organizational, technical, and economic characteristics of a national sample of establishments belonging to 21 manufacturing industries at the 3-digit level of the S.I.C.[7] This set of 21 industries, whose products range from cars and aircraft to coffee grinders and scientific instruments, comprises a size-stratified national random sample of establishments that use the machining production process intensively.[8]

Machine tools are used throughout the manufacturing sector of the economy and, for that matter, in the service sector as well; however, compared with other manufacturing industries, those selected here are relatively machining intensive. That is, according to the 1985 Industry-Occupation Matrix of the U.S. Bureau of Labor Statistics, benchmarked to the 1982 Census of Manufactures and the 1980 Census of Population, 10 percent or more of the production workforce in these industries were employed in machining occupations, and the industry accounted for at least 1 percent of all workers employed in the machining process among all industries. In 1987 this set of 21 industries accounted for 25 percent of all U.S. manufacturing employment and roughly the same share of all manufacturing shipments.

The geographic data we use in this article come from four sources: (1) CES provided information on the number of metalworking establishments, value of shipments, and employment in the 21 industries in each county in the continental United States in 1982 and 1987;[9] (2) U.S. Census Bureau's 1983 *County and City Data Book;* (3) Census Bureau's 1982 and 1987 County Business Patterns (CBP); and (4) Economic Research Service (ERS) of the U.S. Department of Agriculture provided Rural to Urban Continuum Codes. The latter, commonly referred to as the Beale Codes, classify each U.S. county according to its degree of urbanization, defined as a function of population and proximity of the county to a Standard or Consolidated Metropolitan Statistical Area. (See exhibit 1.)

Exhibit 1

Urbanization Index[1]		
0	=	Central county of a metro area with population of 1 million or more.
1	=	Fringe county of a metro area with population of 1 million or more.
2	=	County in a metro area with population of 250,000 to 1 million.
3	=	County in a metro area with population under 250,000.
4	=	County with population of 20,000 or more, adjacent to a metro area.
5	=	County with population of 20,000 or more, not adjacent to a metro area.
6	=	County with population of 2,500 to 19,999 adjacent to a metro area.
7	=	County with population of 2,500 to 19,999 not adjacent to a metro area.
8	=	County with population of less than 2,500, adjacent to a metro area.
9	=	County with population of less than 2,500, not adjacent to a metro area.

Gant's Transformation Index[2]		
0	=	Core (population > 1 million) metro county.
1	=	Adjacent to core metro county.
2,3	=	Small (population < 1 million) metro county.
4,6,8	=	Adjacent to small metro county.
5,7,9	=	Neither metro nor adjacent; that is, "rural."

[1] The Beale index as a measure of urbanization or "diversity" was originally constructed by the Economic Research Service of the U.S. Department of Agriculture in 1975, using the 1970 census of population. It was revised in 1983 and again in 1988 at ERS by demographer Calvin Beale. The unit of spatial analysis is the county. We use the 1983 codes, defined above.

[2] Jon Gant's transformation of the index provides a most-to-least-urbanized 5-point scale.

Exhibit 2 displays the number of metalworking sector establishments by county in 1987, drawn from CBP. Exhibit 3 aggregates counties into Bureau of Economic Analysis (BEA) labor market areas, using the agency's 1983 definitions.[10] These proper supersets of counties were created originally with the assistance of geographer Brian Berry and are much used by government agencies, especially for employment training purposes, because they were designed to constitute commuting fields and are periodically updated. Again, the census counts of metalworking plants are displayed. Exhibit 3 clearly reveals a number of first-order metalworking complexes in the country: southern California, Phoenix, Gary and Chicago, Detroit, most of New Jersey, New York City plus Long Island, Rhode Island, eastern and central Massachusetts, and southern New Hampshire. Second-order clusters are apparent in the Portland-to-Seattle area, San Francisco–Oakland, Houston and Dallas–Fort Worth, Minneapolis, St. Louis, Philadelphia, Pittsburgh, Miami, Connecticut, western Massachusetts, and southern Vermont.

This pronounced clustering notwithstanding, the metalworking sector is sufficiently well represented across more than two-thirds of the country's approximately 3,000 counties to make the econometric analysis of variance in innovative firm behavior, as a function of the properties of locale, a meaningful exercise. The first-order correlation coefficient between the relative frequencies of plants by county in our 1987 sample and the 1987 CBP population is 0.92.

The Dependent Variable

A straightforward measure of the occurrence of technological change is whether or not an organization has acquired a new nonincremental technology (that is, one that indicates a shift to a new technological regime) and has installed it for use within the organization. Adoption studies typically consider the reasons why a firm selects a new technology at a particular point in time by using dichotomous choice models (Thirtle and Ruttan, 1987). All of the sample establishments are potential adopters of the particular technology we are studying because—whatever else they may be doing—each is engaged in the production process for which this technology was designed.

Production managers in all of the surveyed plants were asked whether, by 1987, they had adopted at least one machine tool for regular production use that was numerically controlled, computer numerically controlled, or a component of a flexible machining system. The dependent variable, which is coded *1* if the answer to any of these questions is *yes* and *0* otherwise, distinguishes adopters from nonadopters. Fifty-two percent of U.S. metalworking plants had taken up at least some computer programmable automation (PA) by 1987. All estimates are weighted by the reciprocal of the probability of selection in the sample stratum. Mean, standard deviation, median, and range for each variable are presented in exhibit 4.

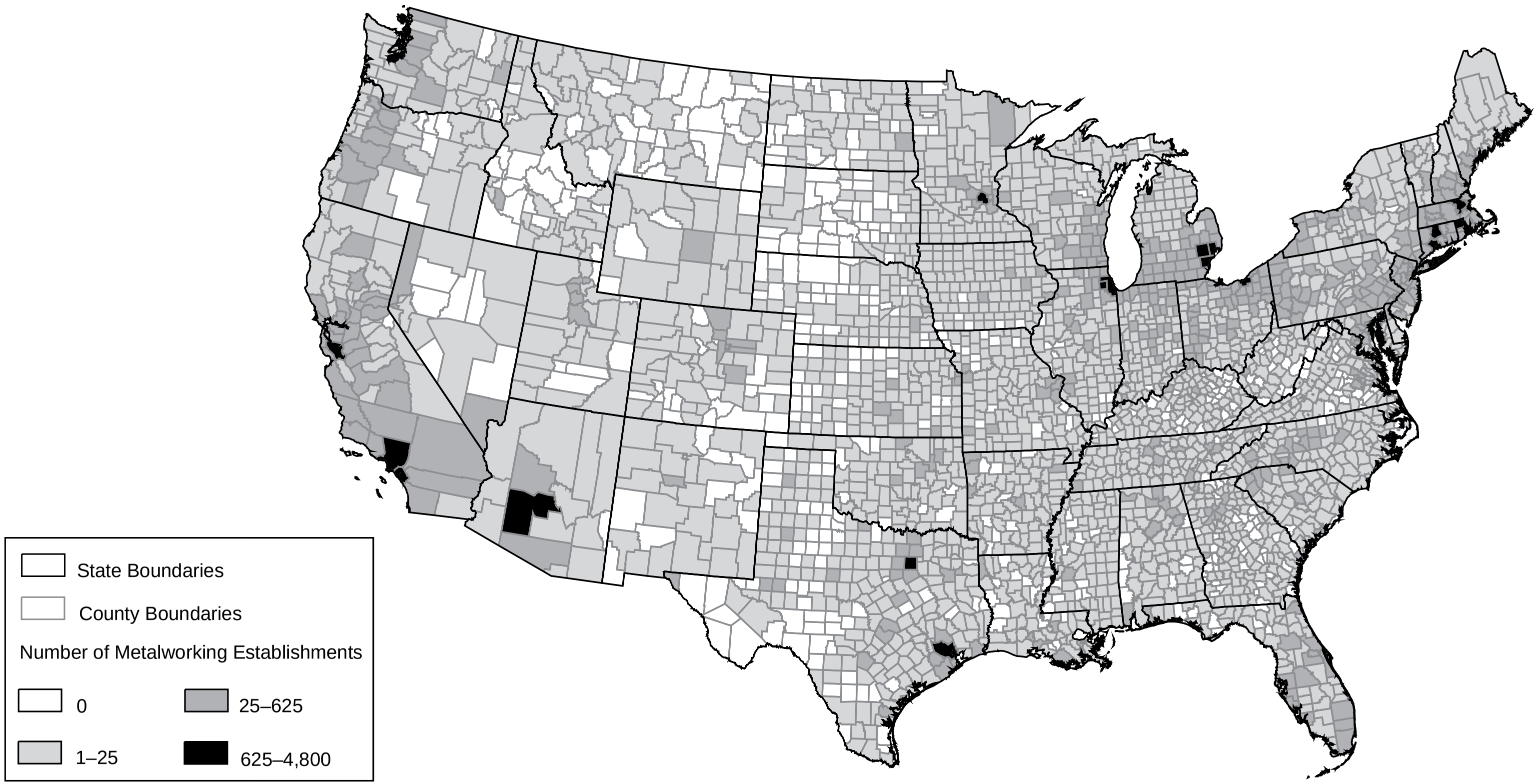
By 1987 the properties of PA were becoming better known to firms in the sector. However, there was considerable room for further adoption, because only 11 percent of all machine tools installed in U.S. plants were computer controlled. PA was also a relatively recent source of technological change: 50 percent of all PA machines in place in 1987 had been installed in the preceding 5 years.

Modelling the Local Milieu

The theory that motivates the modelling that follows is that the likelihood of an establishment in the metalworking sector shifting from a technological trajectory consisting entirely of the use of conventional tools to a trajectory that includes the use of at least some

Exhibit 2

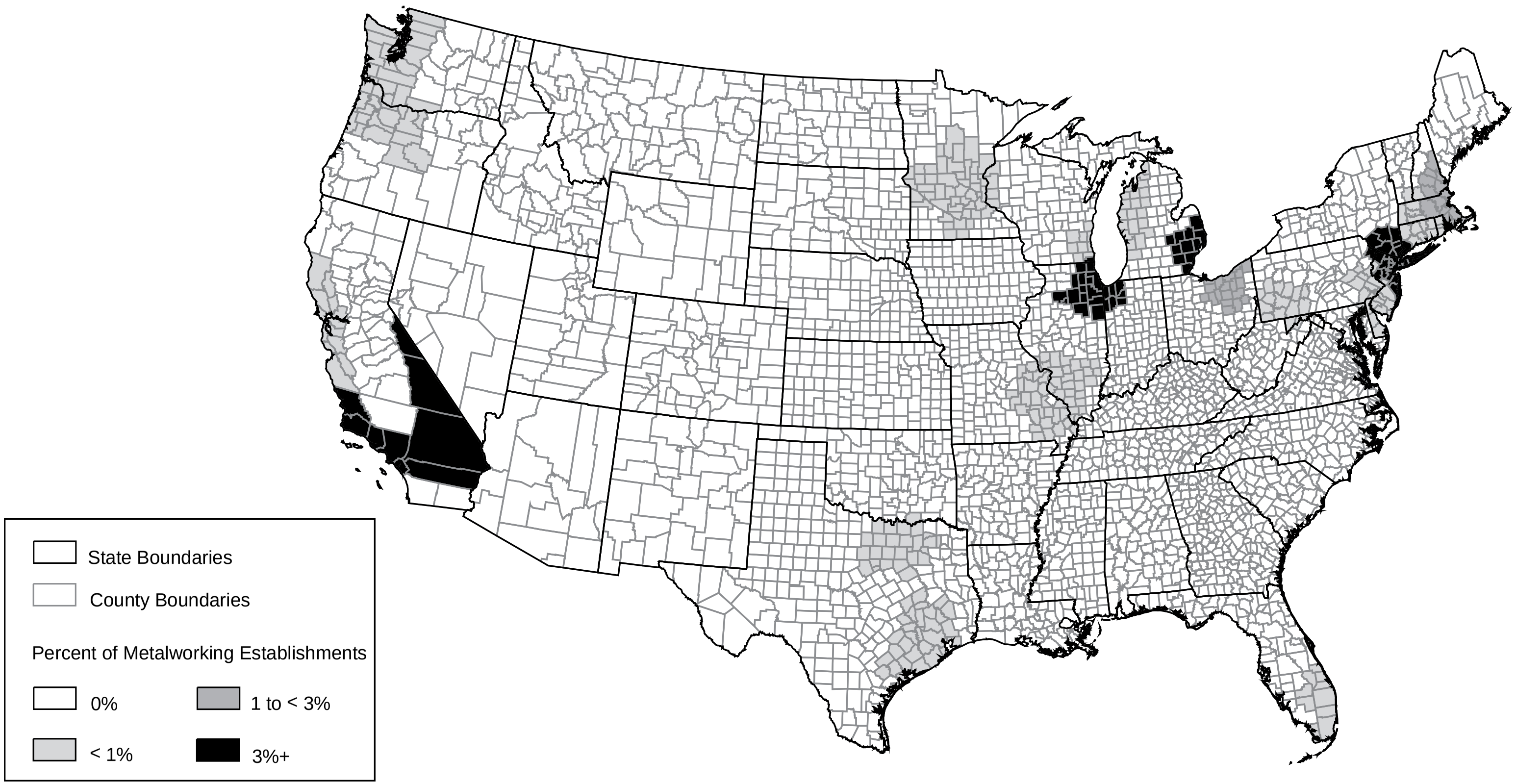
Number of Metalworking Establishments in the United States, by County



Source: 1987 County Business Patterns (n = 82,553)

Exhibit 3

Percent of All Metalworking Establishments in the United States, by U.S. Bureau of Economic Analysis (BEA) Area



Source: 1987 County Business Patterns

Exhibit 4

Mean, Standard Deviation, Median, and Range of All Variables (n = 962)

	Mean	Standard Deviation	Median	Minimum	Maxium
LOG OF THE RATIO OF METALWORKING SHIPMENTS FROM 1987 TO 1982	0.303	0.381	0.284	–1.847	2.089
COUNTY SQUARE MILES/10,000 IN 1983	0.106	0.148	0.061	0.002	2.006
LOG NO. METAL ESTABS IN THE COUNTY, 1982	5.475	1.678	5.652	1.099	8.569
LOG METAL EMP IN THE COUNTY, 1982	9.456	1.811	7.438	3.951	12.656
LOG EMP LOC QUOTIENT IN THE COUNTY, 1982	0.769	0.270	0.801	0.073	1.345
LOG METAL ESTABS > 250 EMP IN THE COUNTY, 1982	2.298	1.323	2.303	0	4.852
LOG METAL ESTABS > 500 EMP IN THE COUNTY, 1982	1.702	1.120	1.609	0	4.007
ANY METAL ESTABS > 250 EMP IN THE COUNTY, 1982	0.678	0.271		0	1
ANY METAL ESTABS > 500 EMP IN THE COUNTY, 1982	0.453	0.376		0	1
CORE (POP > 1 MILLION) METRO COUNTY	0.334	0.472		0	1
ADJ. TO CORE (POP > 1 MILLION) METRO COUNTY	0.238	0.426		0	1
SMALL (POP < 1 MILLION) METRO COUNTY	0.303	0.460		0	1
ADJ. TO SMALL METRO COUNTY	0.079	0.270		0	1
NEITHER METRO NOR ADJ. (RURAL)	0.046	0.209		0	1
LOG EMP IN SAMPLE PLANT	3.051	1.556	4.249	0	9.689
LOG NUMBER OF MACHINE TOOLS OF ALL TYPES	2.763	1.032	3.219	0	8.045
PCT OF CONVENTIONAL TOOLS THAT ARE > 10 YRS. OLD	63.862	34.774	77.778	0	100
PRODUCTION MANAGERS PERCEPTION THAT MACHINING IS AN “IMPORTANT” OR “VERY IMPORTANT” PROCESS IN THIS PLANT	0.870	0.336		0	1

Exhibit 4 (continued)

Mean, Standard Deviation, Median, and Range of All Variables (n = 962)

	Mean	Standard Deviation	Median	Minimum	Maxium
PLANT PRODUCES IN BOTH SMALL (< 50 PIECES) AND LARGE (> 100) BATCHES	0.474	0.499		0	1
PLANT PRODUCES > 50 PARTS OR PRODUCTS	0.725	0.447		0	1
PLANT USES INFORMATION TECHNOLOGY IN PRODUCTION (e.g., CAD/CAM)	0.574	0.495		0	1
PLANT IS UNIONIZED	0.153	0.360		0	1
LOG OF PCT OF THE PLANT’S MAIN 3-DIGIT SIC INDUSTRY’S SALES TO DEFENSE IN 1985	1.885	0.700	1.946	–0.223	4.271
PLANT SELLS MACHINING OUTPUT TO THE MARKET (NOT JUST TO OTHER PLANTS WITHIN THE SAME FIRM)	0.840	0.367		0	1
CUSTOMER REQUIRES PA USE	0.121	0.326		0	1
PLANT IS A BRANCH OF A MULTIPLANT FIRM	0.269	0.443		0	1
PLANT ADOPTED PA BY 1987	0.524			0	1

PA is a function of past and present agglomerative properties of the locale in which that establishment was situated in 1987, holding constant those organizational and technical characteristics of the establishment that would be likely to favor (or, alternatively, to retard) adoption. For the purposes of this article, *locality* is defined at the level of the *county*. Agglomeration economies are hypothesized to generate technology spillovers that encourage innovation among firms concentrated in a particular area. We model localization and urbanization effects separately, controlling for variations among counties in their recent histories of economic growth and in their physical size.

In modelling the association between localization and innovation, we capture same-sector effects by measuring the size and relative importance of the metalworking sector in each county. We experiment with 1982 data describing seven alternative measures of localization:

- The number of metalworking establishments located in the county.
- Employment in these metalworking plants.
- The metalworking location quotient (that is, the share of a county's manufacturing employment associated with metalworking).
- The presence in 1982 of "lead firms," defined here as especially large metalworking plants with both continuous (employment greater than 250 and greater than 500) and threshold (dummy variable) forms.[11]

The 5-year lag is consistent with both economic and sociological models of organizational learning and with path-dependent theories of organizational evolution. In a recent article, Henderson (1994) demonstrates the significance of still longer lags in modelling localization effects on regional growth. We expect that focal plants situated in milieu with high rates of localization or with lead firms capable of generating demonstration effects will be more likely to have adopted PA by 1987 than plants whose immediate environment is less densely populated by same-sector organizations capable of generating technological spillovers.

Theory also suggests that metalworking plants may be influenced by the diversity of ideas and information sources originating outside the sector as well as inside. One way to characterize a particular locale's diversity of learning opportunities is by its degree of urbanization. Urbanization can be represented in a number of ways, the most common being by county population. However, population expressed as a continuous variable fails to capture the qualitative, threshold effect of a locale's being (or being located adjacent to) a metropolitan area, which is potentially rich with such information-generating institutions as universities, industry research and development departments, and industry trade associations.

An alternative measure used in this article consists of the ERS Urban to Rural Continuum codes. From the five-level index reported in exhibit 1, we enter four categories in our models as dummy variables. The suppressed ("base case") category, against which the others are to be compared, consists of core places: counties situated within metropolitan areas containing more than 1 million people in 1983. A second category includes counties that are adjacent to the core locations, incorporating most major suburban and exurban communities in the Nation. A third set of counties belong to smaller metropolitan areas, defined by ERS as those with populations of fewer than 1 million. The fourth category in this urbanization scale consists of counties that are adjacent to the smaller metropolitan areas. Finally, we have counties that are neither metropolitan in terms of population nor urban by virtue of adjacency that we call rural. We expect that individual metalworking establishments situated in 1987 within counties that were relatively more urbanized in 1983 will be more likely to have adopted PA, reasoning that dense infrastructure and the presence of institutions that generate knowledge about the relevant production methods (which we cannot observe directly) are likely to be concentrated in more urbanized places.

During the period when most of this investment in new technology was occurring, 1982 to 1987, the metalworking sectors of various locales grew at dramatically different rates, depending on the particular product composition of the place and the competitive position of its firms. County metalworking sector sales growth varied from –84 percent to 707 percent, with a mean growth rate in shipments of 35 percent during the 5 years (not adjusted for inflation). Plant managers whose local metalworking sector experienced more rapid economic growth might be expected to have been more likely to adopt new technology than managers situated in counties whose industries were growing more slowly (or not at all), because of variations in aggregate demand for their particular mix of products. As an example, consider the difference during the first half of the 1980s between the lethargic demand for automobiles (dominating the metalworking sectoral mix in southern Michigan) and the robust global demand for aircraft (the principal industry in Seattle's metalworking district). Consequently, we control for differences in industry mix, as reflected in metalworking sales growth rates across localities.

One further geographic control is needed. The size of counties varies enormously across the United States. For historical reasons counties located east of the Mississippi River tend to be small and densely populated, while those to the west are typically much larger and often sparsely populated. In 1983 counties in the United States varied in size from 20 to 20,060 square miles. If the successful diffusion of information is in some sense inversely related to distance between the generator or demonstrator and the recipient of that information, then the likelihood that plant managers will have adopted PA by 1987 and the geographic size of the regions in which they are located should be inversely related.

Controlling for the Organizational Structure of the Establishment

As has been shown in earlier research (Kelley, 1993; Kelley and Brooks, 1991), the adoption decision at the plant level is influenced by organizational characteristics, including the availability of resources for investment, scale of the production process, appropriateness of PA technology, sources of information that are not explicitly location specific, and labor relations. We incorporate many of the same measures into the present models, essentially as controls, for the purpose of isolating geographic effects from the influence of these features of firm-specific organization. That is, we ask: When firm- and plant-specific sources of heterogeneity are accounted for, to what extent do localization or urbanization—the bases for the realization of agglomeration economies—continue to condition innovative firm behavior?

Because analysis of the properties of these variables drawn from the 1987 Kelley-Brooks survey appears elsewhere, the attention they receive here is deliberately minimal. From among some 200 items in the original survey, we draw here on only 12. These items have been selected to capture access of the potential PA adopter to financial and other resources, such as whether or not the plants are linked to Porter's and von Hippel's demanding customers, whether they face potential barriers (such as unions) to the organizational rule changes without which the productivity advantages from the technology are less likely to be realized and—most important—the *relevance* of PA technology to the individual plant. This relevance can be measured by whether or not the latter produces many parts or products in a diverse mix of batch sizes, in which case economizing on setup time and material wastage (among the major technical advantages of PA) would be especially desirable.

Organizational resources. Ideally, one would like to measure all of the various forms of information and financial and technical resources available for each activity related to adopting an innovation. A proxy for the level of organizational resources is plant employment, based on the count of the total number of employees (unfortunately, our extract from the 1987 survey does not include information on employment in the parent firm as a whole). The mean of employees per plant in the pooled sample is almost 64; however, the distribution of plant employment is highly skewed, with the largest plants employing close to 16,000 workers. We transform plant employment by taking the natural logarithm. We expect that the greater the log of employment, the greater the availability of resources and, therefore, the greater the likelihood that the plant will have adopted PA by 1987.

Scale of the production process. The scale of the production process is measured by counting the total number of machine tools—conventional and programmable—in operation at each plant. The mean of machine tools is 31 and the median is 25, with 24 very large plants using 650 or more machine tools. Like other skewed variables, we enter the log transform into our regressions. The greater the scale of machining operations at a plant, the more likely it is that PA will be advantageous for a particular operation. Moreover, the greater the number of tools in use, the less disruptive it is to experiment with a new technology by adopting a few new tools. Hence the larger the scale of metalworking operations, the greater the likelihood of PA adoption.[12]

Appropriateness of PA technology. We include in this category five indicators that distinguish the relevance of PA technology for each plant in the sample. Having already accounted for the scale of the tool stock, as the first indicator we hypothesize that plants whose conventional (nonprogrammable) tools are older are more likely to shift trajectory and adopt at least some PA than plants whose conventional tools are relatively new and not fully amortized. We measure this by the percent of all conventional (nonprogrammable) tools in use in the plant that are more than 10 years old. In the pooled sample, a mean of 64 percent of the conventional tool stock in each plant was at least 10 years old in 1987 (the median was 78 percent). Conversely, the age of the tool stock may act as a proxy for the age of the plant, so that newer plants are the most likely to adopt PA. Such a vintage effect would appear as a *negative* relationship between this covariate and the probability of adopting PA.

The second indicator is "machining importance," measured here by a dummy variable indicating whether or not the plant manager perceives machining to be at least moderately important to the core competence of that plant. This variable is based on the assumption that managers who believe technology to be important to their operations will be more alert and receptive to information about the properties and availability of the technology. In the pooled sample, 87 percent of metalworking plant managers said they thought machining was at least moderately important. We expect machining importance will be positively related to PA adoption.

Third, in order to satisfy customers who may have a variety of product requirements, plants often must be able to produce an item in both small and large batches. Batch size diversity is measured by a dummy variable that takes on the value *1* if the plant produces any output in small batch sizes of fewer than 50 pieces and also produces output in large batch sizes of either 100 to 500 units or more than 500 units. Nearly one-half of the plants (48 percent) report that they are required to produce output in diverse batch sizes. We expect this indicator of diversity in production requirements to be positively related to PA adoption.

Fourth, plants in this sector are often expected to be able to produce a number of different parts using machine tools in order to satisfy the needs of diverse customers. As the number of parts produced at a plant increases, plant managers may be attracted to a machine tool technology that minimizes changeover costs, one of PA's acknowledged advantages. Here, a dummy variable is coded *1* if the plant produces 50 or more parts. On average, branch plants are more likely to produce that many distinct parts than are companies with only one plant. In the pooled sample, 72 percent of the plants have this high a degree of variety of products. We expect this variety to be positively related to PA adoption.

Fifth, it may be difficult for some employees and management to understand PA's relevance to the plant's production processes, because they are generally unfamiliar with information technologies (ITs) being used in the machining area. However, many plants have invested in complementary IT applications for computer-aided design (CAD), planning and scheduling activities, or the monitoring and control of materials flow. Such complementary applications provide an opportunity for employees and managers to learn about information technologies in familiar work situations. We construct a dummy variable to indicate whether or not a plant is using computer technology in any one of its nonmachining applications. Fifty-seven percent of plants report that they use computer technology in planning, control, or design activities. Eighty-four percent of the branch plants follow this practice, as compared with 48 percent of the single-plant firms. We expect plants whose employees are familiar with any of the other applications of computer-controlled technology within their organization to be more likely to adopt PA.[13]

Customer demand. Porter (1990) suggests that demanding customers will extend their interest in best management practices to the activities of the suppliers. Dore (1986) reports much the same about the large firms that constitute the apex of the vertical Japanese *keiretsu*. From this information we should expect that if a customer of the focal establishment explicitly requests that PA equipment be used to manufacture a particular order, that plant will be more likely to adopt PA than will a plant with customers that have not made the request. Twelve percent of the plants report that their customers have requested that PA be used. Slightly more than 84 percent of the 962 plants report that they sell their PA-assisted machining output to another enterprise (an *external customer*). The remaining 16 percent use the output from the machining process only as input into other production processes within their own operations. When a plant sells machining output to an external customer, a dummy variable control for the existence of an external customer is coded as *1*. This effectively conditions the response to the previous variable.

One especially important class of customer for machining output is the U.S. Department of Defense (DOD) and its various prime contractors. Through the direct and indirect influence of purchases made by DOD, particular industries are closely tied to leading users of programmable technology. Funds provided by DOD for research and development of new process technologies were a key factor in the development of numerically controlled technology during the 1950s and 1960s (U.S. Congress, Office of Technology Assessment, 1990). Moreover, by the mid-1980s DOD was an influential customer for many U.S. manufacturers (Henry and Oliver, 1987; U.S. Congress, Office of Technology

Assessment, 1990). The 1987 survey data do not contain information on sales from the machining operations of our manufacturing plants to DOD or to any of its prime contractors. However, from unpublished 3-digit S.I.C.-level data provided by the U.S. Bureau of Labor Statistics (Kelley, 1993), it is possible to calculate the 1985 DOD share of total industry sales for each of the 21 metalworking industries. This industry-level information is used as a proxy variable for estimating the relative impact of DOD as an important customer having special requirements and policies likely to favor the use of PA technology by its suppliers (Kelley and Watkins, 1995).

Labor relations considerations. We include a dummy variable to indicate whether or not the focal plant is unionized. Thirty-three percent of the branch plants and 8.6 percent of the single-plant enterprises had unions in 1987. There is some dispute in the industrial relations literature about the way unionization affects the propensity of a firm to invest in new technology. The effect is likely to be different for large, multisite firms than for smaller, single-plant businesses. For the latter, the presence of a union is expected to spur investment in productivity-enhancing technology such as PA, while the managers of branch plants are more apt to choose to invest in their nonunion facilities as a strategy for avoiding both the constraints that collective bargaining may impose on the way the technology is deployed and the relatively higher wage levels known to be associated with unionization (Kelley, 1989). Therefore, we are uncertain about the likely effect of unionization on PA adoption in the pooled sample.

Findings

Exhibit 5 (see p. 80) reports the results of estimating 7 logit regressions (Agresti, 1984; Cramer, 1991) on models of the joint impacts of urbanization, localization, land area, the recent sales growth of the county's metalworking sector, and 12 measures of firm- and plant-specific organizational and technical characteristics, on the likelihood that the establishment's managers will have adopted at least one piece of programmable factory automation by 1987. The specifications are identical except for the alternative measure of localization that we used.

Across the seven models, the organizational and technology results are quite robust. Larger (and, therefore, presumably more resourceful) plants are more likely to have adopted this technology by 1987. Those plants would be ones whose managers perceive machining to be important to their operations, that produce in diverse batch sizes (for whom economizing on setup time should matter), that use other forms of information technology such as CAD in production, whose principal product falls into a 3-digit S.I.C. that ships a large fraction of its sales to DOD or its prime contractors, and whose principal customers specifically ask that PA technology be used by suppliers in machining parts or assembly. The results presented in exhibit 5 offer strong support for the vintage hypothesis on age of plant. That is, to the extent that age of tools does act as a proxy for age of establishment, the younger plants are most likely to adopt the new technology, all other factors being equal.

About one-fourth of the plants in the metalworking sector are wholly owned branches of multi-plant firms. The other three-quarters are at least de jure stand-alone businesses (for ways in which this distinction between legal and actual independence of small firms might matter for industrial and technology policy, see Harrison [1994] and sources cited therein). Thus decisions about adoption of new technology within this sector are being made at both the corporate and the plant levels.[14] When firm- and plant-specific effects are controlled for, the relative importance of geography becomes more sharply defined than in previous research.

Lagged growth in the local metalworking sector is not statistically significant in any of these specifications, although the sign is invariably positive, as expected. Apparently we have accounted sufficiently well for the individual characteristics of plants and companies that contribute to sales growth, leaving no room for additional aggregate explanation.

As hypothesized, the likelihood that plant managers will have adopted PA by 1987 is strongly and significantly inversely related to the physical size of the regions in which they are located. This result is, clearly, completely independent of the way we measure localization. The finding is consistent with (although, by itself, it does not prove) the supposition that successful diffusion of information is inversely related to distance between the generator or demonstrator and the recipient of that information.

Conversely, localization by itself has barely any effect on the adoption of PA. Six of the seven alternative indicators of sameness—concentration of metalworking activity in an area—are statistically insignificant. Only the number of local metalworking sector plants with more than 250 employees remains a significant predictor of PA adoption, and then only at a confidence level of 0.09. By contrast, urbanization—our indicator of diversity—is a consistently significant predictor of innovative firm behavior.

The graphic depicted in exhibit 6 (see p. 82) helps to summarize what we have learned. Here we compute the expected probability of PA adoption within the sample as a function of urbanization. The effects of all input/output variables and a selected measure of localization (the lagged number of metalworking plants in the county) are evaluated at their sample means, based on the first equation reported in exhibit 5. Recall that the unconditioned mean incidence of PA adoption among all plants in this sector in 1987 was 0.52. We find that the expected probability of adoption among core-metro plants is only 0.40. It is slightly lower in the rural areas, as we should expect if learning about technology from neighbors is indeed one of the processes that underlies diffusion. The conditional odds of adoption are 65:35 for plants located in counties that are adjacent to the urban core. The odds are somewhat lower for establishments situated in smaller metropolitan areas, but they return nearly to their adjacent-core-metro level in counties adjacent to smaller metropolitan areas.

Thus, as noted by Marie Howland at the HUD Roundtable on Regionalism, December 8–9, 1994, the effects of urbanization—diversity—on innovation are not uniform across all types of urban counties. The locale that is most supportive of technological upgrading by establishments in the machining sector is the set of counties adjacent to the largest core metropolitan areas—that which we might loosely call the suburbs. The next-most-innovation-inducing local environment is to be found in counties adjacent to smaller metropolitan areas—again, usefully thought of as suburban. Computer programmable automation adoption is also significantly more likely to occur among establishments located inside smaller metropolitan counties than inside the base case of the largest urban areas.

These differences require an explanation.[15] At least three selection stories are consistent with these findings. First, we consider those generally smaller, stand-alone firms whose median number of employees is 40, in contrast to a median of 150 workers for the branch plants in this sector. The oldest firms may be the least likely to change technological trajectory, choosing instead to live off of old capital. Perhaps the oldest small firms are to be found disproportionately in the oldest locations: the inner urban core and the rural areas. If we assume that the share of old tools among a plant's conventional tool stock is at least correlated with the age of the plant, the spatial distribution of this variable should tell us where the oldest small plants tend to be located. Those should be the locales in which the expected probability of PA adoption is lowest.

Exhibit 5

Partial Effects of Localization and Urban (County Level) Measures of Industrial Organization on the Probability of Adoption of Programmable Automation by U.S. Metalworking Establishments by 1987

INTERCEPT	–5.414***	–5.730***	–4.934****	–5.487***	–5.312***	–5.438***	–5.214
LOG OF THE RATIO OF METALWORKING SHIPMENTS FROM 1987 TO 1982	0.205	0.216	0.178	0.240	0.218	0.230	0.202
COUNTY SQ MILES/10,000 IN 1983	–1.717**	–1.746**	–1.585**	–1.792**	–1.748**	–1.552**	–1.625
LOG NO. METAL ESTABS IN THE COUNTY, 1982	0.058						
LOG METAL EMP IN THE COUNTY, 1982		0.067					
LOG EMP LOC QUOTIENT IN THE COUNTY, 1982			–0.190				
LOG METAL ESTABS > 250 EMP IN THE COUNTY, 1982				0.151*			
LOG METAL ESTABS > 500 EMP IN THE COUNTY, 1982					0.115		
ANY METAL ESTABS > 250 EMP IN THE COUNTY, 1982						0.423*	
ANY METAL ESTABS > 500 EMP IN THE COUNTY, 1982							0.273
ADJ. TO CORE (POP > 1 MILLION) METRO COUNTY, 1983	0.939***	0.957***	0.893***	1.045***	0.991***	0.941***	0.975
SMALL (POP < 1 MILLION) METRO COUNTY, 1983	0.652**	0.670***	0.508**	0.768***	0.683***	0.691***	0.642
ADJ. TO SMALL METRO COUNTY, 1983	0.689*	0.719*	0.477	0.859**	0.727**	0.802**	0.704
NEITHER METRO NOR ADJ. (RURAL), 1983	–0.414	–0.375	–0.674	–0.246	–0.386	–0.267	–0.433
LOG EMP IN SAMPLE PLANT	0.404***	0.401***	0.405***	0.395***	0.395***	0.394***	0.392
LOG NUMBER OF MACHINE TOOLS OF ALL TYPES	0.119	0.123	0.110	0.128	0.128	0.138	0.128
PCT OF CONVENTIONAL TOOLS THAT ARE > 10 YRS. OLD	–0.011***	–0.011***	–0.011***	–0.011***	–0.011***	–0.011***	–0.011
PRODUCTION MANAGER'S PERCEPTION THAT MACHINING IS AN "IMPORTANT" OR "VERY IMPORTANT" PROCESS IN THIS PLANT	1.709***	1.720***	1.707***	1.713***	1.715***	1.698***	1.704

Exhibit 5 (continued)

Partial Effects of Localization and Urban (County Level) Measures of Industrial Organization on the Probability of Adoption of Programmable Automation by U.S. Metalworking Establishments by 1987

PLANT PRODUCES IN BOTH SMALL (< 50 PIECES) AND LARGE (>100) BATCHES	0.999***	0.998***	1.001***	1.002***	1.000***	0.984***	1.000
PLANT PRODUCES > 50 PARTS OR PRODUCTS	0.275	0.269	0.291	0.270	0.266	0.264	0.283
PLANT USES OTHER INFORMATION TECHNOLOGY IN PRODUCTION (e.g., CAD/CAM)	0.832***	0.835***	0.831***	0.835***	0.832***	0.860***	0.829
PLANT IS UNIONIZED	0.113	0.110	0.109	0.128	0.125	0.129	0.122
LOG OF PCT OF THE PLANT'S MAIN 3-DIGIT S.I.C. INDUSTRY'S SALES TO DEFENSE IN 1985	0.778***	0.768***	0.815***	0.751***	0.767***	0.746***	0.770
PLANT SELLS MACHINING OUTPUT TO THE MARKET (NOT JUST TO OTHER PLANTS WITHIN THE SAME FIRM)	–0.392	–0.392	–0.395	–0.385	–0.386	–0.361	–0.340
CUSTOMER REQUIRES PA USE	1.725***	1.720***	1.738***	1.709***	1.715***	1.688***	1.746
PLANT IS A BRANCH OF A MULTIPLANT FIRM	0.161	0.157	0.178	0.156	0.158	0.153	0.161
N	962	962	962	962	962	962	962
D.F.	19	19	19	19	19	19	19
–2 LOG L	918.6***	918.2***	918.8***	916.3***	917.6***	915.4	917.1

Source of data on firm/plant chartacteristics and on adoption of Computer-programmable factory automation: 1987 Kelley-Brooks' establishment survey (metalworking consists of the 21 three-digit industries that included nearly 100% of all machining workers in the United States in 1985).

Source of localization data: extracts from the 1982 and 1987 censuses of manufactures (prepared for us by the U.S. Census Bureau's Center for Economic Studies).

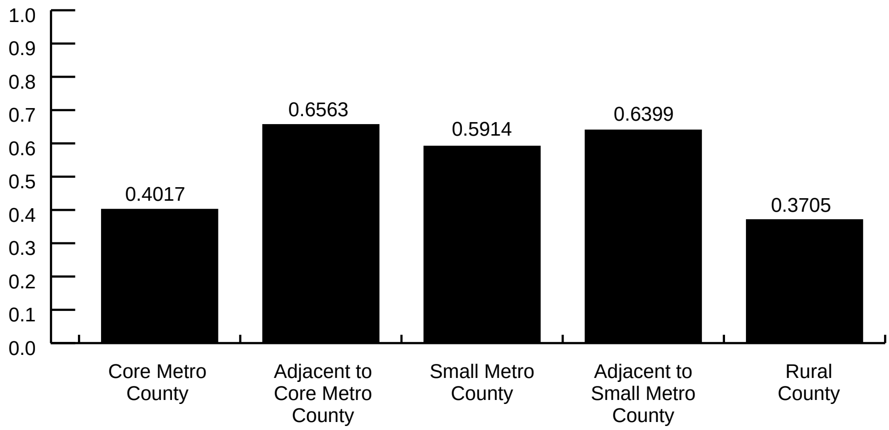
Source of urbanization data: Transformation by Jon Gant of the 1983 "Beale" Index, Economic Research Service, U.S. Department of Agriculture.

Source of land area data: 1983 City and County Data Book, U.S. Census Bureau.

*** p < .01 ** p .05 * p < .10

Exhibit 6

Expected Probability of PA Adoption by 1987 as a Function of Urbanization
(with localization measured by log of number of metalworking establishments
in the county in 1982*)



* all other variables held constant at their sample means

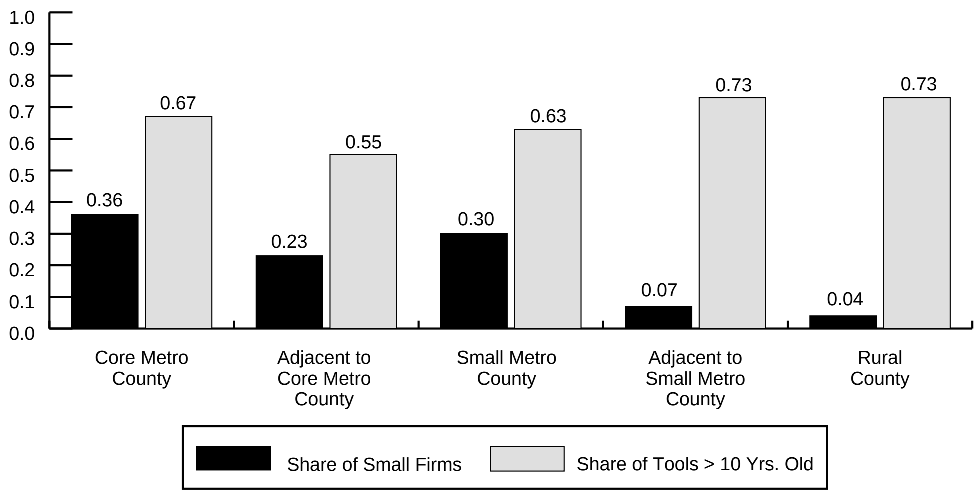
Exhibit 7 confirms just such a hypothesis. Core metropolitan counties are indeed the modal sites for single-plant metalworking firms, whose locational incidence falls off rather consistently with distance from the most highly urbanized centers. Also, it is clearly in the largest core metropolitan counties and in the least populous counties that the tool stock, as a proxy for plant age, is the oldest. A second possible source of selection is a corollary to the first. Of those relatively few plants that relocate from one type of county to another, the "best" plants—those most inclined to modernize—have systematically moved from old urban core areas to suburban counties.

Finally, among the branch plants of multi-plant companies, it is plausible that corporate management has decided to place new investments in its relatively newer "greenfield" facilities while gradually disinvesting in its older, less productive "brownfield" sites. Among branch plants in metalworking in 1987, the share of old tools was about 10 percent greater among facilities located in core metropolitan counties than in the counties adjacent to the core and fully one-third greater than in smaller metropolitan counties.

These mutually consistent, plausible explanations for the relatively poor performance of metalworking establishments still situated within the largest metropolitan counties in 1987 indicate a direction for future research. A second wave of interviews with the plant managers studied in 1987 was conducted by Kelley in 1991. Nearly all of the plants that relocated during the interim were identified and reinterviewed. Establishments that exited the metalworking sector or shut down altogether were successfully distinguished from the others. Preliminary research on the two waves of interviews, using the larger BEA area as the spatial unit of analysis, has teased out the importance of localization (specialization) as well as urbanization (ecological diversity) in shaping technological change, especially for small enterprises (Kelley and Helper, 1996).

Exhibit 7

Distribution of Single-Plant Enterprises and Age of Their Conventional Tool Stocks, by Degree of Urbanization in 1987



In remarks at the HUD Roundtable on Regionalism, Margaret Dewar correctly observed that for better access to the sources of variation among places as to how well or poorly they support innovative firm behavior, especially among smaller businesses, we should indicate something about geographic variation in labor-management, racial, and other "climates." She alluded to Massey's (1984) geological metaphor, well-known to geographers and planners, according to which local economies should be understood as the result of partially overlapping and interpenetrating layers of successive waves of development. Some of these waves impose features on the history of a place that may last long after the pinnacle of that particular industry has been reached. We believe that such historical markers can be formally modelled and that the rekindled interest in path-dependent theories of technological change and economic growth provide a supportive intellectual environment for such modelling. However, analysis at this level is beyond the scope of the present article.

Thus all we can conclude for now is that—at least for the metalworking sector, and in cross-sectional (as distinct from panel) data—variation among locales in the degree of same-industry specialization plays a weaker role in explaining variation in the innovative behavior of private companies than the research of Sabel, Saxenian, and others might have led us to expect. By contrast, variation among places in terms of diversity—as reflected in population density and the centrality of the locale within the national system of counties—contributes significantly to differences in innovative behavior among firms, even after holding constant many of the firm- and establishment-specific characteristics that have been widely held to be important for capturing the inclination and ability of a business to learn from others. Whether, and to what extent, these results hold for other sectors, both in manufacturing and in services, can only be answered by collecting data on those sectors and repeating the study.

Conclusions

Economic activity commonly clusters in space. Of that there can be no doubt. Even in the metalworking sector, with facilities spread among two-thirds of all U.S. counties in 1987, there are still a countable number of locations in which employment and output are disproportionately concentrated.

The existence of clustering does not, by itself, imply the presence of tight local input/output linkages—the basic fabric of the canonical industrial district, however deeply embedded in noneconomic institutions. With a longer historical perspective, we might well have discovered that many of those observed clusters originated as localized concentrations centered on particular industries: aircraft in St. Louis, shipfitting in Detroit, and small-arms production in the Connecticut River Valley. But by the 1980s, such relatively narrow specialization had become less relevant to the continuing functioning of these places as growth centers. In other words, at least a portion of these clusters may have become artifacts.

More important to our conclusions is the fact that most prior research in industrial geography has inadequately accounted for differences in the nonspatial characteristics of firms under study. This situation has almost surely led many observers to exaggerate the relative importance of locality—including the magnitude and significance of potential agglomeration economies—as a determinant of firm behavior. In this article we show that industrial organization, scale and scope of production, and locality all play a role in shaping at least one important aspect of such behavior: the implementation of innovative production technology. Where characteristics of locale hypothesized to be sources of potential agglomeration economies are significant, it is *diversity*, reflecting the property of urbanization, more consistently than *sameness* or localization, that appears to be the motivating factor (although again, as is suggested by the panel data results reported by Kelley and Helper [1996], this may be an artifact of the present article's relying on a cross-section).

Being situated within the least dense, least diverse rural regions creates especially severe problems of isolation for independently owned, stand-alone firms. Among these typical small companies, the odds of adopting PA are only a little better than 1:9. By contrast, 8 out of 10 rural branch plants of multilocational, sometimes transnational firms with access to the information networks of their corporate parents adopt computer-controlled technology. The implication is that urbanization—a diverse economic and institutional environment—is especially important for smaller companies (this finding is strongly confirmed in the panel-based research conducted by Kelley and Helper [1996]). This implication also constitutes evidence in support of our thesis that establishments belonging to multilocational or network firms have access to relevant information that is independent of their immediate location.

Thus we add our voices to those who have found that "Jacobs" effects—in a word, *diversity*—are likely to be sources of dynamic external economies at least as important as the presence of many other firms or workers in the same industry or sector: the variable emphasized in the industrial district literature. Urbanization, or diversity, is as important as, or more important than, localization, or sameness, in contributing to an explanation of which kinds of firms adopt new technologies and which are less likely to do so.

Authors

Bennett Harrison is visiting professor of political economy in the Taubman Center for State and Local Government at Harvard University's John F. Kennedy School of Government. In September 1996, he becomes professor of urban political economy in the Milano Graduate School of Management and Urban Policy at The New School for Social Research. His most recent books in the field of economic development are Lean and Mean: The Changing Landscape of Corporate Power in the Age of Flexibility *(Basic Books) and* Building Bridges: CDC's and the World of Employment Training *(The Ford Foundation).*

*Maryellen R. Kelley is visiting scholar in the Industrial Performance Center at the Massachusetts Institute of Technology, on leave of absence from Carnegie Mellon University. Among her most recent papers in the field of technology policy are "In From the Cold: Prospects for Conversion of the Defense Industrial Base" (*Science Magazine*) and "The Role of Institution-Building in U.S. Industrial Modernization Programs" (*Research Policy*).*

Jon Gant is a doctoral candidate in public policy at the Heinz School of Public Policy and Management at Carnegie Mellon University. He is co-author of Building Bridges *and is a specialist in geographic information systems.*

Notes

1. This article is part of ongoing research begun in Cambridge, Massachusetts, in 1985 by Maryellen Kelley and Harvey Brooks at the Center for Business and Government of the Kennedy School of Government at Harvard University, under National Science Foundation (NSF) grant SES–8520174. Their 1986–87 interviews with production managers in more than 1,000 manufacturing plants were repeated in 1991 at Carnegie Mellon University (CMU) by Kelley with Todd Watkins (Lehigh University), under NSF grant SES–8911141. Data on the properties of the counties in which the sample plants were located, together with supplementary information on the sample plants and their principal customers, suppliers, machining subcontractors, and machine tool vendors, were then assembled by Kelley, Harrison, and four Heinz School/CMU doctoral students, Cathleen McGrath, Robert Greenbaum, Uma Surkund, and Jon Gant in 1992–1994 under NSF grant SES–9122155 and grants from the Carnegie Bosch Institute for Research on International Management and the Duquesne Light Fund of CMU's Center for Economic Development. We are grateful for comments from Margaret Dewar, Denise Dipasquale, Michael Enright, Marie Howland, Adam Jaffe, Richard Nelson, Karen Polenske, and Allen Scott.

2. Economists have shown empirically, or have speculated, that this essentially sociological process can facilitate the diffusion of agricultural innovations when trusted and more experienced neighbors who are already users significantly influence a farmer's decision to adopt a new technology (Case, 1992; Griliches, 1960; Thirtle and Ruttan, 1987).

3. Following the now classic conception and deriving from Marshall (1920), Enright (1994b) defines regional clusters as "a group of firms in the same industry, or in closely related industries, that are in close geographic proximity to one another" (p. 24).

4. Industrial districts—as the concept has been developed by Sabel, Piore, Scott, Storper, Saxenian, and, of course, the Italians in north-central Italy—turn on much more than just agglomeration economies (Harrison, 1992). The glue that binds the districts involves a degree of reciprocal collaboration (paradoxically combined with sometimes intense competition) embedded in local noneconomic institutions (Granovetter, 1985; Putnam, 1993). This collaboration is not captured in conventional economic models of agglomeration or in the theory of repeated games. Nevertheless, for the purposes of this article, we do not explicitly incorporate this distinction, but accept the popular usage by which the term *district* has become virtually synonymous with *cluster, complex,* and *agglomeration.*

5. Static agglomeration economies are said to occur when a business establishment's unit costs of production are lower in the context of a relatively dense cluster of firms or specialized resources (such as skilled labor and infrastructure), than they would be if the "focal" business were located elsewhere. Dynamic agglomeration economies are said to occur when location in a dense urban cluster heightens the prospect that technological learning—rather than simply a reduction in unit costs of production—will occur.

6. In principle, powerful leading firms may also *thwart* the local diffusion of information that could be used in making decisions about adopting an innovation, or the firm may dominate late-comers to the technology in other ways, such as spoiling their labor markets by offering above-average wages and benefits. Such oligopolistic or oligopsonistic behavior is explored by Appold (1991).

7. The industries are: nonferrous foundries (SIC 336); cutlery, hand tools, and hardware (SIC 342); heating equipment and plumbing fixtures (SIC 343); screw machine products (SIC 345); metal forgings and stampings (SIC 346); ordnance and accessories not elsewhere classified (SIC 348); miscellaneous fabricated metal products (SIC 349); engines and turbines (SIC 351); farm and garden machinery and equipment (SIC 352); construction and related machinery (SIC 353); metalworking machinery and equipment (SIC 354); special industrial machinery (SIC 355); general industrial machinery and equipment (SIC 356); miscellaneous machinery, excluding electrical (SIC 359); electrical industrial apparatus (SIC 362); motor vehicles and equipment (SIC 371); aircraft and parts (SIC 372); guided missiles and space vehicles (SIC 376); engineering and scientific instruments (SIC 381); measuring and controlling instruments (SIC 382); jewelry, silverware, and plateware (SIC 391).

8. This process incorporates the cutting, shaping, grinding, and bending of various metals. It is not limited solely to "machine shops."

   The establishments were randomly sampled by size in order to yield a sample with an equal number of establishments from each of 5 size strata: fewer than 20 employees, 20–49, 50–99, 100–249, and 250 or more employees. Although fewer than 10 percent of all plants in the population have more than 100 employees, this procedure produced a sample with a sufficient number of large establishments to allow for variation among larger plants in their use of technology and in their organizational structure. The original sampling frame was obtained from the McGraw-Hill and Dun and Bradstreet companies. Overall response rates, appropriately weighted, were 53.8 percent for a mail survey and 89.3 percent for the extract of 1,363 usable cases containing variables common to both mail and telephone surveys. This combined extract is the data set we use in this article. Compared with most surveys of business establishments, these response rates are extraordinarily high.

For further details on sampling methodology, consult Kelley and Brooks (1991).

9. Due to CES policy of protecting the identity of individual respondents, data on some counties were suppressed, but this suppression was minor. Of the 1,363 cases in the extract from the 1987 Kelley-Brooks survey that combines information from both the mail and telephone questionnaires, we were able to obtain from CES complete, unsuppressed data on the properties of counties containing 1,276 of these cases. The consequences of losing the 87 observations resulting from data suppression are unremarkable. That is, the truncated sample means and variances are almost identical to those in the original full sample. Details and tables are available from the authors.

10. In ongoing research we are examining the properties of models in which we define *milieu* at the level of U.S. Bureau of Economic Analysis (BEA) labor market areas: population nodes and supersets of counties that constitute commuting fields around them. For a progress report, see Kelley and Helper (1996).

11. In selecting the threshold for the dummy variables, we observed that 90 percent of the counties with any metalworking contained at least one large plant. By contrast, 68 percent of establishments in this sector are located within counties having at least 5 plants with 250 or more employees, while 45 percent are situated in places with at least 5 establishments having 500 or more workers. Thus five seems a reasonable threshold for characterizing the cutoff point for a county that is a potential leader in terms of metalworking plants.

12. Much has been written about the relevance of firm size and the scale of production to innovation and technological change. Whether the young Schumpeter (who saw competitive small firms as important sources of innovation in market economies) or the mature Schumpeter (the essayist on the advantages accruing to what he, and Galbraith after him, called big business) was correct continues to be the subject of much research and theorizing, especially in industrial economics and business strategy (Harrison, 1994b). We share the assessment of Scherer (1992): “Favoring large firms is the possibility that economies of scale exist in staffing and equipping R&D laboratories, that risk can be spread more widely, and that financial resources can be tapped at lower cost. Working against size is the possibility of hierarchical incentive failures, coordination breakdowns, and bureaucratic sluggishness. How these advantages and handicaps balance out can only be ascertained empirically.”

13. Obviously, the causality could run in the other direction. Ideally we would like to know whether the presence of other (non-PA) IT antedates the adoption of PA. Because the time pattern of which came first is unobservable in our data, all that can be inferred here is the strength of the correlation between the presence of IT in the form of PA on the shop floor and the presence of complementary IT applications in the form of (generally) off-the-floor overhead functions, such as planning, design, and control.

14. The way this difference between firm- and plant-level decisionmaking differentially affects the choice of a make/buy strategy with respect to supplier relations (that is, how much of a product to manufacture in-house rather than outsource to an external

supplier) is the subject of Kelley and Harrison (1990). On the more general economics of the multi-unit firm, see Caves (1989) and Scherer et al. (1975).

15. Rural plants are no more likely to adopt PA than are core-metro plants. Indeed, they may even be less likely to do so. The sign on rural counties is invariably negative across the seven different specifications of localization.

References

Agresti, Alan. 1984. *Analysis of Ordinal Categorical Data.* New York: John Wiley and Sons.

Angel, David P. 1994. *Restructuring for Innovation: The Remaking of the U.S. Semiconductor Industry.* New York: Guilford Press.

Appold, Stephen J. August 1991. “The Location Process of Industrial Research Laboratories,” *The Annals of Regional Science*, pp. 131–144.

Arthur, Brian. 1989. “Industry Location Patterns and the Importance of History.” CEPR publication no. 84. Center for Economic Policy Research, Stanford University.

Badaracco, Joseph L., Jr. 1991. *The Knowledge Link: How Firms Compete Through Strategic Alliances.* Boston: Harvard Business School Press.

Best, Michael. 1990. *The New Competitors.* Cambridge, MA: Harvard University Press.

Bianchi, Patrizio, and Nicola Bellini. October 1991. “Public Policies for Local Networks of Innovators,” *Research Policy* 20(5):487–497.

Bosworth, Brian, and Stuart A. Rosenfeld. 1993. *Significant Others: Exploring the Potential of Manufacturing Networks.* Chapel Hill, NC: Regional Technology Strategies, Inc.

Case, Anne. September 1992. “Neighborhood Influence and Technological Change,” *Regional Science and Urban Economics* 22:491–508.

Caves, Richard. 1989. *Multinational Enterprise and Economic Analysis.* Cambridge, UK: Cambridge University Press.

Chinitz, Benjamin. May 1961. “Contrasts in Agglomeration: New York and Pittsburgh,” *American Economic Association/Papers and Proceedings of the 73rd Meeting* 51:12–27.

Cohen, Wesley M., and Daniel A. Levinthal. April 1990. “Absorptive Capacity: A New Perspective on Learning and Innovation,” *Administrative Science Quarterly* 35:128–152.

Cramer, J.S. 1991. *The Logit Model: An Introduction for Economists.* London: Edward Arnold.

Cyert, Richard, and James March. 1963. *A Behavioral Theory of the Firm.* Englewood Cliffs, NJ: Prentice-Hall.

Dore, Ronald. 1986. *Flexible Rigidities: Industrial Policy and Structural Adjustment in the Japanese Economy 1970–1980.* London: Athlone Press.

Dosi, Giovanni. March 1988. "Sources, Procedures, and Microeconomic Effects of Innovation," *Journal of Economic Literature* 26:1120–1171.

Edquist, Charles, and Staffan Jacobsson. 1988. *Flexible Automation: The Global Diffusion of New Technology in the Engineering Industry.* Oxford: Basil Blackwell.

Enright, Michael J. 1994a. "Organization and Coordination in Geographically Concentrated Industries," in Daniel Raff and Naomi Lamoreaux, eds., *Coordination and Information: Historical Perspectives on the Organization of Enterprise.* Chicago: University of Chicago Press for the National Bureau of Economic Research.

_____. June 1994b. "Regional Clusters and Firm Strategy." Paper prepared for the Prince Bertil Symposium on The Dynamic Firm: The Role of Regions, Technology, Strategy and Organization, Stockholm School of Economics.

_____. February 1993. "The Determinants of Geographic Concentration in Industry." Working paper 93–052. Division of Research, Harvard Business School.

Florida, Richard, and Martin Kenney. 1990. *The Breakthrough Illusion.* New York: Basic Books.

Gerlach, Michael L. 1992. *Alliance Capitalism.* Berkeley: University of California Press.

Glaeser, Edward, Hedi Kallal, Jose Scheinkman, and Andrei Schleifer. December 1992. "Growth in Cities," *Journal of Political Economy* 100:1126–1152.

Glasmeier, Amy. October 1991. "Technological Discontinuities and Flexible Production Networks: The Case of Switzerland and the World Watch Industry," *Research Policy* 20:469–485.

Granovetter, Mark. 1985. "Economic Action and Social Structure: The Problem of Embeddedness," *American Journal of Sociology* 91:481–510.

Griliches, Zvi. March 1960. "Hybrid Corn and the Economics of Innovation," *Science* 3422:275–280.

Hagerstrand, Torsten. 1967. *Innovation Diffusion as a Spatial Process.* Chicago: University of Chicago Press.

Harrison, Bennett. February 1994a. "Concentrated Economic Power and Silicon Valley," *Environment and Planning* 26:307–328.

_____. 1994b. *Lean and Mean: The Changing Landscape of Corporate Power in the Age of Flexibility.* New York: Basic Books.

_____. October 1992. "Industrial Districts: Old Wine in New Bottles," *Regional Studies* 26:469–483.

Henderson, Vernon J. "Externalities and Industrial Development." June 1994. Paper prepared for the Prince Bertil Symposium on The Dynamic Firm: The Role of Regions, Technology, Strategy and Organization, Stockholm School of Economics.

_____. 1988. *Urban Development: Theory, Fact and Illusion.* New York: Oxford University Press.

Henry, David, and R. Oliver. August 1987. "The Defense Buildup, 1977–85: Effects on Production and Employment," *Monthly Labor Review* 110:3–11.

Hoover, Edgar M. 1971. *An Introduction to Regional Economics.* New York: Knopf, 1st ed.

Huber, George P. February 1991. "Organizational Learning: The Contributing Processes and the Literatures," *Organizational Science* 2:88–115.

Isard, Walter. 1956. *Methods of Regional Science.* Cambridge, MA: M.I.T. Press.

Jacobs, Jane. 1967. *The Economy of Cities.* New York: Random House.

Jaffe, Adam B., M. Trajtenberg, and Rebecca Henderson. August 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics* 108:577–598.

Kelley, Maryellen R. November 1993. "Organizational Resources and the Industrial Environment: The Linkage to the Adoption of Advanced Manufacturing Technology," *International Journal of Technology Management* 8:33–68.

_____. 1989. "Alternative Forms of Work Organization Under Programmable Automation," in Stephen Wood, ed., *The Transformation of Work?* London: Unwin and Hyman.

Kelley, Maryellen R., and Ashish Arora. Spring 1996. "The Role of Institution-Building in U.S. Industrial Modernization Programs," *Research Policy.*

Kelley, Maryellen R., and Harvey Brooks. March/April 1991. "External Learning Opportunities and the Diffusion of Process Innovations to Small Firms: The Case of Programmable Automation," *Technological Forecasting and Social Change* 39:103–125.

Kelley, Maryellen R., and Bennett Harrison. September 1990. "The Subcontracting Behavior of Single vs. Multiplant Enterprises in U.S. Manufacturing: Implications for Economic Development," *World Development* 18:1273–1294.

Kelley, Maryellen R., Bennett Harrison, and Cathleen McGrath. October 1994. "Collaborative Practices Within and Between U.S. Manufacturing Establishments in 1991," *Industrial Relations Research Association, Proceedings of the Boston Meetings.*

Kelley, Maryellen R., and Susan Helper. February 1996. "Firm Size and Capabilities, Regional Agglomeration, and the Adoption of New Technology." Working paper. Cambridge, MA: Massachusetts Institute of Technology, Industrial Performance Center.

Kelley, Maryellen R., and Todd A. Watkins. April 28, 1995. "In From the Cold: Prospects for Conversion of the Defense Industrial Base," *Science* 268:525–532.

Krugman, Paul. 1991. *Geography and Trade.* Cambridge, MA: M.I.T. Press.

Leonard-Barton, Dorothy. October 1988. "Implementation as Mutual Adaptation of Technology and Organization," *Research Policy* 17:251–267.

Lincoln, James R., Michael L. Gerlach, and Peggy Takahashi. October 1992. "*Keiretsu* Networks in the Japanese Economy: A Dyad Analysis of Intercorporate Ties," *American Sociological Review* 57:561–585.

Lorenz, Edward. 1988. “Neither Friends Nor Strangers: Informal Networks of Subcontracting in French Industry,” in Diego Gambetta, ed., *Trust: Making and Breaking Cooperative Relations.* New York and Oxford: Basil Blackwell.

Malerba, Franco. July 1992. “Learning by Firms and Incremental Technical Change,” *Economic Journal* 102:845–859.

March, Artemis. 1989. “The U.S. Machine Tool Industry and its Foreign Competitors,” in *Working Papers of the MIT Commission on Industrial Productivity* vol. II. Cambridge, MA: M.I.T. Press.

Marshall, Alfred. 1920 [originally pub. 1890]. *Principles of Economics.* London: MacMillan, 8th ed.

Martinelli, Flavia, and Erica Schoenberger. 1991. “Oligopoly is Alive and Well: Notes For a Broader Discussion of Flexible Accumulation,” in Georges Benko and Mick Dunford, eds., *Industrial Change and Regional Development: The Transformation of New Industrial Spaces.* London and New York: Belhaven Press/Printer.

Massey, Doreen. 1984. *Spatial Divisions of Labor.* New York: Methuen.

Mowery, David, ed. 1988. *International Collaborative Ventures in U.S. Manufacturing.* Cambridge, MA: Ballinger.

Nelson, Richard R. Forthcoming. “Recent Evolutionary Theorizing About Economic Change,” *Journal of Economic Literature.*

Nelson, Richard R., and Sidney Winter. 1982. *An Evolutionary Theory of Economic Change.* Cambridge, MA: Harvard University Press.

Ormrod, Richard K. April 1990. “Local Context and Innovation Diffusion in a Well Connected World,” *Economic Geography* 66:109–122.

Park, Robert E., and Ernest W. Burgess. 1967. *The City.* Chicago: University of Chicago Press.

Perroux, Francois. June 1955. “Note Sur la Notion de ‘Pole de Croissance,’” *Economie Appliquee.* January–June 1955. pp. 307–320.

Perrow, Charles. 1992. “Small Firm Networks,” in Nitin Nohria and Robert G. Eccles, eds., *Networks and Organizations.* Boston: Harvard Business School Press.

Piore, Michael, and Charles F. Sabel. 1984. *The Second Industrial Divide.* New York: Basic Books.

Porter, Michael. 1990. *The Competitive Advantages of Nations.* New York: The Free Press.

Porter, Michael, and Peter Brantley. 1992. “Competitive Cooperation in Biotechnology: Learning Through Networks?” in Nitin Nohria and Robert G. Eccles, eds., *Networks and Organizations: Structure, Form, and Action.* Boston: Harvard Business School Press.

Powell, Walter W. 1990. “Neither Market Nor Hierarchy: Network Forms of Organization,” *Research in Organizational Behavior* 12:295–336.

Putnam, Robert D. 1993. *Making Democracy Work: Civic Traditions in Modern Italy*. Princeton, NJ: Princeton University Press.

Romer, Paul. 1986. "Increasing Returns and Long-Run Growth," *Journal of Political Economy* 94:1002–1037.

Rosenfeld, Stuart A. 1992. *Competitive Manufacturing: New Strategies for Regional Development.* New Brunswick, NJ: Center for Urban Policy Research, Rutgers University.

Sabel, Charles F. 1992. "Studied Trust: Building New Forms of Co-operation in a Volatile Economy," in Frank Pyke and Werner Sengenberger, eds., *Industrial Districts and Local Economic Regeneration.* Geneva: International Institute for Labour Studies, International Labour Office.

_____. 1989. "Flexible Specialization and the Re-emergence of Regional Economies," in Paul Hirst and Jonathan Zeitlin, eds., *Reversing Industrial Decline?* Oxford: Berg.

Sako, Mari. 1992. *Prices, Quality and Trust: Interfirm Relations in Britain and Japan.* Cambridge, UK: Cambridge University Press.

Saxenian, AnnaLee. 1994. *Regional Advantage.* Cambridge, MA: Harvard University Press.

Scherer, F.M. September 1992. "Schumpeter and Plausible Capitalism," *Journal of Economic Literature* 30:1416–1433.

Scherer, F.M., Alan Beckenstein, Erich Kaufer, and R.D. Murphy. 1975. *The Economics of Multi-Plant Operation.* Cambridge, MA: Harvard University Press.

Scott, Allen J. June 1994. "The Geographic Foundations of Industrial Performance." Paper prepared for the Prince Bertil Symposium on The Dynamic Firm: The Role of Regions, Technology, Strategy and Organization. Stockholm, Sweden: Stockholm School of Economics.

_____. 1990. *Metropolis: From the Division of Labor to Urban Form.* Berkeley: University of California.

_____. 1988. *New Industrial Spaces.* London: Pion.

Scott, Allen J., and D. Bergman. October 1993. "Advanced Ground Transportation Equipment Manufacturing and Local Economic Development: Lessons for Southern California." Working paper no. 8. Los Angeles: University of California, Lewis Center for Regional Policy Studies.

Shapira, Philip. 1994. "Evaluating Industrial Modernization Programs: Issues, Practices and Strategies." Atlanta: Georgia Institute of Technology, School of Public Policy and Economic Development Institute.

Simmel, Georg. 1971. *On Individuality and Social Forms: Selected Writings.* Chicago: University of Chicago Press.

Storper, Michael. August 1993. "The Resurgence of Regional Economies, Ten Years Later: The Region as a Nexus of Untraded Interdependencies." Los Angeles: University of California, Graduate School of Architecture and Urban Planning.

Storper, Michael, and Bennett Harrison. October 1991. "Flexibility, Hierarchy and Regional Development: The Changing Structure of Industrial Production Systems and Their Forms of Governance in the 1990s," *Research Policy* 20:407–422.

Storper, Michael, and Allen J. Scott. 1989. "The Geographical Foundations and Social Regulation of Flexible Production Complexes," in Jennifer Wolch and Michael Dear, eds., *Territory and Social Reproduction.* Boston and London: Unwin and Hyman.

Thirtle, Colin, and Vernon Ruttan. 1987. *The Role of Demand and Supply in the Generation and Diffusion of Technical Change.* New York: Harwood Academic Publications.

U.S. Congress, Office of Technology Assessment. 1990. "Making Things Better: Competing in Manufacturing," Report No. OTA–ITE–443. Washington, D.C.

von Hippel, Eric. 1988. *The Sources of Innovation.* New York: Oxford University Press.

U.S. Department of Housing and Urban Development
Office of Policy Development and Research
Washington, DC 20410–6000