Inside-Out: Regional Networks and Industrial Adaptation in Silicon Valley and Route 128

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Abstract

The competitive advantages of regional clusters are the focus of much scholarly and policy attention. The literature relies heavily on the concept of external economies to explain the advantages derived from the spatial clustering of economic activity. This article compares two of America's leading technology regions—California's Silicon Valley and Massachusetts' Route 128, to suggest the limits of the notion of external economies and to propose an alternative network approach to analyzing regional economies. By rejecting the sharp distinction between what occurs inside and outside the firm, the network approach illuminates the complex and historically evolved relations between firms and the social structures and institutions of a particular locality. Through a set of comparisons of companies in Silicon Valley and Route 128, the article explains the divergent performance of these two apparently comparable regional clusters, and in so doing provides insights into the local sources of competitive advantage.

The competitive advantages of regional clusters have become a focal point of scholarly and policy attention. The work of Paul Krugman (1991) and Michael Porter (1990) has spurred widespread interest in regions and regional development, once the sole province of economic geographers and regional scientists. These newcomers have ignored an already extensive and sophisticated literature on the dynamics of industrial localization (see, for example, Storper, 1989; Scott, 1988a, 1988b; Vernon, 1960). Yet, like their predecessors, they share a reliance on external economies to explain the advantages of clustering of economic activity.

This article compares California's Silicon Valley with the Route 128 beltway around Boston, Massachusetts, to suggest the limits of the concept of external economies and to propose an alternative network approach to analyzing regional economies. The common notion of external economies is based on an assumption that the firm is an atomistic unit of production with clearly defined boundaries. But by drawing a sharp distinction between what occurs inside and what occurs outside the firm, scholars overlook the complex and historically evolved relations among the internal organization of firms and their connections to one another and to the social structures and institutions of a particular locality. The network perspective helps explain the divergent performance of apparently comparable regional clusters, such as Silicon Valley and Route 128, and provides important insights into the local sources of competitive advantage.

The Limits of External Economies

Alfred Marshall (1920) developed the notion of "external economies of scale" to refer to the sources of increased productivity that lie outside individual firms. In the classic view, producers derive external benefits by sharing the fixed costs of common resources, such as infrastructure and services, skilled labor pools and specialized suppliers, and a common knowledge base. In addition, some theorists distinguish external economies that depend on the size of the market—including such factors as a labor pool and specialized supplier base (pecuniary external economies)—from those that involve spillovers of knowledge between firms (technological external economies). When these factors of production are geographically concentrated, firms gain the additional benefits of spatial proximity, or "agglomeration economies." Once established in a locality, such an advantage becomes self-reinforcing through a dynamic process of increasing returns (Arthur, 1990; Krugman, 1991; Scott, 1988b; Storper, 1989).

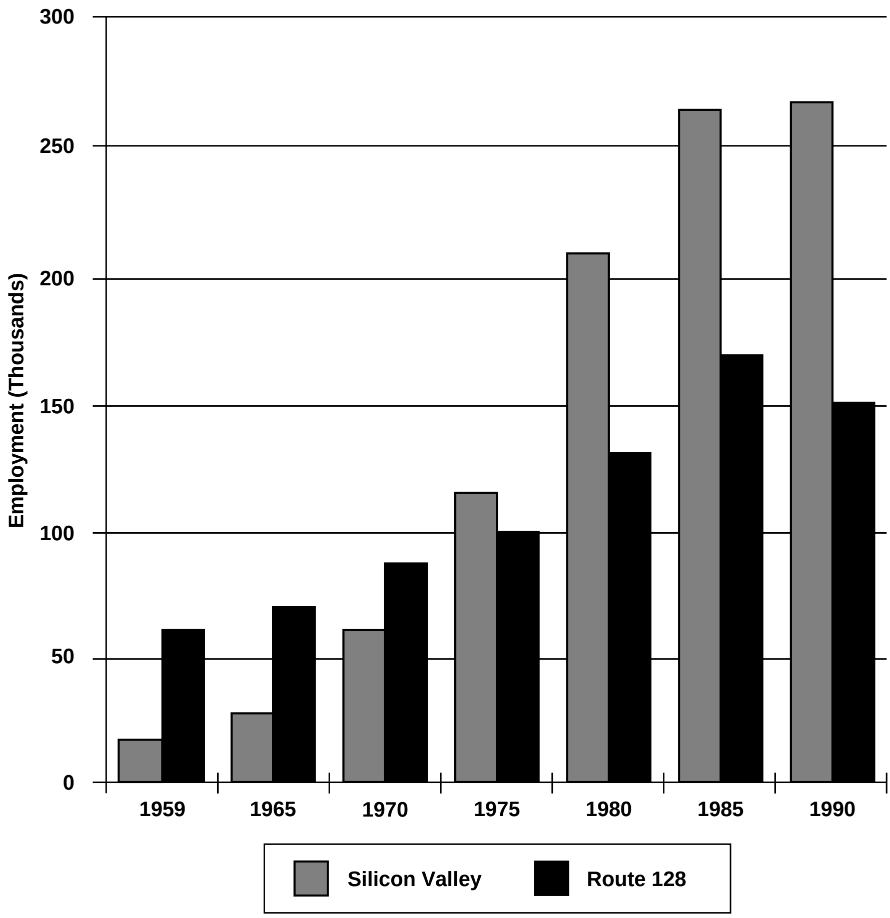
Students of regional development typically treat Silicon Valley and Route 128 as classic examples of the external economies that are derived from industrial localization. They are seen as cumulatively self-reinforcing agglomerations of technical skill, venture capital, specialized input suppliers and services, infrastructure, and spillovers of knowledge associated with proximity to universities and informal information flows (see, for example, Castells, 1989; Hall and Markusen, 1985; Krugman, 1991; Porter, 1990; Scott, 1988b). Some researchers have compared them with the 19th century industrial districts described by Alfred Marshall (Piore and Sabel, 1984).

Yet this approach cannot account for the divergent performance of the two regional economies. In spite of their common origins in postwar military spending and university-based research, Silicon Valley and Route 128 have responded differently to intensified international competition. Although both regions faced downturns in the 1980s, Silicon Valley recovered quickly from the crisis of its leading semiconductor producers. Route 128, however, shows few signs of reversing a decline that began in the early 1980s. The rapid growth of a new wave of start-up businesses and the renewed dynamism of established companies such as Intel and Hewlett-Packard (HP) were evidence that Silicon Valley had regained its former vitality. By contrast, start-ups along Route 128 failed to compensate for continued layoffs at the Digital Equipment Corporation (DEC) and other minicomputer companies. By the end of the 1980s, Route 128 producers had ceded their longstanding dominance in computer production to Silicon Valley.

Regional data underscore this divergence. Between 1975 and 1990, Silicon Valley firms generated some 150,000 new technology jobs—triple the number created along Route 128—even though the two areas enjoyed roughly the same employment level in 1975.

Figure 1

Total High Technology Employment, Silicon Valley and Route 128, 1959 to 1990

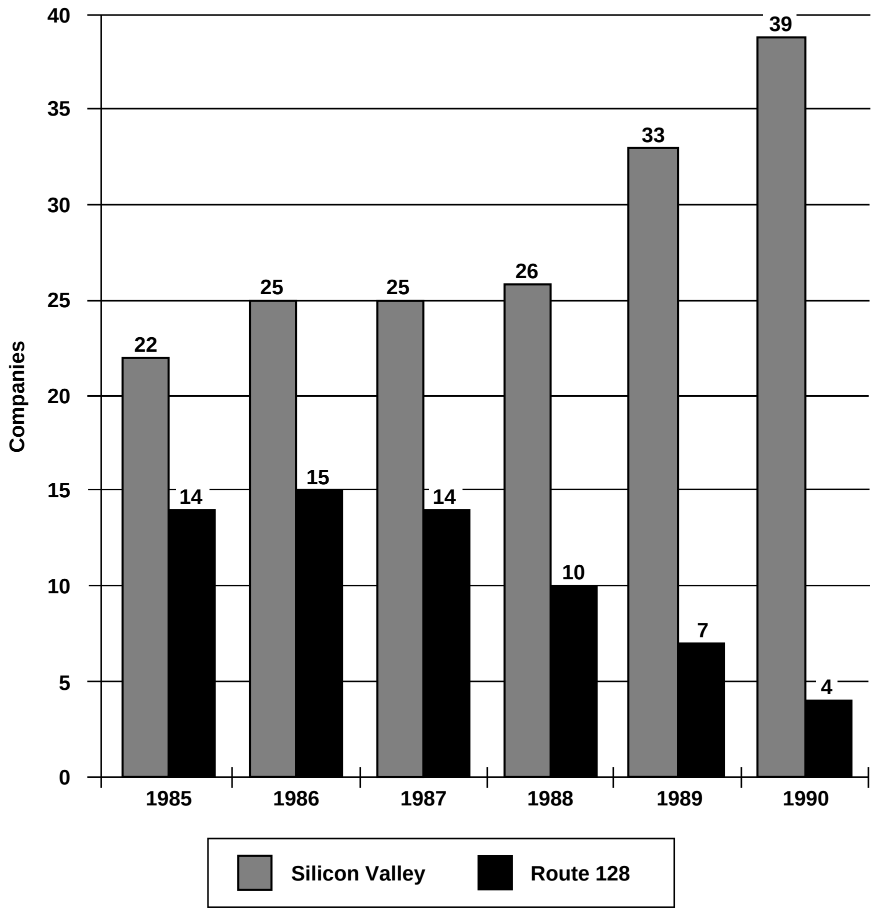


Source: County Business Patterns

In 1990 Silicon Valley-based producers exported more than $11 billion in electronics products—almost one-third of the Nation's total—compared with Route 128's $4.6 billion (*Electronic Business*, 1992). Finally, Silicon Valley was the home of 39 of the Nation's 100 fastest-growing electronics companies, whereas Route 128 claimed only 4. By 1990 both southern California and Texas had surpassed Route 128 as locations of fast-growing electronics firms. These rankings are based on the growth rates of 5-year sales, but the list is not limited to small firms. Multibillion dollar companies, such as Sun Microsystems, Apple Computers, Intel Semiconductor, and HP, ranked among the fastest-growing enterprises in 1990.

Figure 2

Fastest Growing Electronics Firms, Silicon Valley and Route 128, 1985 to 1990



Source: *Electonic Business*, “The Top 100 Exporters”

The concepts of agglomeration and external economies alone cannot explain why clusters of specialized technical skills, suppliers, and information produced a self-reinforcing dynamic of increasing industrial advances in Silicon Valley while producing relative decline along Route 128. The concepts account for regional stagnation or decline through imprecise references to “diseconomies” of agglomeration or the accumulation of negative externalities. Yet if such diseconomies are related to the overall size of a regional cluster, the degree of congestion, or the costs of production, growth should have slowed in the more densely populated Silicon Valley long before Route 128. The simple fact of spatial proximity evidently reveals little about the ability of firms to respond to the fast-changing markets and technologies that now characterize international competition.

The distinction between internal and external economies is based on the assumption that the firm is an atomistic unit of production with clearly defined boundaries. Treating regions as collections of autonomous firms has even led some observers to conclude that Silicon Valley suffers from excessive, even pathological, fragmentation (Florida and Kenney, 1990). Proponents of this argument overlook the complex of institutional and social relationships that connect the producers in a fragmented industrial structure. Researchers who adopt the broadest interpretations of technological external economies recognize that firms learn from one another through the flow of information, ideas, and know-how (Storper, 1989), but they do so only by denying the theoretical distinction between internal and external economies, between what is inside and outside the firm.

A Network Approach to Regions

Far from being isolated from what lies outside them, firms are embedded in networks of social and institutional relationships that shape and are shaped by their strategies and structures (Granovetter, 1985). The network perspective helps illuminate the historically evolved relationships among the internal organization of firms and their connections to one another and to the social structures and institutions of their particular localities (Nohria and Eccles, 1992b; Powell, 1987).

A network approach can be used to argue that, despite similar origins and technologies, Silicon Valley and Route 128 evolved distinct industrial systems in the postwar period. The differences in productive organization have been overlooked by economic analysts or treated simply as superficial differences between “laid-back” California and the more “buttoned-down” east coast. Far from superficial, these variations demonstrate the importance of local social and institutional determinants of industrial adaptation. In particular, they help explain why these two regions have responded so differently to the same external forces, from the lowering of global trade barriers and the intensification of international competition to cuts in the domestic military budget.

Silicon Valley has a regional, network-based industrial system that promotes learning and mutual adjustment among specialist producers of a complex of related technologies. The region’s dense social networks and open labor markets encourage entrepreneurship and experimentation. Companies compete intensely while at the same time learning from one another about changing markets and technologies through informal communication and collaborative practices. Loosely linked team structures encourage horizontal communication among firm’s divisions and with outside suppliers and customers. The functional boundaries within firms are porous in the network-based system, as are the boundaries among firms and between firms and local institutions, such as trade associations and universities.

In contrast, the Route 128 region is dominated by autarkic corporations that internalize a wide range of productive activities. Practices of secrecy and corporate loyalty govern relations between these firms and their customers, suppliers, and competitors, reinforcing a regional culture that encourages stability and self-reliance. Corporate hierarchies ensure that authority remains centralized, and information tends to flow vertically. Social and technical networks are largely internal to the firm, and the boundaries among firms and between firms and local institutions remain far more distinct in this independent, firm-based system.

Regional Networks and Industrial Adaptation

Understanding regional economies as networks of relationships rather than as clusters of atomistic producers and thinking of the regions as examples of two models of industrial systems—the regional, network-based system and the independent, firm-based system—helps illuminate the divergent trajectories of the Silicon Valley and Route 128 economies during the 1980s. For example, Silicon Valley's superior performance cannot be attributed to differentials in real estate costs, wages, or tax levels. Land and office space were significantly more costly in most of Silicon Valley than in the Route 128 region during the 1980s; the wages and salaries of production workers, engineers, and managers were higher (Sherwood-Call, 1992); and there was no significant difference in tax rates between California and Massachusetts (Tannenwald, 1987).

Nor can the differences in regional performance be traced to patterns of defense spending. Route 128 has historically relied more heavily on military spending than has Silicon Valley and thus is more vulnerable to defense cutbacks. However, the downturn in the Massachusetts electronics industry began in 1984, when the value of prime contracts to the region was still increasing. Although defense spending cannot account for the timing of the downturn in the region's technology industry, military spending cutbacks that began in the late 1980s exacerbated the difficulties of an already troubled regional economy.

Finally, while it may be tempting to attribute Silicon Valley's prosperity to the ability of local firms to shift low-wage jobs elsewhere, that alone cannot account for the differential performance of the two regions. Technology firms from both Silicon Valley and Route 128 have, since the 1960s, moved their routine manufacturing operations to lower wage regions of the United States and the Third World (Scott, 1988b; Saxenian, 1985).

Route 128's difficulties lie in the rigidities of the local industrial system. The independent, firm-based system flourished in an environment of market stability and slowly changing technologies, because extensive integration offered the advantages of scale economies and market control (Chandler, 1977). Route 128 has been overwhelmed, however, by changing competitive conditions. Corporations that invest in dedicated equipment and specialized worker skills find themselves locked into obsolete technologies and markets, and their self-sufficient structures limit their ability to adapt in a timely fashion. The surrounding regional economy, in turn, is deprived of resources for self-regeneration, because large firms tend to internalize most local supplies of skill and technology.

In contrast, regional, network-based industrial systems such as Silicon Valley's are well suited to conditions of technical and market uncertainty. Producers in these systems deepen their capabilities by specializing while engaging in close—but not exclusive—relations with other specialists. Network relations promote a process of reciprocal innovation that reduces the distinctions between large and small firms and between industries and sectors (DeBresson and Walker, 1991). Evidence from the industrial districts of Europe suggests that the localization of know-how and information encourages the pursuit of diverse technical and market opportunities through spontaneous regroupings of skill, technology, and capital. The region, if not all of the firms in the region, is organized to innovate continuously (Best, 1990; Sabel, 1988).

The competitive advantages of network organizational forms are reflected in the experience of Japanese industry as well. Japanese producers of electronics and automobiles, for example, rely on extensive networks of small- and medium-sized suppliers, to which they are linked through ties of trust and partial ownership. Although Japan's large firms may have exploited subcontractors in the past, many of these firms are increasingly collaborating with suppliers, encouraging them to expand their technological capabilities and organizational autonomy (Nishiguchi, 1989). Like their Silicon Valley counterparts, these firms tend to be geographically clustered and to depend heavily on informal information exchange as well as more formal forms of cooperation (Friedman, 1988; Imai, 1989).

As the case of Japan suggests, there are large- as well as small-firm variants of network-based systems (Fruin, 1992; Herrigel, 1993). Large corporations can integrate into regional networks through a process of internal decentralization. As competition forces independent business units to achieve the technical and productive standards of outsiders, these units often rely on external institutions that facilitate knowledge sharing and collaboration with suppliers and customers.

Of course all economic activity does not cluster within a single regional economy. Firms in network systems serve global markets and collaborate extensively with distant customers, suppliers, and competitors. Producers of new electronics and computing technologies, in particular, are highly international. However, the most strategic relationships are often local, because timeliness and face-to-face communications are very important in complex, uncertain, and fast-changing industries (Nohria and Eccles, 1992a).

Regional Network Versus Firm-Based Systems

In the remainder of the article, I use a set of paired comparisons to illustrate the differing organizational and adaptive capacities of Silicon Valley's regional network and Route 128's independent, firm-based industrial systems. The comparison of Apollo Computers and Sun Microsystems—both 1980s' generation start-up companies competing in the emerging workstation market—demonstrates how small firms benefit from the open flow of information, technology, and know-how in a network system. The comparison of DEC and HP—the leading computer systems producers in the two regions—in turn shows how regional networks can facilitate the reorganization of large firms.

Clearly, these cases alone cannot encompass the total experience of two complex regional economies, nor can the focus on individual firms fully portray the myriad decentralized relationships in a regional, network-based system. Indeed, the resilience of Silicon Valley's network system lies precisely in the fact that it does not depend on the success of any individual firm. However, these comparisons illustrate the social and institutional dimensions of productive organization that are overlooked in the concept of external economies and the competitive advantages of regional networks under current economic conditions. For an extended treatment of the origins and evolution of the two regional economies, see Saxenian (1994).

Start-Up Companies: Apollo Computer and Sun Microsystems

The largest wave of start-ups in Silicon Valley's history began in the late 1970s and accelerated during the 1980s. The region was home to scores of new ventures that specialized in everything from workstations and semi-custom semiconductors to disk drives, networking hardware and software, and computer-aided engineering and design. These start-ups contributed to the diversification of the regional economy from its original concentration in semiconductors to a complex of computer-related specialties.

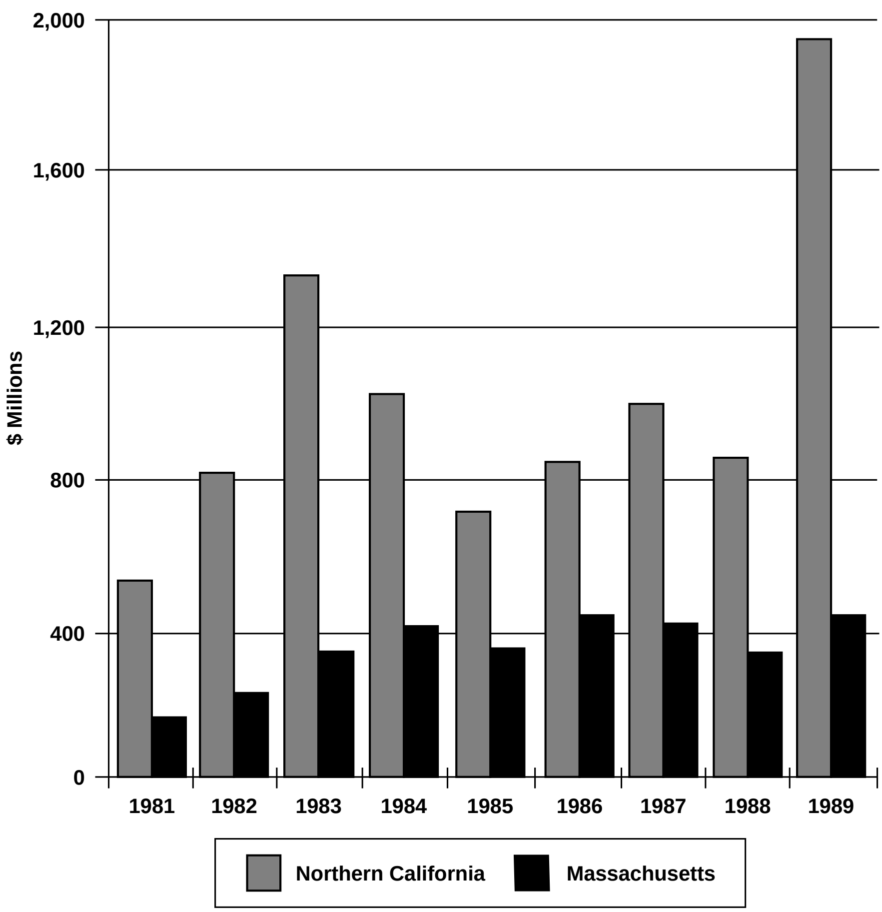
In contrast to the upsurge of entrepreneurial activity in Silicon Valley, the pace of start-ups along Route 128 slowed during the 1980s. Massachusetts experienced lower rates of new high-technology firm formation between 1976 and 1986 than either the rest of New

England or the United States as a whole (Kirchoff and McAuliffe, 1988). Also, the performance of companies founded during the 1980s was disappointing. Nothing in the Route 128 experience matched the spectacular successes of the 1980s' generation of Silicon Valley start-ups, such as Sun Microsystems, Conner Peripherals, and Silicon Graphics. By the end of the decade, public companies started in Silicon Valley during the 1980s collectively accounted for more than $22 billion in sales, whereas their Route 128 counterparts had generated only $2 billion (Standard & Poor's, 1992).

Investment decisions contributed to this divergence. Annual venture capital investments in northern California during the 1980s were double or triple those in Massachusetts. Moreover, there was a significant regional reallocation of capital away from Massachusetts and into northern California. Over the course of the decade, Massachusetts-based companies received about $3 billion in venture capital, or 75 percent of the total raised within the region, whereas firms in northern California received $9 billion, or 130 percent

Figure 3

Venture Capital Investment, Northern California and Massachusetts



Source: *Venture Capital Journal*

of the total capital raised locally. As a result, Silicon Valley companies were consistently awarded at least one-third of the Nation's total venture capital pool during the 1980s and early 1990s (*Venture Capital Journal,* 1980–92).

By 1992, 113 technology enterprises located in Silicon Valley reported revenues exceeding $100 million, compared with 74 companies along Route 128. Moreover, the great majority of Silicon Valley's $100 million enterprises were started during the 1970s and 1980s, whereas the overwhelming number along Route 128 had been started prior to 1970 (CorpTech, 1993).

The comparison of Apollo Computer and Sun Microsystems demonstrates how the autarkic structures and practices of Route 128's independent, firm-based system created disadvantages for start-ups in a technologically fast-paced industry. Apollo pioneered the engineering workstation in 1980 and was enormously successful initially. By most accounts the firm had a product that was superior to that of its Silicon Valley counterpart, Sun Microsystems (which was started 2 years after Apollo, in 1982). The two firms competed neck and neck during the mid-1980s, but in 1987 Apollo fell behind the faster moving, more responsive Sun and never regained its lead. By the time Apollo was purchased by HP in 1989, it had fallen to fourth place in the industry, whereas Sun led the industry with more than $3 billion in sales (Bell and Corliss, 1989).

Apollo's founder, 46-year-old William Poduska, was one of Route 128's few repeat entrepreneurs, having worked for Honeywell and helped to found Prime Computer before starting Apollo. Not only was Poduska himself well steeped in the culture and organizational practices of the region's established minicomputer firms, but the entire Apollo management team moved with him from Prime. This history contrasts with that of the typical Silicon Valley start-up, in which talent typically was drawn from a variety of firms and industries representing a mix of corporate and technical experience.

Not surprisingly, Apollo's initial strategy and structure reflected the model of corporate self-sufficiency of the region's large minicomputer companies. In spite of its pioneering workstation design, for example, the firm adopted proprietary standards and chose to design and fabricate its own central processor and specialized integrated circuits. Although it contracted for components, such as disk drives, monitors, and power supplies, Apollo began with a proprietary operating system and architecture that made its products incompatible with other machines.

Sun, in contrast, pioneered open systems. The firm's founders, all in their twenties, adopted the UNIX operating system, because they felt that the market would not accept a workstation custom-designed by graduate students. By making the specifications for its systems widely available to suppliers and competitors, Sun challenged the proprietary and highly profitable approach of industry leaders, such as IBM, DEC, and HP, which restricted customers to a single vendor of hardware and software.

Sun's strategy allowed it to specialize—to focus on designing the hardware and software for its workstations and to limit manufacturing to prototypes, final assembly, and testing. Unlike the traditional, vertically integrated computer manufacturers, Sun purchased virtually all of its components from external vendors and subcontracted the manufacture and assembly of its printed circuit boards. (In the late 1980s, Sun began assembling some of its most advanced printed circuit boards internally.) The firm even relied on outside partners for the design and manufacture of the reduced instruction set computing (RISC)-based microprocessor at the heart of its workstations and encouraged its vendors to market the chip to its competitors.

Although specialization is often an economic necessity for start-ups, Sun did not abandon this strategy even as the firm grew into a multibillion-dollar company. Why, asked Sun's Vice President of Manufacturing Jim Bean in the late 1980s, should Sun vertically integrate when hundreds of Silicon Valley companies invest heavily in maintaining a lead in the design and manufacture of integrated circuits, disk drives, and most other computer components and subsystems? Relying on outside suppliers greatly reduced Sun's overhead and ensured that the firm's workstations contained state-of-the-art hardware.

This focus on purchasing equipment also allowed Sun to introduce complex new products rapidly and to alter its product mix continuously. According to Bean, "If we were making a stable set of products, I could make a solid case for vertical integration." (Whiting, 1987.) Relying on external suppliers allowed Sun to introduce an unprecedented four generations of major new products during its first 5 years in operation and to double the price/performance ratio each successive year. Sun eluded clone-makers through the sheer pace of its new product introduction. By the time a competitor could reverse-engineer a Sun workstation and develop the manufacturing capability to imitate it, Sun had introduced a successive generation of the product.

As a result the Sun workstations, although vulnerable to imitation by competitors, were significantly cheaper to produce and sold for half the price of the proprietary Apollo systems (Bulkeley, 1987). Sun Chief Executive Officer (CEO) Scott McNealy described the advantage for customers: "We were totally open with them and said, 'We won't lock you into anything. You can build it yourself if we fail,' whereas our competition was too locked up in this very east coast minicomputer world, which has always been proprietary, so that encouraging cloning or giving someone access to your source code was considered like letting the corporate jewels out or something. But customers want it." (Sheff, 1989.)

It quickly became apparent that customers preferred the cheaper, nonproprietary Sun workstations. However Apollo, like the Route 128 minicomputer producers, was slow to abandon its proprietary operating system and hardware. As late as 1985, the firm's management refused to acknowledge the growing demand for open standards and even turned down the offer of a state-of-the-art RISC microprocessor from Silicon Valley-based MIPS Computers. Apollo finally committed 30 percent of its research and development budget to RISC development in 1986, but the effort became an economic burden, and the chip it ultimately developed internally was no faster than the chip it could have purchased 2 years earlier from MIPS.

Sun's innovative computing strategy was inseparable from the firm's location in the sophisticated and diversified technical infrastructure of Silicon Valley. Apollo, in contrast, responded sluggishly to industry changes, in part because of a more limited regional infrastructure. According to Jeffrey Kalb (1991), an engineer who worked for DEC along Route 128 for many years before moving to Silicon Valley to start the MasPar Computer Corporation:

> It's hard for a small company to start in Route 128 because you can't get stuff like IC's and disk drives fast. Route 128 is dominated by large, vertically integrated firms that do everything themselves. In Silicon Valley, you can get anything you want on the market.
>
> You can get all those things in Route 128 sooner or later, but the decisions are much faster if you're in Silicon Valley. From the east coast, interacting with the west coast is only possible for 3–4 hours a day because of the time difference, and you spend

> lots of time on the phone. It's no one thing, but if you get a 20–30 percent time to market advantage by being in Silicon Valley, that's really significant.

Apollo's other major misstep was its 1984 choice of a president and CEO to replace Poduska. Following the tradition of the large Route 128 companies, Apollo hired a long-time east coast corporate executive who had worked his way up through the ranks at General Electric to become the president of GTE Corporation. The 53-year-old Thomas Vanderslice was asked to bring "big-company organizational skills" to fast-growing Apollo and help the firm "grow up." He could not have had a background more different from the young graduate students and computer experts who had founded Sun Microsystems 2 years earlier (Beam and Frons, 1985).

The media played up the superficial differences between Apollo and Sun: the buttoned down, conservative Apollo executives versus the casually attired, relaxed founders of Sun. The contrast made for great journalism: Vanderslice enforced a dress code and discouraged beards and moustaches at Apollo, while Sun threw monthly beer parties and employees showed up on Halloween in gorilla suits. Whereas Vanderslice was chauffeured to work in a limousine, an April Fool's Day prank at Sun involved placing founder Bill Joy's Ferrari in the middle of the company's decorative pond. However, the important differences between the two firms lay in their management styles and organization: Vanderslice brought to Apollo a traditional, risk-averse management team that focused on imposing financial and quality controls, cutting costs, and diversifying the firm's customer base. Former employees describe him as an archetypical "bean counter" who established formal decisionmaking procedures and systems at a time when flexibility and innovation were most needed.

This commitment to formality, hierarchy, and long-term stability—which typified most large Route 128 companies—could not have offered a greater contrast to the "controlled chaos" that characterized Sun (Weiss and Delbecq, 1987). Like many Silicon Valley companies, Sun developed decentralized organizational forms as a way to preserve the flexibility and enthusiasm of a start-up company even as it grew. Corporate strategy was generated by discussions among representatives of autonomous divisions rather than being dictated by a central committee, and Sun's culture encouraged informal communications, participation, and individual initiative (Levine, 1988).

In the late 1980s, when Sun surpassed Apollo in both sales and profitability, more than a dozen Apollo managers defected to their west coast rival. There they joined other experienced and ambitious engineers from ailing Route 128 companies who recognized that opportunities to join or start technologically exciting new ventures lay not in New England but along the increasingly crowded freeways of northern California. As skilled engineers moved west, the advantages of Silicon Valley's network-based industrial system multiplied.

Large Firms: Digital Equipment and HP

The successes of the 1980s' generation of start-ups were the most visible sign that Silicon Valley was adapting faster than Route 128, but changes within the region's largest firms were equally important. Established producers in Silicon Valley began to decentralize their operations, creating interfirm production networks that built on the region's social and technical interdependencies and strengthened its industrial system. By institutionalizing longstanding practices of informal cooperation and exchange, they formalized the process of collective learning in the region. Local firms redefined themselves by participating in local production networks, and the region as a whole organized to create new markets and sectors.

Adaptation in the Route 128 economy, by contrast, was constrained by the autarkic organization and practices of its leading producers. Focused inward and lacking dynamic start-ups from which to draw innovative technologies or organizational models, the region's large minicomputer firms adjusted very slowly to the new market conditions. By the end of the decade, they were struggling to survive in a computer industry that they had once dominated.

Although developing accurate and useful measures of vertical integration is difficult, one indication of the greater reliance of Route 128 firms on internal production are the lower sales-per-employee figures shown in table 1 for the leading Route 128 firms and their Silicon Valley counterparts.

A comparison of DEC with HP during the 1980s highlights the way the relationship of large firms to their region differed in the network and firm-based industrial systems. By 1990 both were $13 billion companies and the largest and oldest civilian employers in their respective regions. (Lockheed Missile and Space and the Raytheon Corporation were the largest private employers in Silicon Valley and Route 128, respectively, but both were military contractors with limited commercial business.) Both DEC and HP were vertically integrated producers of proprietary minicomputers with shared origins in an earlier era of computing. Yet the companies responded differently to comparable competitive challenges. HP gradually opened up by building a network of local alliances and subcontracting relationships while strengthening its global reach. DEC, in spite of its formal commitment to decentralization, retained a substantially more autarkic organizational structure and corporate mindset.

The transformations in the computer industry during the 1980s placed a premium on speed and focus. Computer makers were forced to develop new products and bring them to market faster than ever before—often in a matter of months. In 1988 HP Vice President of Corporate Manufacturing Harold Edmondson claimed that half of the firm's orders in any year came from products introduced in the preceding 3 years. At the same time, the

Table 1

1990 Sales Per Employee of Silicon Valley and Route 128 Firms ($ Thousands)

Silicon Valley		Route 128	
Apple	$382.6	Prime	$128.7
Sun	214.6	Wang	123.7
Silicon Graphics	200.0	Data General	114.8
HP	143.8	DEC	104.4

Source: "The Electronic Business 200," and "Annual 10K Company Reports," *Electronic Business* (22 July 1991) 43–49.

cost of developing new products increased as they became more technologically complex. Innovation in all segments of the industry—from microprocessors and logic chips to system and applications software to disk drives, screens, input-output devices, and networking devices—meant that it was more and more difficult for a single firm to produce all of the components, let alone remain at the forefront of the underlying technologies. This increasingly competitive environment posed a challenge for established computer makers such as DEC and HP. By 1990, however, HP had successfully managed the transition from minicomputers to workstations with open systems, whereas DEC remained dependent on its proprietary VAX line of minicomputers. As a result, even though both enjoyed 1990 revenues from electronics products of $13 billion, HP earned $771 million and DEC lost $95 million.

Variations in corporate performance always have multiple causes, but the firms' organizational structures and their relationships to their respective regions help explain these differences. DEC maintained clear boundaries between itself and other companies or institutions in the region. This was, in part, a result of extensive vertical integration: The firm designed and manufactured virtually all software and hardware components for its computers internally. Moreover, DEC's corporate culture rewarded secrecy and corporate loyalty. Thus departed employees typically were treated like pariahs and cut off from the corporate "family." (Rifkin and Harrar, 1990.) As a result the technical and social networks that mattered were all internal, and there were few opportunities for collaboration, learning, and exchange with other local firms.

HP was both less dominant in Silicon Valley and more open to the surrounding economy. DEC dominated the Route 128 region in a way that no firm did in Silicon Valley. With more than 30,000 Massachusetts employees in 1990, DEC accounted for almost 20 percent of regional high-technology employment, whereas HP's 20,000 Silicon Valley employees were only 8 percent of the regional total. HP benefitted from a long history of participation in the region's rich associational life and fluid labor markets. Continuous and open exchange about everything from the latest start-up companies to technical breakthroughs allowed local engineers to stay at the leading edge of new computing technologies and market trends (Vedoe, 1990).

HP's decentralized divisional structure also offered an ideal training ground for general managers. Former HP executives were responsible for starting more than 18 firms in Silicon Valley between 1974 and 1984, including such notable successes as Rolm, Tandem, and Pyramid Technology (Mitchell, 1989). A 16-year veteran of DEC who now works for HP described the way the firm's autonomous divisions preserve opportunities for entrepreneurship:

> Running a business at the division level, you get a chance to be a general manager. You get a chance to learn . . . to be creative. . . . There are a lot of new divisions springing up [within HP], new ideas springing up, brand new businesses, and old divisions that couldn't make it anymore transform themselves into new businesses (Porter, 1993).

In contrast, DEC's matrix organization—which represented only a partial break from traditional functional corporate hierarchies—stifled the development of managerial skill and initiative in the Route 128 region. The matrix demanded continuous negotiations to reach consensus, and despite the addition of cross-functional relations among product groups, final authority remained highly centralized (Schein, 1985). As a result it is difficult to identify any successful spin-offs from DEC other than Data General.

Both DEC and HP began the 1980s with the bureaucracy and internal conflicts typical of large firms. Both missed opportunities and made false starts in workstation and RISC markets, and both had difficulty keeping up with newer, more agile competitors. Yet HP quickly became the leading producer in the fastest-growing segments of the market. By 1990 HP controlled 31 percent of the $8 billion RISC computer systems market—a market in which DEC still had no presence. HP also boasted a 21-percent share of the $7.2 billion workstation market and 13 percent of the $33 million UNIX computer systems market, compared with DEC's 16 percent and 8 percent, respectively. In addition, HP controlled 66 percent of the market for desktop laser printers and 70 percent of the market for ink-jet printers (Nee, 1991).

HP reinvented itself by investing heavily in RISC microprocessor technology and the UNIX operating system well before most established computer companies recognized the importance of open standards. By betting the future of its computer division (which accounted for 53 percent of HP revenues) on RISC systems in 1985 and by undertaking internal reorganizations that unified and rationalized the firm's disparate computer divisions and component technologies, HP positioned itself advantageously for emerging markets (Yoder, 1991). In 1990, for example, the firm created an independent team to develop a RISC workstation. The ultimate product, the Series 700 workstation, was far ahead of the rest of the industry and allowed HP to quickly become one of the world's biggest sellers of UNIX systems. A financial analyst for Salomon Brothers assessed the situation: "They [HP] have done an excellent job of identifying trends in the computer market such as UNIX, RISC, and PCs. No other major computer company has done a better job of positioning. . . . They are the one company I can count on surviving. HP has a better base today than IBM or DEC." (Greene, 1990.)

HP's ability to identify market trends earlier than its competitors reflected the firm's openness to external changes and the Silicon Valley location that gave it easy access to state-of-the-art information markets and technologies. This flexibility contrasts sharply with DEC's prolonged denial of the growing demand for personal computers and UNIX-based systems. In the words of a former DEC marketing manager: "DEC had its head in the sand. They didn't believe that the world would really change. . . . They got focused on the internal evolution of the company rather than on the customer or markets." (Vedoe, 1990.) As late as 1985, Ken Olsen, DEC's CEO and founder, referred to personal computers as "snake oil." (Rifkin and Harrar, 1990.)

DEC was plagued by ongoing internal conflicts and a series of costly course reversals in its efforts to enter the workstation and open-systems markets. The firm's strategy remained confused and inconsistent even after the defection of large customers such as GE and AT&T forced Olsen to authorize a shift to open systems away from the vision of a single proprietary VMS operating system and VAX architecture for all DEC systems (DeNucci, 1991).

DEC's research laboratory in Silicon Valley developed state-of-the-art RISC and UNIX technologies in the early 1980s, but its discoveries were virtually ignored by the Route 128 headquarters, which continued to favor the highly profitable VAX-VMS system (Comerford, 1992). Insiders claim that DEC's Palo Alto lab contributed more to Silicon Valley firms such as Sun and MIPS than it did to DEC, because its findings were quickly diffused through technical papers and local industry forums (Basche, 1991; Furlong, 1991).

DEC finally decided to build its own RISC-based workstation in 1986, following conventional wisdom within the firm that the RISC microprocessor should be designed and built in-house. It was not until 1992, however, after a series of costly reversals, that the firm finally introduced its own RISC processor, Alpha (Comerford, 1992). By this time DEC controlled only 13 percent of the workstation market (McWilliams, 1992).

The contrast between DEC's Palo Alto laboratory and its east coast headquarters is instructive. Engineers who worked at both locations emphasize how different the two were: DEC East was internally focused, whereas DEC Palo Alto was well integrated into Silicon Valley's social and technical networks. According to Joe DeNucci, a former employee:

> DEC definitely relates differently to the regional economy in Silicon Valley than in Route 128. DEC is the largest employer in Route 128 and you come to think that the center of the universe is North of the Mass Pike and East of Route 128. The thinking is totally DEC-centric: all the adversaries are within the company. Even the non-DEC guys compete only with DEC.
>
> DEC Palo Alto is a completely different world. DEC is just another face in the crowd in Silicon Valley; the adversaries are external, firms like Intel and Sun. It forces a far more aggressive and "prove-it" mind set (DeNucci, 1991).

Describing his years with the DEC engineering and development group in Palo Alto, DeNucci said:

> We had an immense amount of autonomy, and we cherished the distance from home base, from the "puzzle palace," and from the "corridor warriors" and all the endless meetings. It was an idyllic situation, a group of exceptionally talented people who were well connected to Stanford and to the Silicon Valley networks. People would come out from Maynard [Massachusetts] and say "this feels like a different company." The longer they stayed, the more astounded they were.

Tom Furlong, who headed a DEC workstation division in Maynard before moving west in 1985, described the newly formed Workstation Group in Palo Alto as a typical Silicon Valley start-up. The group's autonomy from headquarters allowed members to take full advantage of the knowledge available within the regional economy. At the same time, the group benefitted from the financial backing and reputation of a large, well-established corporation. By 1990 Furlong was the manager of a 275-employee group. He compared his work experience in the two locations:

> It would be very difficult for me to do what I'm doing here within DEC on the east coast. I'm a fairly autonomous business manager out here, with all the functions necessary to success reporting to me and the freedom to use outside suppliers. Back East, I would have to rely on DEC's internal suppliers and functional groups for everything.
>
> We're like a start-up organization here. We're not really significant to DEC, we're only contributing $.5 billion to them, but we have the advantages of their resources and name.

Furlong (1991) explained the consequences of these organizational differences for product development:

> The same job of bringing a new workstation to market takes two times as long in the East coast and many more people than it does here. In Maynard, I had to do everything inside the company. Here I can rely on the other companies in Silicon Valley. It's easier and cheaper for me to rely on the little companies in Silicon Valley to take care of the things I need, and it forces them to compete and be more efficient. At DEC, the commitment to internal supply and the familial environment means that bad people don't get cut off. I had to depend on all sorts of inefficient people back at DEC East.

The Workstation Group did not achieve this independent position without resistance: "It was a huge embarrassment to them that we had to rely on external suppliers such as MIPS. DEC takes great pride in being vertically integrated, in having control over its entire system." (Furlong, 1991.) DEC was ultimately unable to assimilate the lessons of its geographically distant Palo Alto group, in spite of its technical advances, and in 1992 transferred it back to the Maynard headquarters. Furlong and other members of the workstation team left DEC to work for Silicon Valley companies.

HP began the 1980s with a level of vertical integration comparable to DEC's but soon recognized that it could not continue to produce everything in-house. Late in the decade, HP began outsourcing most of the sheet metal fabrication, plastics, and machining for its computer systems. The firm also consolidated the management of some 50 disparate circuit technology units into two autonomous divisions, Integrated Circuit Fabrication and Printed Circuit Board Fabrication. These divisions were organized as internal subcontractors for the company's computer systems and instrument divisions. They were forced to compete with external vendors for HP's business and were expected to remain competitive in technology, service, and cost in order to sell successfully to outside customers.

HP also built alliances with local companies that offered complementary technologies. During the 1980s the firm created partnerships with Octel Communications for voice-data integration, with 3Com for local area network-manager servers, and with Weitek for semiconductor design. An HP manager explained the acquisition of a 10-percent stake in Octel: "In the business and office processing environment, no one company can develop everything on its own, so we're increasingly looking at forming alliances to meet our customers' needs." (Tuller, 1988.)

The partnership between HP and semiconductor design specialist Weitek illustrates the way a large firm benefitted from Silicon Valley's networks. Tiny Weitek, which lacked manufacturing capacity of its own, was the leading designer of ultra-high-speed "number crunching" chips that were used in complex engineering problems. In 1987 HP allowed Weitek to use its state-of-the-art fabrication facility as a foundry, hoping to improve the performance of the Weitek chips in its workstations. HP engineers, realizing that the manufacturing process at the foundry Weitek used slowed the chips' performance, suggested fully optimizing the Weitek designs by manufacturing them with HP's more advanced fabrication process. This suggestion culminated in a 3-year agreement that allowed each firm to benefit directly from the other's technical expertise.

The arrangement assured HP of a steady supply of Weitek's chips and allowed HP to introduce its new workstation faster than if it had designed the chip in-house. It provided Weitek with a market, the legitimacy of a close association with HP, and access to a state-of-the-art foundry. Moreover, the final product represented a significant advance over that which either firm could have produced independently. This partnership allowed each company to draw on the other's distinctive and complementary expertise to devise a novel solution to a shared problem.

HP opened itself to other outside influences during the 1980s, creating a model of a large firm that is internally decentralized and horizontally linked to networks of other specialists. DEC's dominant and isolated position along Route 128, by contrast, hindered its efforts to shift to new technologies or a new corporate form. Saddled with an autarkic organizational structure and located in a region that offered little social or technical support for a more flexible business model, DEC's difficulties worsened.

CEO Olsen was forced to resign in 1992, after the company reported a $2.8 billion quarterly loss—the biggest in computer industry history. One year later, HP surpassed DEC in sales to become the Nation's second largest computer company, after IBM. As a final irony, in 1993 DEC moved a design team for its new Alpha microprocessor from the east coast to Palo Alto to immerse Alpha engineers in the Silicon Valley semiconductor community. According to industry analyst Ronald Bowen of Dataquest: "Digital is finding the support network of other companies is very, very limited back East. In effect, what's been happening is the people who work on the East coast spend a lot of time flying to San Jose anyway." (Nash and Hayes, 1993.)

Conclusion

This comparison of Silicon Valley and Route 128 industries highlights the analytical leverage gained by treating regions as networks of relationships rather than as collections of atomistic firms. By transcending the theoretical distinction between what lies inside and outside the firm, this approach offers important insights into the structure and dynamics of regional economies. It directs attention to the complex networks of social relationships within and between firms and between firms and local institutions.

The Silicon Valley experience also suggests that the network form of organization flourishes in regional agglomerations. Proximity facilitates the repeated, face-to-face interaction that fosters the mix of competition and collaboration required in today's fast-paced technology industries. Yet the case of Route 128 demonstrates that geographic clustering alone does not ensure the emergence of regional networks. Competitive advantage derives as much from the way that skill and technology are organized as from their presence in a regional environment.

Author

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