

Working Paper 605

Inside-Out:

*The Industrial Systems of
Silicon Valley and Route 128*

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This is a revised version of a paper prepared for the 35th Annual Meeting of the Association of Collegiate Schools of Planning in Philadelphia, October 1993. It summarizes some of the arguments made in a forthcoming book entitled, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Harvard University Press, 1994).

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Abstract

This paper uses a comparison between California's Silicon Valley and Route 128 in Massachusetts to suggest the limits of the concept of external economies for analyzing regional clusters, and proposes an alternative approach that treats regions as industrial systems. The notion of external economies assumes that the firm is an atomistic unit of production with clearly defined boundaries. By drawing a sharp distinction between what occurs inside and what occurs outside of the firm, scholars overlook the complex and historically evolved relations between the internal organization of firms and their connections to one another and the social structures and institutions of a particular locality. The concept of an industrial system helps explain the divergent performance of apparently comparable regional clusters such as Silicon Valley and Route 128. It also provides important insights into the local sources of competitive advantage. Paired comparisons of small and large firms in the two regions suggest the advantages of industrial systems based on regional networks in the current competitive environment.

Introduction

The competitive advantages of regional clusters have become the focus of scholarly and policy attention. Once the province of economic geographers and regional scientists alone, the work of Paul Krugman (1991) and Michael Porter (1990) has spurred widespread interest in regions and regional development. 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 the notion of external economies to explain the advantages that derive from the spatial clustering of economic activity.

This essay compares California's Silicon Valley and Route 128 in Massachusetts to suggest the limits of the concept of external economies for analyzing regional clusters, and proposes an alternative approach that treats regions as industrial systems. The notion of external economies assumes that the firm is an atomistic unit of production with clearly defined boundaries. By drawing a sharp distinction between what occurs inside and what occurs outside of the firm, scholars overlook the complex and historically evolved relations between the internal organization of firms and their connections to one another and the social structures and institutions of a particular locality. The concept of an industrial system 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.

External Economies

Alfred Marshall (1920) developed the notion of "external economies of scale" to refer to the sources of a productivity increase that lie outside of the individual firm. In the classic view, producers derive external benefits by sharing the fixed costs of such common resources as infrastructure and services, skilled labor pools and specialized suppliers, and a common knowledge base.¹ When these factors of production are geographically concentrated, firms gain the additional benefits of spatial proximity, or "agglomeration economies." Once established in a particular 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 derive from industrial localization: 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, Hall and Markusen, 1985; Castells, 1989; Scott, 1988b; Porter, 1990; Krugman, 1991). Some have compared them to the 19th century industrial districts described by 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. Both regions faced

downturns in the 1980s. Yet Silicon Valley recovered quickly from the crisis of its leading semiconductor producers, while Route 128 showed few signs of reversing a decline that began in the early 1980s. The rapid growth of a new wave of start-up companies and the renewed dynamism of such established companies as Intel and Hewlett-Packard were evidence that Silicon Valley had regained its former vitality. Along Route 128, by contrast, start-ups failed to compensate for continuing layoffs at the Digital Equipment Corporation 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 they enjoyed roughly the same employment levels in 1975 (Chart 1). In 1990, Silicon Valley-based producers exported more than \$11 billion in electronics products, almost one-third of the nation's total, compared to 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, while Route 128 claimed only four (Chart 2)² By 1990, both Southern California and Texas had surpassed Route 128 as locations of fast-growing electronics firms.

The concepts of agglomeration and external economies cannot explain why clusters of specialized technical skill, suppliers, and information produced a virtuous and self-reinforcing dynamic of increasing industrial advance in Silicon Valley, while producing relative decline in Route 128³ 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 assumes 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). This argument overlooks the complex of institutional and social relationships that connect the producers in its fragmented industrial structure. The broadest interpretations of technological external economies recognize that firms learn from each other through flows 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.

Local Industrial Systems

Far from being isolated from what lies outside them, firms are embedded in a social and institutional setting that shapes, and is shaped by, their strategies and structures (Granovetter, 1985; Harrison, 1992). The concept of a local industrial system illuminates the historically evolved relationship between the internal organization of firms and their connections to one another and to the social structures and institutions of their particular localities.⁴

It is helpful to think of a region's industrial system as having three interrelated dimensions: local institutions and culture, industrial structure, and firm organization. Regional institutions include public

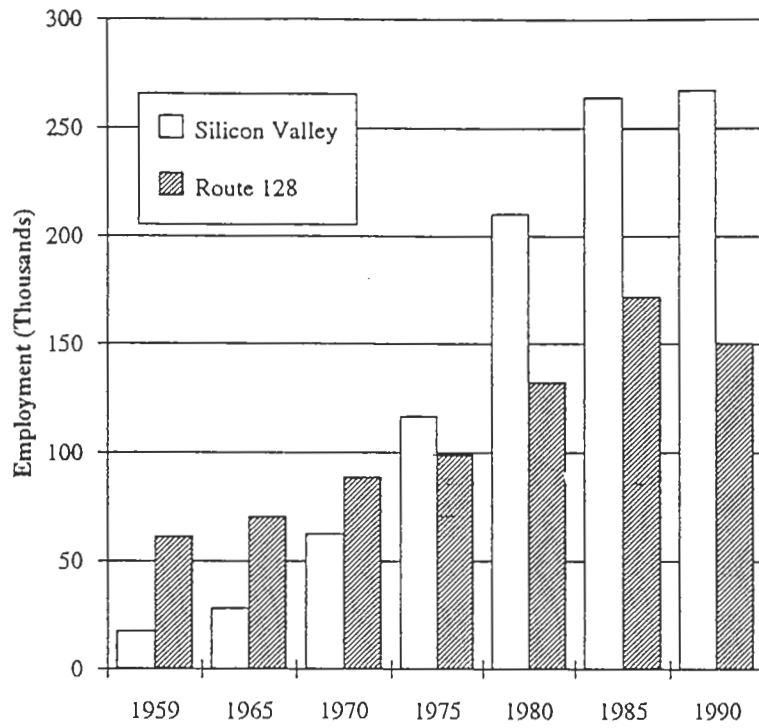


Chart 1. Total High Technology Employment,
 Silicon Valley and Route 128, 1959-1990
 (County Business Patterns)

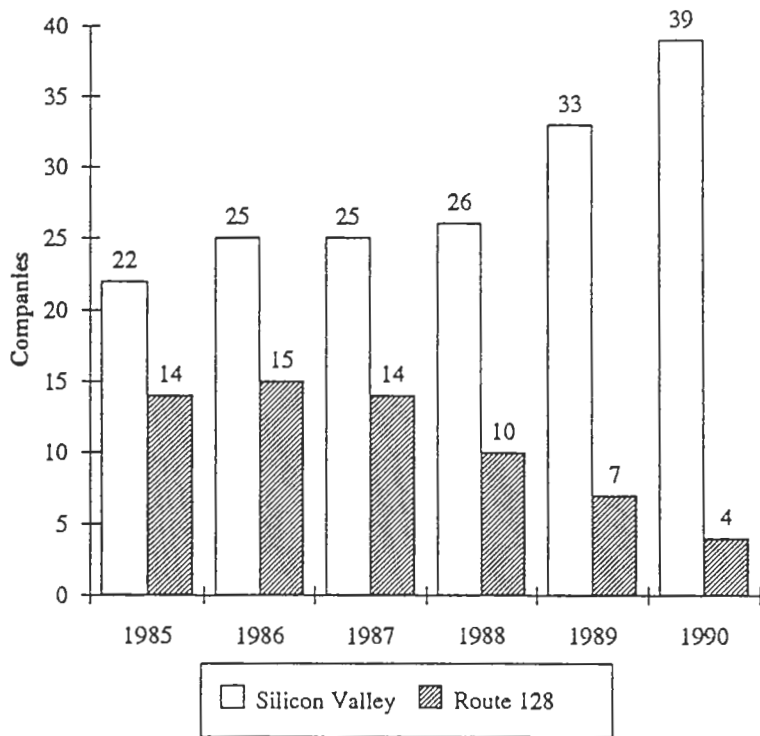


Chart 2. Fastest Growing Electronics Firms,
 Silicon Valley and Route 128, 1985-1990
 (Electronic Business, Top 100)

and private organizations such as universities, business associations, and local governments, as well as the many less formal hobbyist clubs, professional societies, and other forums that create and sustain regular patterns of social interaction in a region. These institutions shape and are shaped by the local culture; that is, the shared understandings and practices that unify a community and define everything from labor market behavior to attitudes toward risk-taking. A region's culture is not static, but rather is continually reconstructed through social interaction.

Industrial structure refers to the social division of labor—the degree of vertical integration—as well as to the extent and nature of linkages between customers, suppliers, and competitors in a particular sector or complex of related sectors. Students of regional development have analyzed this aspect of industrial systems the most extensively, but often at the cost of neglecting its close relationships to the other two dimensions of an industrial system.

The final dimension, internal firm organization, includes the degree of hierarchical or horizontal coordination, centralization or decentralization, and the allocation of responsibilities and specialization of tasks within the firm.

The three dimensions of an industrial system are deeply interconnected. Recent research has revealed the importance of these interrelations. Economists now recognize, for example, that innovation is a product of interactions among customers and suppliers, a firm's internal operating units and the institutional environment (Dosi, 1988; Kline and Rosenberg, 1986). Similarly, sociologists and political scientists have identified the importance of shared identities and local culture as a source of the trust needed to foster collaboration and industrial adjustment (Putnam, 1993; Sabel, 1992).

No single dimension taken in isolation adequately accounts for the adaptive capacity of a regional economy, nor is any single variable prior to or causal of the others. Regional culture, for example, is important, but it is not decisive in promoting particular industrial forms. For example, during the 1970s, Silicon Valley's chipmakers embraced the dominant management models and pursued autarkic business strategies despite a regional culture that promoted open exchange and informal cooperation (Saxenian, 1994).

Differing combinations among the three dimensions of an industrial system are possible, although they tend, in practice, to become mutually reinforcing components in coherent regional economies. Dense networks of social relations play an important role in integrating the firms in Silicon Valley's fragmented industrial structure. Elsewhere, the small, specialized firms in regional clusters remain isolated and backwards, linked only by arms-length market relations (Elbaum and Lazonick, 1986). Moreover, apparently analogous institutions can play different roles in different industrial systems. Universities, for example, are widely viewed as sources of knowledge and information for their regional economies. Yet Stanford University, which actively promoted local technology start-ups during the postwar years, is far more actively involved with companies in its region than MIT.

Network and Firm-based Industrial Systems

This paper argues that, despite similar origins and technologies, Silicon Valley and Route 128 evolved distinct industrial systems in the postwar period. It compares the experiences of firms located in the two regions during the 1980s, in order to illuminate the important variations in productive organization that have been overlooked by traditional analyses, or treated simply as the superficial differences between "laid back" California and the more "buttoned-down" East Coast. Far from superficial, these variations demonstrate the importance of the local social and institutional determinants of industrial adaptation.

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 learn from each other about changing markets and technologies through informal communications and collaborative practices. Loosely linked team structures encourage horizontal communication among firm divisions and with outside suppliers and customers. The functional boundaries within firms are porous in a network-based system, as are the boundaries between firms themselves and between firms and local institutions such as trade associations and universities.

The Route 128 region, in contrast, is dominated by a small number of tightly integrated corporations. Its industrial system is based on independent firms that internalize a wide range of productive activities. Practices of secrecy and corporate loyalty govern relations between 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. The boundaries between and within firms and between firms and local institutions thus remain far more distinct in this independent firm-based system.

Regional Networks and Industrial Adaptation

Understanding regional economies as industrial systems 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.

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 were no significant differences in tax rates between California and Massachusetts (Tannewald, 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 Silicon Valley, and hence 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. While defense spending cannot account for the timing of the downturn in the region's technology industry, the military spending cutbacks that began in the late 1980s exacerbated the difficulties of an already troubled regional economy.

Route 128's difficulties lay in the rigidities of its local industrial system. The independent firm-based industrial system dominated in an environment of market stability and slow-changing technologies because the vertical integration of its leading producers offered the advantages of scale economies and market control (Chandler 1977, 1990). It 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, while their centralized structures limit their ability to adapt in a timely fashion. The surrounding regional economy in turn is deprived of the resources for self-regeneration because the vertically integrated corporation tends to internalize most local supplies of skill and technology.

Regional network-based industrial systems like that of Silicon Valley, in contrast, are well-suited to conditions of technical and market uncertainty. Producers in these systems deepen their own 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). The localization of know-how and information encourages the pursuit of diverse technical and market opportunities through spontaneous regroupings of skill, technology, and capital; and the region, if not all the firms in the region, is organized to innovate continuously (Sabel, 1988; Best, 1990).

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. Technology firms, in particular, are highly international (Gordon, 1991). However, the most strategic relationships are often local due to the importance of timeliness and face-to-face communications in complex and fast changing industries.

The balance of this paper uses two paired comparisons to illustrate the differences in the organization and adaptive capacities of Silicon Valley's network-based and Route 128's independent firm-based industrial systems. The comparison of Apollo Computers and Sun Microsystems— both 1980s-generation start-ups competing in the emerging workstation market— demonstrates how small firms benefit from the open flows of information, technology, and know-how in a network system. The comparison of the Digital Equipment Corporation (DEC) and Hewlett-Packard Company (HP)— the leading computer systems producers in the two regions— shows how regional networks facilitate the reorganization of large firms. The experience of a DEC division located in Silicon Valley underscores the differences between the two industrial systems.

Clearly these cases alone cannot encompass the experience of two complex regional economies. However, they illustrate the social and institutional dimensions of productive organization that are overlooked by the concept of external economies, and they highlight the advantages of regional networks in

the current competitive conditions. These cases are drawn from the research for a forthcoming book that compares in detail the evolution of the two regions in the postwar period (Saxenian, 1994).

Start-Ups: 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 the 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 away from its original concentration in semiconductors and into a complex of computer-related specialists.

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-tech firm formation between 1976 and 1986 than either New England or the United States as a whole (Kirchoff and McAuliffe, 1988). In addition, 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 such Silicon Valley start-ups as Sun Microsystems, Conner Peripherals, and Silicon Graphics. By the end of the decade, public companies that were started in Silicon Valley during the 1980s collectively accounted for more than \$22 billion in sales, while their Route 128 counterparts had generated only \$2 billion (Standard & Poor's, 1992).

Investment decisions reflected this divergence. Annual venture capital investments in Northern California during the 1980s were double or triple those in Massachusetts. Over the course of the decade, Massachusetts-based companies received some \$3 billion in venture capital, or 75 percent of the total raised in the region, while firms in Northern California received \$9 billion, or 130 percent of the total capital raised locally (Chart 3). Silicon Valley companies were consistently awarded at least one-third of the nation's total venture capital pool.

By 1992, there were 113 technology enterprises located in Silicon Valley reporting revenues exceeding \$100 million, compared to 74 in Route 128. Moreover, the great majority of Silicon Valley's \$100 million enterprises were started during the 1970s and 1980s, while those in Route 128 were overwhelmingly started prior to 1970 (Corporate Technology Information Services, 1993).

The comparison of Apollo Computer and Sun Microsystems demonstrates how the autarkic structures and practices of Route 128's independent firm-based system were a disadvantage to start-ups in a technologically fast-paced industry. Apollo pioneered the engineering workstation in 1980, and initially it was enormously successful. By most accounts, the firm had a product that was superior to that of its Silicon Valley counterpart, Sun Microsystems (which was started two 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 it was purchased by Hewlett-Packard in 1989, Apollo had fallen to fourth place in the industry, while Sun led the industry with over \$3 billion in sales (Bell and Corliss, 1989).

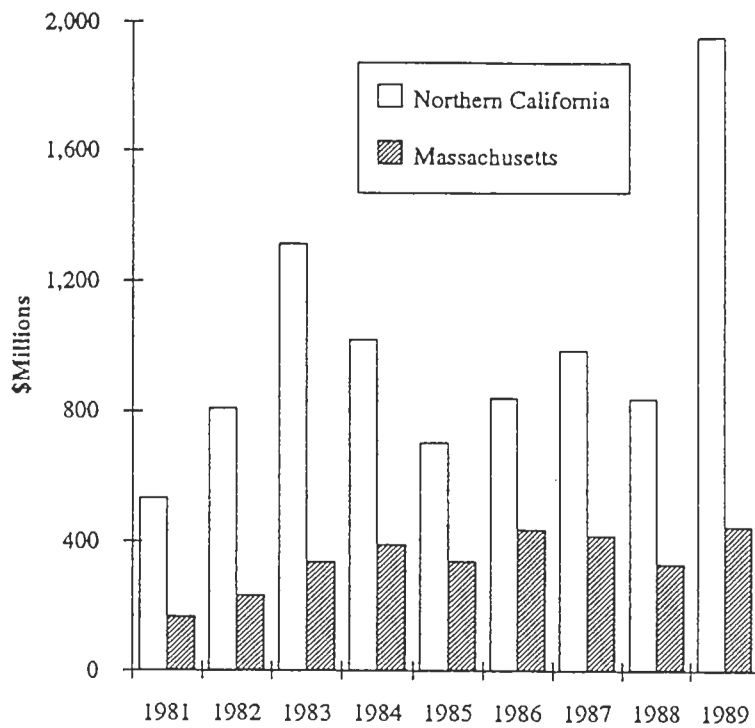


Chart 3. Venture Capital Investment, Northern California and Massachusetts, 1981-1989 (Venture Capital Journal)

Apollo's founder, 46-year old William Poduska, one of Route 128's few repeat entrepreneurs, had 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 mini-computer firms, but the entire Apollo management team moved with him from Prime. This is contrasted by the typical Silicon Valley start-up, in which talent was typically drawn from a variety of different firms and even industries, representing a mix of corporate and technical experience.

Not surprisingly, Apollo's initial strategy and structure reflected the corporate self-sufficiency model 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. Though it sourced 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 never accept a workstation custom-designed by four 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 IBM, DEC, and HP, which locked customers in to a single vendor of hardware and software. This strategy allowed Sun 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 off-the-shelf from external vendors and subcontracted the manufacture and assembly of their printed circuit boards. (In the late 1980s, however, 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.

While specialization is often an economic necessity for start-ups, Sun did not abandon this strategy even as the firm grew into a multi-billion 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 staying at the leading edge 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, while ensuring that the firm's workstations contained state-of-the art hardware.

This focus also allowed Sun to introduce complex new products rapidly and to alter their product mix continuously. According to Bean: "If we were making a stable set of products, I could make a solid case for vertical integration." Relying on external suppliers allowed Sun to introduce an unprecedented four major new product generations during its first five years of operations, and to double the price-performance ratio each successive year. Sun eluded clone-makers through its sheer pace of new product intro-

duction. 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.

As a result, the Sun workstations, while vulnerable to imitation by competitors, were also significantly cheaper to produce and sold for half the price of the proprietary Apollo systems (Bulkeley, 1987). In the words of Sun founder and CEO Scott McNealy: "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, non-proprietary 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 they ultimately developed internally was no faster than the chip they could have bought two 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, an engineer who worked for DEC in 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% time to market advantage by being in Silicon Valley, that's really significant (Kalb, 1991).

Apollo's other major misstep was in its 1984 choice of a President and CEO to replace Poduska. Following the tradition of the large Route 128 companies, they hired a long-time East Coast corporate executive who had worked his way up the ranks at General Electric and then 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 to "grow up." He couldn't have had a more different background than the twenty-something graduate students and computer whizzes who had founded Sun Microsystems two years earlier (Beam and Frons, 1985).

The media played up the superficial differences between Apollo and Sun: the buttoned-down, conservative Apollo executives alongside the casually attired, laid-back founders of Sun. It made for great journalism: while Vanderslice enforced a dress code and discouraged beards and moustaches at Apollo, Sun threw monthly beer bashes and employees showed up on Halloween in gorilla suits. While Vanderslice was chauffeured to work daily 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 in a traditional, risk-averse management team that focused on imposing financial and quality controls, cutting costs, and diversifying the firm's customer base. Former Apollo employees describe him as an archetypical "bean counter" who established formal decision-making procedures and systems in the firm 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 with the "controlled chaos" that characterized Sun (Weiss and Delbecq, 1987). Like many Silicon Valley companies, Sun developed decentralized organizational forms in its efforts to preserve the flexibility and enthusiasm of a start-up even as it grew. Corporate strategy was generated by discussions among representatives of autonomous divisions rather than 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. They joined other experienced and ambitious engineers at 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 the Silicon Valley's network-based industrial system multiplied.

Large Firms: Digital Equipment and Hewlett-Packard

The successes of the 1980s generation start-ups were the most visible sign that Silicon Valley was adapting faster than Route 128, but changes within the regions' largest firms were equally important. Established producers in Silicon Valley began to decentralize their operations, creating inter-firm production networks that built on the region's social and technical interdependencies and strengthened its industrial system. By institutionalizing long-standing 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 (Saxenian, 1994).

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 only 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.

While it is very difficult to develop accurate and useful measures of vertical integration, one indication of the greater reliance of Route 128 firms on internal production is the lower sales per employee figures shown below for the leading Route 128 firms and their Silicon Valley counterparts.

**1990 Sales Per Employee:
Silicon Valley and Route 128 (\$ thousands)**

<u>Silicon Valley</u>		<u>Route 128</u>	
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; Annual 10K Reports

The comparison of DEC and HP during the 1980s highlights the differing relationship of large firms to the region in network and firm-based industrial systems. By 1990, both were \$13 billion companies and were the largest and oldest civilian employers in their respective regions.⁵ Both were vertically integrated producers of proprietary minicomputers with shared origins in an earlier era of computing. And both faced comparable competitive challenges, although they responded quite differently. HP gradually opened itself 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 mind-set.

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

In the past, we had a ten year lead in technology. We could put out a product that was not perfectly worked out, but by the time the competition had caught up, we'd have our product in shape. Today we still have competitive technology, but the margin for catch-up is much shorter — often under a year (Edmondson, 1988).

At the same time, the cost of developing new products increased as they became more technologically complex. Innovation was occurring 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. It became more and more difficult for a single firm to produce all of these components, let alone to stay at the forefront of each of the underlying technologies.

This fast-paced and increasingly competitive environment posed a challenge for established computer industry leaders like DEC and HP. By 1990, however, HP had successfully managed the transition from minicomputers to workstations with open systems, while 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, while DEC lost \$95 million.

Although variations in corporate performance always have multiple causes, the two firms' organizational structures and their relationships to their respective regions help explain these differences. As a classic large firm in an independent firm-based industrial system, DEC maintained clear boundaries between itself and other companies or institutions in the region. This was, in part, a result of vertical integration. DEC designed and manufactured virtually all of the software and hardware components for its computers internally. The corporate culture rewarded secrecy and corporate loyalty, further minimizing opportunities for collaboration, learning, and exchange with other local firms. And departed DEC employees were typically treated like pariahs and cut off from the corporate "family" (Rifkin and Harrar, 1990). By the late 1980s, DEC dominated the Route 128 economy in a way that neither HP or any single firm ever dominated Silicon Valley.⁶

HP was both less dominant in Silicon Valley and more open to the surrounding regional economy. The firm benefitted from a long history of participation in the region's rich associational life and fluid labor markets, which allowed its engineers to stay at the leading edge of new computing technologies and market trends. Former DEC employees compared the openness of Silicon Valley, where gossip about everything from the latest start-ups to technical breakthroughs was continuous, with Route 128, where there were few forums in which to follow trends in technology and markets or learn from the experiences of others (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 eighteen firms in Silicon Valley between 1974 and 1984, including such notable successes such as Rolm, Tandem, and Pyramid Technology (Mitchell, 1989). A 16-year veteran of DEC, who now works for HP, described how the firm's autonomous divisional structure preserves entrepreneurship within a large firm:

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, aside from Data General, it is difficult to identify successful spin-offs from DEC.

Both DEC and HP began the decade of 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 to DEC's 16 percent and 8 percent, respectively. HP also controlled 66 percent of the market for desktop laser printers and 70 percent of the market for ink-jet printers (Nee, 1991).

Hewlett Packard 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 the 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, the firm created an independent team to develop a RISC workstation. The ultimate product, the Series 700 workstations, was far ahead of the rest of the industry. This aggressive strategy 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 early reflected the firm's openness to external changes and a Silicon Valley location that gave it easy access to state-of-the-art information markets and technologies. This 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, DEC CEO Olsen referred to personal computers as "snake oil" (Harrar and Rifkin, 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 and away from the vision of a single proprietary VMS operating system and VAX architecture for all DEC systems (DeNucci, 1990).

DEC's Research Lab in Silicon Valley developed state-of-the-art RISC and Unix technologies in the early 1980s, but its discoveries were virtually ignored by headquarters, which continued to favor the highly profitable VAX-VMS system (Comerford, 1992). Company insiders claim that DEC's Palo Alto lab contributed more to other Silicon Valley firms such as Sun and MIPS than it did to DEC because their findings quickly diffused to other Silicon Valley firms through technical papers and local industry forums. They compared the Palo Alto lab to Xerox PARC, well-known for inventions that were ultimately commercialized by other firms (Basche, 1991; Furlong 1991).

DEC finally decided to build its own RISC-based workstation in late 1986. The conventional wisdom within the firm was that the RISC microprocessor should be designed and built in-house. An internal team, generously financed and based in the state of Washington, was assigned to develop Prism, DEC's first commercial RISC computer. Two years later, this 100-person group still had very little to show for their efforts (Comerford, 1992).

DEC's Palo Alto workstation group— watching the impressive technical and commercial advances being made in RISC technology by Silicon Valley firms— offered to develop a workstation based on non-DEC chips. The resulting conflict, predictably, was over the wisdom of turning to outside suppliers for a key technology. One faction was of the opinion that DEC had invented small computers and didn't need Silicon Valley "twerps" to design for them; another group feared the loss of control over DEC systems; still others remained reluctant to give up the VAX vision of a single architecture for the entire product line.

In an unprecedented victory, Palo Alto eventually overcame the deep internal resistance at DEC to outsourcing the microprocessor. For the first time in DEC history, the senior executive committee approved the development of a workstation based on an external architecture. The Prism project was canceled, and DEC invested heavily in Silicon Valley's MIPS Computer Systems to develop a RISC chip. This appeared to be evidence that DEC was, at last, opening its doors to the outside world.

Four years later, however, DEC reversed course once again and announced an internal RISC design named Alpha that could run under either Unix or VMS. Abandoning its relationship with MIPS, DEC transferred the Palo Alto workstation group back to Maynard. The result of this inconsistent strategy left the firm with only 13 percent of the workstation market (McWilliams, 1992). When it was announced in 1992, the Alpha chip was the fastest RISC processor available, but it was a very late entrant and left DEC's long-term prospects uncertain.

The contrast between DEC's Palo Alto lab and its East Coast operations is instructive. Engineers who worked at both emphasize how different the two were: DEC East was internally focused,

while 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.

He described his years with the DEC engineering and development group in Palo Alto:

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 and say 'this feels like a different company.' The longer they stayed, the more astounded they were (DeNucci, 1991).

Tom Furlong, who headed a DEC workstation division in Maynard for five years before moving to Palo Alto in 1985, described the growth of the newly formed Palo Alto Workstation Group in the late 1980s as a typical Silicon Valley start-up. The group's autonomy from headquarters allowed members to take full advantage of the local 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-person group. He compared his experience working 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.

He explained the consequences of these organizational differences for new 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 their technical advances, and in 1992 transferred the group back to Maynard headquarters. Fur-long and other members of the Workstation design and engineering team left DEC to work for MIPS.

Hewlett Packard began the decade with a level of vertical integration comparable to DEC, but soon recognized that it could not continue to produce everything in-house. In the late 1980s, HP began out-sourcing 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 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 Hewlett-Packard and semiconductor design specialist Weitek illustrates how 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 for complex engineering problems. In 1987, HP opened up its state-of-the-art fabrication facility to Weitek for use as a foundry, hoping to improve the performance of the Weitek chips in its workstations. Realizing that the manufacturing process at the foundry Weitek used slowed the chips down, the HP engineers suggested fully optimizing the Weitek designs by manufacturing them with HP's more advanced fabrication process. This culminated in a three-year agreement that allowed the two firms to benefit directly from each other's technical expertise.

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

HP opened itself to outside influences during the 1980s, creating a model of a large firm which is internally decentralized and horizontally linked through complex supplier relationships to specialist companies. DEC's dominant and isolated position in Route 128, by contrast, hindered its efforts to shift to new technologies or a new corporate form. Saddled with an autarkic organizational structure and loca-

ted in a region that offered little social or technical support for a more flexible business model, DEC's difficulties worsened.

In 1992, DEC CEO and founder Ken Olsen was forced to resign under pressure 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 claim the position as 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 in order 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 demonstrates the analytical leverage gained by treating regions as industrial systems rather than collections of atomistic firms. Transcending the theoretical distinction between what lies inside and outside of the firm, and examining the complex relationships between local institutions and culture, industrial structure, and firm organization, provides important insights into the structure and dynamics of regional economies. The competitive advantage of regional clusters is derived as much from the way that skill and technology are organized as from their presence in the external environment.

The paired comparisons of firms in the two regions also suggests that industrial systems built on regional networks are more technologically dynamic than those in which learning is confined to individual firms. The experience of both Apollo and DEC demonstrate how the autarkic institutions and practices of an independent firm-based industrial system hinder adaptation. While the Route 128 region generated new firms and technologies in the 1980s, its producers failed to commercialize them rapidly or consistently enough to sustain regional prosperity, and the region continued to stagnate in the early 1990s.

The cases of Sun Microsystems and Hewlett-Packard suggest the competitive advantages of a network system in the current competitive environment. Nor are they unique in Silicon Valley. The region is home to hundreds of specialist producers that adjust to one another's needs through shifting patterns of competition and collaboration. This does not mean that all of the firms in a regional network-based system flourish. The difficulties of Apple Computer — which failed to open up the proprietary architecture of its Macintosh personal computer — are a reminder that even once-innovative companies can succumb to autarkic strategies. Failure is common in Silicon Valley, and some of the failures are spectacular. But it is a system in which even failures become opportunities for learning.

NOTES

- ¹Some theorists distinguish external economies that depend on the size of the market, including such things as a labor pool and specialized supplier base (pecuniary external economies) from those that involve spillovers of knowledge between firms (technological external economies).
- ²These rankings are based on five-year sales growth rates, but the list is not limited to small firms. Multi-billion dollar companies such as Sun Microsystems, Apple Computers, Intel Semiconductor, and Hewlett Packard all ranked among the fastest growing enterprises in 1990.
- ³These theories 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.
- ⁴The notion of an industrial system is adapted from Herrigel's (1989) concept of "industrial order." It avoids the term "industrial organization," which assumes a strict boundary between the economy and society and politics. Herrigel defines industrial order as "the sum of practices, rules and institutions that constitute and shape the way that the production of goods and its administration takes place."
- ⁵Lockheed Missile and Space and Raytheon Corporation were the largest private employers in Silicon Valley and Route 128, respectively. Both, however, were military contractors that remained largely detached from the commercial technology businesses of the region.
- ⁶With over 30,000 employees in Massachusetts by 1990, DEC accounted for almost 20 percent of regional high-technology employment, while HP's 20,000 Silicon Valley employees, by contrast, were only 8 percent of the regional total and, according to local engineers, appeared still less important.

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