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CREATING SELF-SUSTAINING, HIGH SKILL ECOSYSTEMS

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I. INTRODUCTION

A decade ago David Soskice and I described Britain as trapped in a *low-skill equilibrium:*

> "a self-reinforcing network of societal and state institutions which interact to stifle the demand for improvement in skill levels…(resulting in) the majority of enterprises staffed by poorly trained managers and workers produc(ing) low quality goods and services (Finegold and Soskice, 1988)."

Prior to that, the prevailing explanation for the low skill levels of the British workforce was cultural – that the British class structure had instilled a set of anti-education and anti-industry attitudes that discouraged investment in the skills needed for a modern economy (Wiener, 1981). We argued instead that the decision by most British young people to leave school at 16 with no recognized qualification (still the case in the mid-1980s) could be seen as a rational response to the set of incentives they faced. These incentives were shaped by an education system that offered few opportunities for the majority who could not qualify for higher education, and a youth labour market that offered no premium for additional years of educational investment that did not lead to a degree. Likewise, we showed that most managers' decisions to adopt a low-skill form of work organization, even if it hurt the performance of the British economy as a whole, could be seen as a rational response to the institutional conditions – e.g. short-term financial markets, an adversarial industrial relations system, a low supply of skills in the labour market – in which they operated.

One advantage of an institutional over a cultural explanation of Britain's skills shortfall was that it suggested that if the incentives facing firms and individuals could be altered, then Britain might be able to break out of the low-skill equilibrium. Britain, however, has historically lacked effective corporatist institutions, such as strong employer organizations, capable of overcoming the market failure problems associated with convincing firms to invest in transferable skills; past government efforts to remedy this deficiency (the Industrial Training Boards and Manpower Services Commission) have not proved very successful. Hence, we (Soskice, 1993; Finegold et al., 1990, 1992) have argued for a focus on greatly increasing the participation in full-time further and higher education as a first step toward making the shift toward a higher skill economy.

This is in fact exactly what has begun to occur in Britain over the last decade, in part by accident and in part by design. Britain entered the 1980s with just 7% of the working population possessing a university degree and one of the lowest levels of participation in post-compulsory education in the OECD (NEDO/MSC, 1984); by 1995, there had been a dramatic increase in staying-on rates, with close to 25% of young people obtaining a bachelor's degree, a level comparable to the U.S.'s mass higher education system. While Britain has been improving its education participation rates, so too have most of the advanced industrial countries; as Table 1 illustrates, Britain continues to trail some of its top competitors in the percentage of young people staying on in education until the age of 18 and obtaining economically vital intermediate (craft or technical) qualifications.

INSERT Table 1

Ironically, the badly needed reforms of the higher education system that were a key factor contributing to an improvement in the supply of skills leaving the education system may have inadvertently undermined Britain's capacity to create high-skill enterprises (for a more complete discussion of the factors leading to improved education participation rates see Finegold, 1992). In the late 1980s, the government merged the polytechnics and universities into a unified higher education sector and overhauled the funding formulas for post-compulsory education. This channeled additional resources to those institutions that were able to expand student enrollments most significantly at the lowest unit cost. While the competition among providers for a smaller cohort of young people[1] led to a major increase in the percentage of individuals participating in higher education, this competition tended to favor institutions concentrating on undergraduate education over world-class research institutions. Just as universities have a key role to play in fostering a high-skill economy by creating an adequate supply of highly educated manpower, so too the research that they produce can be a key enabler of new high-technology enterprises.

The remainder of this essay will focus on two of the world's most dynamic and successful economic regions: California's dense concentration of biomedical and computer hardware and software firms clustered between San Diego and San Francisco. It will show how these clusters or industrial districts have become self-sustaining *high-skill ecosystems (HSEs),* that once started, generate a positive, mutually reinforcing dynamic that fuels ongoing knowledge creation and growth and adaptation to changing competitive conditions. An HSE is a geographic cluster of organizations (both firms and research institutions) employing manpower with advanced, specialized skills in a particular industry and/or technology. The basic concepts of the firm, individuals' careers, and skill development will be shown to operate differently in these HSEs than in the traditional economy. Among the key questions the essay addresses are:

- Why are high-skill ecosystems important? What is their impact on wealth and employment generation?
- What are the conditions necessary for creating and maintaining this type of HSE?
- How are the processes of skill-creation and incentives for investing in skills sustained in firms that experience such high levels of labor mobility?
- What threats exist to the sustainability of these HSEs?
- Can this model be translated to the UK?

II. HIGH-SKILL ECOSYSTEMS

The low/high-skill equilibrium approach remains useful for understanding why Britain suffered from a skills deficit and the set of institutional changes required to address this problem. The original formulation of the framework, however, did have several, related shortcomings. First, while the stark

[1] Between 1985 and 1995 the number of young people leaving the school system in Britain dropped by approximately 25%.

categorization of a national economy as either a predominantly high or low-skill equilibrium was useful for theoretical purposes in illustrating the self-reinforcing nature of institutions and the interactions between the supply and demand side of the skill equation, it entailed a major over-simplification of reality. Not only are there significant high-skill regions existing within otherwise relatively low-skill economies (e.g. in the Third Italy), but the classification of sectors or regional economies as either high or low skill may itself be misleading. International comparisons of economic performance suggest that there are at least three meaningful skill segments in most countries (intermediate or medium, as well as high and low skill) and that the requirements for success in each skill segment may be very different (Crouch, Finegold and Sako, 1999).

Second, like much political economy work of the 1980s, our examples tended to over-emphasize the strengths of the Japanese and German approaches to skill creation and economic decision-making, and underestimate the potential of the more market-based systems of the US and UK to compete successfully in high-skill markets. Despite their recent economic difficulties, Japan's state education system and large-company-driven networks, and Germany's corporatist dual system continue to be world leaders in solving one of the key skill problems facing industrialized countries: how to get a large majority of the population to a high foundation level of skills for entering the workforce? And they have created companies that effectively use and continue to develop this large supply of workers with intermediate skills to compete successfully in global markets (see Crouch, Finegold and Sako, 1999).[2] Where they have been less successful, however, is in generating major new research breakthroughs and new forms of business services and the flexible, high technology start-ups that can turn these ideas into successful enterprises. Japan and Germany's relative failure in the highest skill markets, I will argue later, is a product of the very same set of institutions that have made them successful in generating supply and demand for intermediate skills.

These high skill, high technology operations are growing in relative importance for the advanced industrial countries (AICs) for two reasons. First, because of the rapid pace of innovation and high level of research capability and technical skills they require, the types of jobs in these sectors are the least likely to move to lower wage nations as global competition intensifies; thus, for example, while manufacturing and other elements of the value chain are becoming more globally distributed, R&D is still largely concentrated in the country of origin (Galbraith, 1998). Second, in increasingly knowledge-based economies it is these high skill firms that are generating the greatest share of wealth. In 1998, for example, 9 of the world's 10 corporations with the highest stock market capitalization were American (none were Japanese or German) and the value of many of these firms (like Microsoft and Intel) was primarily in intangible knowledge assets. And this wealth generation is no longer confined to an elite few, but is rather distributed across a wide segment of the population: in 1997, approximately half of all U.S. households owned stock, much of it in 401k pension plans that did not even exist entering the 1980s; these 401k plans now account for over $1 trillion in investment spread across 25 million households (Peterson, 1998).

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[2] It is important to note that at least in the Japanese case, highly productive organizations appear to be generally confined to certain exposed sectors of the economy, with much lower productivity in non-traded services.

A third shortcoming with the LSE/HSE framework is, as suggested by the term “equilibrium”, that the analysis was more static than dynamic. Although there are very strong inertial forces slowing any change in the skill composition of a national economy, the rapid pace of change in technology and global competition reduces the value of static frameworks. This is particularly the case for the highest skill, most knowledge-intensive portions of the economy on which this article focuses. Hence, the decision to change the focus from *equilibria* to *ecosystems*. Both concepts highlight the interdependence of actors in a system, but in the study of ecosystems the focus is on continual evolution; in these high-skill systems, as we shall see, equilibrium is typically associated with stagnation or death of a sector.

III. THE IMPORTANCE OF HIGH-SKILL ECOSYSTEMS

On any measure of economic performance California’s high-skill regions have been immensely successful. These are not niche employers of scientists and engineers, but rather constitute the largest manufacturing sectors in a state which if separated from the rest of the U.S. would rank as the world’s seventh largest industrial economy. It is difficult to define the precise size of these sectors because they are changing more rapidly than the official government statistics; software and internet-based enterprises, for example, that have passed computer hardware and chips as the most dynamic growth sector in Silicon Valley (SV), do not have separate industry classifications in the official statistics, but rather fall under the general heading of “computer services” (California Employment Development Department).

Using conservative estimates, the computer and electronic equipment sectors together employs over 300,000 workers in California, while the diversified healthcare technology sector with more than 200,000 employees has recently become the state’s second largest high technology employer (see Table 2 for employment in California’s largest manufacturing industries).[3] Interestingly, another of the state’s largest employer of highly educated workers, the motion picture industry, also appears to conform closely to the model of an HSE outlined below.

INSERT TABLE 2

The quality, as well as the quantity of jobs that these HSEs are producing is also a clear measure of their success. The wages of workers in these HSEs are significantly higher than those of the average Californian or U.S. employee. In the healthcare technology sector, for example, the average wage was $50,000 in 1997, 54% higher than in the rest of California; biotechnology, which employs the highest percent of advanced manpower in the healthcare sector, had average wages of $67,000 (California Healthcare Institute, 1998).

These employment and wage figures greatly understate the overall impact of these HSEs on California’s economic well-being. These HSEs directly increase the employment in closely related sectors, such as

[3] The healthcare technology sector employment estimate includes individuals engaged in research and distribution of products in this sector, along with an estimated percentage of individuals working in the healthcare portion of broader industry categories, such as control and measuring devices. The other employment estimates are for manufacturing alone at the 3-digit SIC code level.

the finance, legal and other specialized business services that cater to these high tech enterprises; computer services, for example, employed over 113,000 highly skilled individuals in 1990 that are not counted with the computer and electronic manufactures in the figure above. And the tremendous wealth that these sectors have generated for their owners and employees (who are often one in the same because of the ubiquitous use of stock options for compensation in these sectors), has had a very large indirect impact on generating employment in a wide array of relatively high-paying service sector jobs in the region: e.g. high quality restaurants, real estate agents, auto dealerships, travel agencies, etc. It is important to note, however, that the concentration of high-skill employees in these sectors co-exists with a large, much lower skilled and lower paid workforce, both working in some segments of manufacturing within these sectors and providing personal services (gardening, child care, hotel rooms) to the higher skilled workers (Storper and Scott, 1990). One sign of the scale of this multiplier effect is that manufacturing jobs now account for only 15% of non-farm employment in California, projected to decline to 13% by the year 2003 (California EDD, 1998).

On other measures of economic performance, such as balance of trade and growth, these HSEs have also been extremely successful. Computers and electronics have become the state's largest manufacturing export sector, while California's healthcare technology sector generated over $4 billion in exports in 1996 (U.S. Department of Commerce, 1998). This represented a 61% growth rate over just four years earlier.

IV. A MODEL OF SELF-SUSTAINING HIGH-SKILL ECOSYSTEMS

There is a wide variety of research in different fields of economics and across many other disciplines (e.g. management, history, geography) that have contributed to our understanding of the factors necessary for the development of high-skill ecosystems. Starting with the seminal work of Marshall (1920) on industrial districts, economists have been interested in what factors explain the propensity of firms in a given sector to cluster together in a small geographic area. Krugman (1991) points to three supply-side externalities – labor market pooling, the provision of specialized intermediate goods and services, and technology spillover effects – that favor concentration of firms in a common industry even during a period of increasing economic globalization. The incentives for such clustering are even greater, when a new technology is just emerging, and the knowledge associated with it is predominantly tacit, and thus difficult to transmit to those not directly involved in its creation.

In one of the most important recent works in this field, Porter (1990, 71-2) focused on the key factors that enable certain regions to create and sustain successful clusters. His diamond model has four elements: demand conditions, factor conditions, firm strategy and structure, and related or supporting industries. His framework draws heavily on the earlier work of industrial geographers and political economists, who studied the elements necessary for the creation and continued survival of industrial districts (Piore and Sabel, 1984; Scott, 1988).

Population ecologists in the management literature (e.g. Hannan and Freeman, 1977, 1989), have used a different approach, drawn from the study of biological systems, to try to improve our understanding of the conditions necessary for organizations and the individuals within them to survive and prosper. This literature focuses primarily on the birth and death rates of individual firms and whether a particular organizational form will triumph in the "survival of the fittest" in a given set of economic circumstances. While the biological analogy is useful for understanding the process of dynamic growth and interdependence among organisms, the way it has been applied has placed too great and emphasis on competition among firms, underemphasizing the potential for firm cooperative behavior (Schoonhoven and Eisenhardt, 1992). In the framework developed below, I addresses this deficiency, while shifting to a higher level of analysis that has largely been ignored by the organizational ecologists. The focus is on the factors that lead to "the survival or extinction of species of organisms (in this case, clusters of enterprises and individuals) under different environmental conditions" (Young, 1988). Extending on a relatively minor part of Porter's framework, the focus is also the processes of knowledge creation and diffusion that is central to the development of these high-skill ecosystems.

The framework consists of four elements necessary to create and sustain a high-skill ecosystem:

- A catalyst – some event or external trigger that initiates the living reaction
- A supportive host environment – a set of environmental conditions that enables young creatures to grow to maturity
- Fuel or nourishment – to sustain the growth of life on an ongoing basis
- A high degree of interdependence – part of what makes this a system, and not simply a group of separate organisms sharing the same physical space is that they are mutually interdependent, e.g. part of a single food chain.

Different ways of developing successful clusters of high and/or intermediate-skill enterprises have evolved to meet the requirements of different sectors and the distinctive institutional features of a variety of advanced industrial countries (Baptista, 1998; Porter, 1990; Storper and Scott, 1990). In Germany, state and national government-sponsored applied research and technology transfer institutes have been the focal points for clusters in different sectors (Grabher, 1993), while in Italy it is the strong family and community ties that are seen as the glue which binds small, specialized enterprises together (Triglia, 1991). In Japan, by contrast, it has been the giant corporations, such as Toyota, that have served as the hub for tiers of interconnected suppliers (Sako, 1988). However, all of these different clusters fulfill some common underlying conditions if they are to survive and prosper. These conditions for an HSE are summarized in the framework below using examples from California's high-tech clusters. There are two key reasons for focusing on the U.S. model: 1) it has arguably been the most successful at creating rapidly growing, high skill enterprises, and 2) it is best suited institutionally to the UK, which shares the same strong research base and more free market environment.

Catalysts

As with naturally occurring ecosystems, there is a strong element of historical contingency in how and where high-skill regions are formed (Arthur, 1989). To start the process, these regions require some catalyst, or set of catalysts, to trigger the development of successful high-skill enterprises. California's computer and biomedical industries grew from a confluence of government demand and investment and key individuals that helped ignite the explosive growth of new firms.

For Silicon Valley's computer HSE one key stimulus was a large surge in Department of Defense funding for research and demand for new military hardware in the new field of electronics in the 1940s and 1950s. This helped create a cluster of aerospace firms in Southern California (Scott, 1994). As this cluster grew some of these firms set up new facilities in the Santa Clara Valley, attracted by the cheap land, access to military bases, and the supply of engineers from the nearby universities. When the aerospace industry went into one of its periodic downturns, this left an abundance of unemployed engineers who had settled in the area with cutting edge electronics skills that could be transferred easily from military applications.

During this period, Fred Terman, a Stanford engineering professor had encouraged two of his students, William Hewlett and David Packard, to turn their graduate thesis into a commercial product (Aley, 1997). The resulting company not only acted as a magnet for growth and new product innovation in a variety of electronics sectors, but also helped generations of engineer entrepreneurs who then left to set up their own enterprises. Terman was a driving force in establishing some of the crucial initial links between Stanford and industry: the Honors Cooperative Program, that offered part-time degrees to engineers in industry, and one of the world's first science parks, the Stanford Research Park, where HP and numerous other successful high-tech start-ups began and are headquartered.

A very similar set of historical contingencies helped propel the growth of California's biomedical clusters. In healthcare technology, even more so than computing, basic research is a key driver of growth and the location decisions of firms (Prevezer, 1998). A relatively small group of star scientists has accounted for a high percentage of all biotech start up firms (Zucker and Darby, 1996), many of which are started by researchers at locations close to their original laboratories (Oakley et al., 1990); fully one-third of all U.S. biotechnology companies, for example, are located within 35 miles of a University of California campus (California Healthcare Institute, 1998). The large U.S. government and private foundation investment in biomedical research, much of it performed in California's set of world-class research universities and institutes, led directly to one of the two key discoveries that made the biotech industry possible. In 1973, Cohen and Boyer, collaborating between Stanford and the University of California at San Francisco (UCSF), discovered how to recombine DNA, giving rise to Genentech, the pioneering entrant in this sector. The second discovery came in Cambridge, England, but the University failed to patent the techniques for monoclonal antibodies and the result was that there was no incentive for Kohler and Milstein or others to establish a firm near the University to commercialize their technology, since they lacked the exclusive rights to develop it (Prevezer, 1998).

In recognizing the key role that certain entrepreneurs and world-class researchers and their discoveries played in jump-starting the evolution of these HSEs, it is also vital to distinguish between historical contingency and serendipity. The fact that these individuals were located in California and attracting the substantial public and private research funding necessary for the breakthrough to occur, was not mere chance, but rather a testament to the vital role that research universities can play as a catalyst for HSEs.

Nourishment

California's world-class research universities not only provided a powerful initial catalyst for these high tech regions, but also are the source of the most important nutrient – new talent – that sustains their growth. Each year these institutions turn out thousands of new bachelors, masters and Phd graduates who move directly into local companies, and often later start their own firms. And this talent comes not only from the science and engineering fields, but also from the management field; indeed, Stanford Business School one of the most selective in the world, recently dropped in *Business Week*'s MBA program rankings because so many of its graduates were turning down offers from the traditional recruiters at large companies and financial institutions (who are surveyed to compile the rankings) to take positions with more rapidly growing high-tech companies (*BusinessWeek,* 1998).

Once established, the synergistic relationship between these leading research universities and the surrounding firms that hire their graduates and support their research can become self-sustaining as the two act together as a magnet to pull in the brightest students from around the globe. Despite the large supply of graduates coming from California's research universities, the state's high-skill regions are significant net importers of graduates from other U.S. universities and from foreign countries. Across the U.S., more than half of all the science and engineering Phds are now awarded to foreign-born students (North, 1996), and the leading Califronia research universities – University of California campuses in Berkeley, San Francisco, San Diego, Los Angeles, along with private institutions (Stanford, USC, CalTech) -- are among the top choices for these applicants. These foreign-born students and entrepreneurs represent some of the most talented technical manpower from around the world and have played a key role in fostering the growth of California's HSEs (Taylor, 1998). In many cases they bring with them extended family and/or personal business networks that further strengthen the global reach and viability of the HSEs (Saxenian, 1994).

The magnetic attraction of HSEs for employees, however, is not confined to the highest skill occupations. As Table 3 illustrates, while close to a third of all engineers working in California's high-skill industries were born outside the U.S., 45% of skilled craft workers and a majority of all operators had emigrated to the U.S. In some of California's electronic or circuit-board assembly plants, virtually the entire frontline workforce consists of women from Vietnam or Central America. Even with this huge influx of talent, the supply of human capital is not sufficient to keep pace with the rapidly expanding demand; for example, it was estimated that even with immigration, the US would experience a shortage of approximately 350,000 programmers between 1995 and 2000, with Silicon Valley experiencing some of the tightest labor markets (US Department of Commerce, 1998).

Insert Table 3

Alongside the steady intake of human capital, the other vital nutrient that sustains the development of these high risk, but potentially high payoff new enterprises is financial capital. The venture capital industry, which California helped pioneer, serves the vital function of sharing risk – taking much of the financial burden off the researcher or entrepreneur who comes up with the a new innovation, and distributing it among a pool of investors. From an already large base, there has been a dramatic increase in the supply of U.S. venture capital available in the 1990s; the amount invested in venture capital deals grew by 66% in just two years, from \$6.9 billion in 1995 to \$11.5 billion in 1997

(VentureOne Web Page, 1998); and California's high-skill regions both supply and attract a large share of this investment. Silicon Valley firms alone received 23% of all new venture capital investment, by far the largest share of any U.S. region (Herhold, 1998).

Once established, the venture capital process is another part of HSEs that can become self-perpetuating, as the founders of the first generation of successful start-up firms become "angels" for subsequent generations. These angels invest some of the money they have made from a successful public offering or selling off their business into new start-up companies. They often enter the deal at a very early stage, before the company is ready to approach a venture capital firm. Venture capitalists, whether "angels" or firms, provide far more than financial advice to new enterprises. They also supply vital capabilities, e.g. managerial, financial, marketing, legal, and procurement skills, based on years of experience in the sector that the scientist or often very young engineer who has founded the firm may lack. And unlike the outside directors on the boards of many large corporations, venture capitalists tend to play a far more active role in the daily operations of the enterprise, helping to formulate strategy and brokering partnerships with other suppliers and customers in other parts of the value chain (Conger, Finegold and Lawler, 1998).

Supportive Environment

Just as young creatures need a supportive environment free from toxic chemicals and harsh climatic changes if they are to g row, so too clusters of small enterprises are more likely to thrive if they have the right set of external conditions. There are at least three elements of an external environment that are conducive to a HSE: basic infrastructure, a climate that is attractive to knowledge workers, and a regulatory regime that supports risk-taking.

A basic requirement for successful high-skill enterprises in an increasingly global marketplace is good infrastructure. As the key drivers of wealth in the economy have shifted from mass manufacturing to high-technology industries, the underlying basis for economies of scale has shifted from physical concentration of resources natural resources (water, power, iron ore) in a single location to the ability to design and sell new products or services on a worldwide basis. The only way to justify the multi-billion dollar investments required to develop a new drug or to construct a new semiconductor fabrication plant for a chip whose projected life is only 1.5-2 years is to sell the product globally (Galbraith, 1998). This means easy access to international airports that enable individuals to travel to remote locations within their organization, as well as to customers, partners and suppliers scattered around the globe. And it means a good local transportation infrastructure so that individuals can get to and from work efficiently. Most importantly, high tech industries require a state of the art telecommunications infrastructure to enable firms and their employees to take full advantage of the new technologies (the intranet, videoconferencing, electronic data interchange) that make possible effective collaboration on a virtual basis. While these technologies are not yet a complete replacement for face-to-face interaction in the early phases of new knowledge generation, they are a vital compliment to them for making a global organization work effectively.

While possessing a high quality physical and communications infrastructure, California's most successful high-skill regions have gone beyond these basics to create more specialized infrastructure tailored to the needs of new, high-tech enterprises through mechanisms such as incubators, and science or technology parks. These facilities have been created by universities, public authorities or private developers to provide an array of services that small firms are likely to need as they develop, but which they are unlikely to be have developed as in-house capabilities. These services may range from daily requirements (e.g. shared secretarial support and photocopying) to more specialized services such as legal advice, financial accounting, consulting and export marketing. Just as important, the co-location such infrastructure creates can help build informal networks that encourage exchange of lessons learned and generate new business ideas. The development of this sophisticated infrastructure for Northern California's computer industry helped lay the groundwork for the subsequent growth of the region's biomedical HSE, that required many of the same specialized services (Prevezer, 1998).

As improvements in telecommunications give knowledge workers and the firms that employ them far more location options, other elements of the external environment become increasingly important in determining where high-skill enterprises will cluster. Individuals can focus more on whether where they want to *live*, rather than where they have to *work*. Thus, depending on their stage of life, they place a premium on factors such as the climate, and the availability of cultural, recreational or other leisure activities, and/or the availability of affordable housing, safe neighborhoods, and high quality schools. One important caveat to the above factors, however, is that another clear attraction for knowledge workers is being close to others who share the same expertise. Hence, regions which originally grew because they possessed many environmental attractions for knowledge workers, but which no longer possess some of these attributes because of their explosive growth, may still act as magnets for young talent because they already have a critical mass of knowledge workers and enterprises. Whether they can sustain this HSE over the long-term without these environmental conditions in place, however, is an issue to which we will return in the conclusion.

Another essential requirement for fostering the growth of a HSE is a regulatory and cultural regime that supports the risk-taking needed to create new enterprises. This entails relatively low levels of regulations regarding work hours and other company practices that are likely to frustrate entrepreneurs, along with a set of laws that makes it easy to: a) start a business, b) take the business public if the initial idea proves successful, and c) go bankrupt without severe penalties if the business does not succeed. The U.S. in general, and California in particular, meet all of the above criteria. The U.S. has pioneered the development of new stock markets that make it possible for new businesses to raise capital at an early phase in their development, and California has retained its pioneering spirit, with a culture that celebrates the efforts of entrepreneurs, even those that are not successful. This contrasts with Japan and Germany, where regulations prohibit firms from going public until they have a clear revenue stream and where there is more stigma attached to being associated with a failed business.

Interdependence

One characteristic that distinguishes an HSE from an agglomeration of high-skill firms that simply is co-located is the extent of interdependence between the actors in the region. The conditions identified above -- strong universities, good infrastructure, abundance of human and financial capital – are common to many urban areas that do not qualify as HSEs. What the firms and individuals in these regions lack is the shared focus on a common sector and/or technology and a high degree of cooperation among the actors that facilitates the learning process. . In her comparison of the development of the computer industry in Silicon Valley and Route 128, Saxenian (1994) identifies the greater strength of Silicon Valley's knowledge-sharing networks as a key factor in explaining this region's greater growth and dynamism. It is possible to distinguish three different types of interdependency or networks, each of which can play a vital role in building an HSE: 1) horizontal linkages among specialized enterprises, 2) vertical connections between firms along different segments of the value chain, and 3) networks among individuals.

The first type of interdependence stems from the very radical way in which the concept of the "firm" in Silicon Valley differs from the traditional hierarchical corporation. Firms tend to have very flat, team-based structures devoted to the development of a small set of distinctive core technical competencies. This form of specialization requires that companies partner with other organizations that have complimentary expertise. As companies grow larger, they can adopt this network form of organization internally; Sun Microsystems, for example, has organized itself as separate enterprises for chips, hardware, software and system integration, each encouraged to network with other parts of Sun, but also free to partner with other firms if they feel that can better meet their needs (Galbraith, 1998). In contrast, the failure of large companies, like DEC and Wang, to grow through external partnerships was one of the causes of Route 128's weaker networks (Saxenian, 1994), and may likewise account for the relative dearth of new enterprises around Microsoft in Seattle (Fefer, 1997).

A second form of interdependence arises when companies replace vertical integration with partnerships across different segments of the value chain. This is particularly important in biotechnology, where start-up enterprises generally lack the huge investment dollars or global distribution networks required to get a new drug through clinical trials and into the marketplace; instead, much like a food chain in a natural ecosystem, this industry has tended to evolve as a long string of interdependent relationships. A small firm creates some specialized tool (e.g. DNA sequencing machines and drug modeling software) that another firm then uses to develop a library of genetic sequences or a specific new drug; this drug may then be licensed to a large pharmaceutical company that gets regulatory approval, and then manufactures and distributes the drug to healthcare providers. Similar, but separate chains have developed in other segments of the biotech industries, e.g. for agricultural and food applications, as well as many segments of the wider healthcare technology and computer industries. This form of interdependence highlights the crucial role that demand drivers can play in transmitting signals down the value chain that stimulate the development of new enterprises (Porter, 1990).

The complex web of networked enterprises that grows from such arrangements fits many aspects of Piore and Sabel's (1984) concept of *flexible specialization*. These predominantly small firms have the agility to respond quickly to changes in technology or customer demand, and yet together have the collective capabilities and resources needed to develop new products and manufacture them in large numbers for the global marketplace. A key to the flexibility of these networks is their capacity for collective knowledge creation and diffusion. This form of knowledge interdependence is fostered by intermediate institutions that provide a forum for individuals to meet and exchange learning. Northern

California has a wealth of such institutions. These include employer groups, such as NOVA Private Industry Council and Joint Venture Silicon Valley, where firms come together to pursue initiatives (such as improving technical training in community colleges) that are to their mutual benefit. It also includes numerous ways to build individual networks, like the continuing education courses and alumni associations of the region's universities, and the active local chapters of professional associations. San Diego's CONNECT network provides a good illustration of how such institutions operate. It was founded in 1985 to provide a regular meeting where professors and their students could present their most promising proposals for new biomedical businesses that were then discussed and critiqued by a group of industry experts, venture capitalists and other specialized service providers.

V. RECONCEPTUALIZING THE KNOWLEDGE DEVELOPMENT PROCESS

The knowledge creation and diffusion process is at the heart of why firms cluster (Baptista, 1998). It is the difficulty of transmitting tacit knowledge, particularly when it is new and changing rapidly that encourages enterprises to be in direct and frequent contact with each other and the researchers creating the new knowledge. Just as firm structure and inter-firm relationships differ in the HSEs and more traditional settings, so too the process of developing individual capabilities and organizational knowledge within HSEs is very different from conventional approaches to training and skill development.

Given the high level of employee mobility among tightly clustered firms within an HSE, one might expect a skills shortfall to develop, as companies are unwilling to pay for skills investment that may be "poached" by a competitor (Finegold, 1991); Stevens (1996) has shown that firms from a sector require a set of specialized, but transferable skills (like those skills in demand in these high-tech regions), there is likely to be just such an under-investment in training. Her work represents an important advance on human capital theory, and correctly predicts the low levels of employer investment in formal training that occurs in most firms in these high-technology regions. It is important to recognize, however, that a lack of company training does not equate with a skill shortage in all cases.

For the scientists and engineers who are the key drivers of knowledge and wealth creation in these high-skill regions, company-provided formal training is often not the primary vehicle for learning. Rather, they typically enter the workforce with a high level of specialized preparation acquired through higher education and/or self-study. They then continue to learn within the firm by seeking and being given cutting edge technical challenges that often demand the combined talents of a multi-functional project team in order to develop solutions. If they encounter a problem that they cannot solve, they may turn to a professional colleague who is part of a wider personal network of outside technical experts. When individuals do have time to take part in formal courses, it is often in the evenings, in a university extension or continuing education program, where they can further develop their personal networks, rather than in formal company training. The costs of such training to the firm are low, even for those companies that reimburse the employee's full tuition costs, since the courses are often subsidized indirectly by the state and the employee is not being paid for the time spent in training.

The greater utility of informal over formal learning for these highly skilled individuals has been shown in recent research on organizations undergoing rapid change (Tenkasi, Mohrman, and Mohrman, 1998) and is reaffirmed in our current study of the key drivers of technical performance that includes a survey of nearly 2,000 technical professionals in 5 global corporations.[4] These scientists and engineers indicated that the most useful learning experience for them was not formal courses (inside or outside the firm) or structured on-the-job training, but rather visits to customers, suppliers or partner companies (see Table 4). This result is confirmed by an analysis of the relationship between different forms of development with key measures of organizational performance. This indicates that, creating more opportunities for learning in the day-to-day work environment – as measured by a three-item scale "my job assignments provide the opportunity to keep my skills and knowledge up to date" and "we have a good process for mentoring technical employees" and "developing employees is a high priority for managers in this company" – explains a high percentage of the variance in perceived organizational effectiveness (10-16%). In contrast, providing individuals with more days of training explains less than 1% of the variance in organizational performance. The value of informal over formal learning opportunities is likely to be even greater in the smaller enterprises that populate these HSEs, since many of these firms lack an in-house training department and the technology is changing so rapidly that it is hard for many formal courses to keep up with changing skill needs.

Insert Table 4

Within these turbulent, high-skill environments, the responsibility for career development has also shifted from the firm to the individual and the HSE itself.[5] Gone is the notion of a corporation that would provide opportunities for career progression and a high degree of job security in return for employee loyalty and commitment. In its place is a project-based culture, in which individuals have ownership over their own career development. Indeed, Silicon Valley is often cited as the archetype of the new employment relationship in which "employability" – the continuous development of marketable skills -- has replaced "employment security" as the bargain which firms can offer workers in return for their effort toward achieving business objectives (Finegold, 1998).

The high rate of mobility between the dense cluster of firms and universities "facilitates a collective learning process, increasing the speed of diffusion by reducing uncertainty. Innovation becomes, first and foremost, a collaborative social endeavor" (Baptista, 1998, 51). The willingness of individuals to change firms frequently, on which this collective learning process depends, is made possible by a new concept of employment security within the HSEs. Highly skilled individuals can feel confident about

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[4] These survey questions were part of the first year of a much wider three-year study of the conditions that promote excellent performance in 10 technology-intensive global companies.

[5] While the importance of firm investment in individual learning decreases with higher levels of individual ability and mobility, just the reverse is the case for investments in organizational learning. Faced with the reality that their most valuable assets – their employees -- may leave at any time, firms are making major efforts to become more systematic about the way in which they manage their knowledge base. Efforts to take the tacit knowledge within key experts' heads and make it explicit, so that it can be stored, shared and improved on are at the heart of the knowledge management process (Nohira, 1991; Roth and Senge, 1996). Our research indicates that organizations which have more clearly documented and easily accessible best practices and standard work processes as well lessons from past failures are significantly more effective on all key dimensions of performance (Tenkasi, Mohrman, and Mohrman, 1998).

buying a house and choosing a school for their children not because they can assume they will be working for Firm X in three years time, or even that Firm X will still be in business, but because there is a critical mass of other employers all demanding a similar skill set where they can work without ever having to move (Saxenian, 1994). Indeed, in this environment, many individuals are concerned that they may undermine their employment security by staying with a firm for more than 2-3 years and risk not staying on the cutting edge of the latest technology.

The same institutional features that have made the Japanese and German VET systems so successful at the creation of large supplies of individuals with intermediate skills, are poorly suited for the development of this type of individually-driven, collective learning at the most advanced level. In Germany, there is a strong reliance on formal qualifications, from the state-run and heavily regulated universities and the tripartite-governed apprenticeship system. The process of creating new qualifications or updating existing ones is very time consuming, and even with efforts to streamline this process to meet the needs of new information technology and service sectors, it still has difficulty keeping up with the pace of change in high technology skills (Culpepper and Finegold, 1999). In Japan, by contrast, there is very little reliance on formal vocational qualifications, but the low levels of labor mobility between firms and between academia and industry discourage the flow of tacit knowledge that is an essential part of the learning within HSEs.

VI. ADAPTIVE CAPACITY -SUSTAINABILITY OF THE HSES

Just as naturally occurring ecosystems may be threatened if they stop changing, so too the economic well-being of any HSE is threatened if the firms and individuals within it stop the process of growth and adaptation. One rough estimate has put the typical life of such a high tech cluster until it reaches maturity and begins to stagnate at 50 years (Swann and Prevezer, 1998). Some high-skill industrial districts, such as the financial sectors of New York and the City of London, have defied such projections. A brief look at the history of California's HSEs, suggests that they have already demonstrated a strong capacity for adaptation to the changing environment that bodes well for their long-term sustainability, but may also, ironically, be sowing the seeds for an eventual slowdown in their growth rate.

If we trace the changes in Silicon Valley's electronic cluster we can see that it has already evolved through at least three or four generations of different businesses. It began, as noted, with aerospace applications and Hewlett Packard's calculation and memory devices. It grew into a huge memory chip industry personal computer industry. When these products turned into more commodity-like items that were severely threatened by cheaper foreign imports, Silicon Valley firms gravitated into more advanced specialized chips, microprocessors, work stations, network systems, and software. The latest wave of firms is now focused on developing and harnessing the potential of the internet with a vast variety of software and hardware products.

The healthcare technology cluster is newer, and thus has not yet gone through as many stages of evolution, but it is already possible to detect several successive generations of firms in this sector. To give just one example, the process of new drug design has evolved rapidly in the last 15 years from the traditional, laborious method of trying to match diseases with possible new or existing molecular compounds that was common in the large drug companies. A first generation of start ups pioneered advances in molecular modeling and genetic sequencing that have led to an explosion in the array of possible solutions. This triggered the growth of a second set of new start-ups in the early 1990s that pioneered a "rational drug design" method; this reverses the old drug design process, using computers to predict possible applications for new protein structures (Prevezer, 1998). Only a few years later, a new wave of start-ups has emerged devoted to "irrational drug design, using genetic algorithms to mimic the natural selective process as a method for drug development". In all of these cases, the new firms that have pioneered these processes have sprung up around the leading research universities in Northern and Southern California and Cambridge, Massachusetts. This evolution of new firms not only illustrates the strong capacity of HSEs to regenerate themselves, even as particular firms fail or technologies become more standardized or obsolete (Prevezer, 1998).

Part of what fuels the development of new generations of technology is another self-corrective mechanism embedded within the HSEs. As the most successful firms in one generation prosper and grow, they inevitably take on some of the bureaucratic features associated with larger organizations. This bureaucracy can have some very positive features: e.g. fostering career development, building managerial skills, embedding learning into more standardized routines and processes. But it can also have elements that are antithetical to radical innovations, particularly those that threaten existing technology, since the new innovations also threaten the portions of the organization and its employees that have a stake in the ongoing profitability of the older technology. It is for this reason that most path-changing technological breakthroughs generally come from new entrants, rather than the R&D labs of well-established organizations.[6] This phenomena is apparent over and over again in Silicon Valley. The start-up offspring of Fairchild Semiconductor are so ubiquitous, for example, that they've been dubbed the "Fairchildren". And Hewlett Packard has given rise to dozens of new ventures through the skills it helped develop in employees that then left the firm. This dynamic has a dual benefit for the HSEs: it not only creates an ongoing stream of new enterprises that can develop new technologies as older ones become mature or obsolete, but it also generates strong pressure on larger, more successful companies to remain as flat and innovative as possible if they are to retain their talent.

A number of the other features of HSEs discussed above can help strengthen the adaptive capacity of a cluster. First, if the HSE is broadly based, including groups of enterprises in several different parts of the value chain (e.g. chips, hardware, software, networking systems) it is likely to have greater adaptive capacity then if it is concentrated in only area, where there is greater risk that the whole cluster could become obsolete (cite).[7] Likewise, the greater the strength of interpersonal networks, the more the opportunity for creative new ideas that come from the intersection of new technologies or the development of applications for different end users. In addition, the close proximity and interaction with

[6] This logic helps explain why IBM was slow to grasp the importance of the personal computer and why when it belatedly chose to enter the sector it had to do so by setting up an entirely separate business unit, physically and organizationally removed from the mainframe business.

[7] Research on the Third Italy suggests that this diversity may be beneficial in even unrelated sectors; for example, the geographic co-existence of clothing and machine tool clusters is mutually beneficial because they tend to have counter business cycles, so that when the predominantly male machine tool sector is in recession, the women in the community are usually busy in the textile factories, and vice versa.

universities gives firms in these HSEs ongoing access to new research breakthroughs and a source for renewing their human capital stock to help prevent enterprises from becoming stale.

Even with a very strong adaptive capacity, however, no HSE is likely to continue to grow and prosper forever. One possible threat to an HSE's sustainability is a major discontinuity in the environment or technology that undermines the core basis of the HSE. This could take the form of a dramatic shift in the market, such as the end of the Cold War that devastated the Southern California aerospace cluster (Schoeni and Dardia, 1998). As this case illustrates, however, industrial clusters can be very resilient – commercial spinoffs from the defense industry and the surplus engineering talent it generated has helped spur the development of new Southern California business clusters in multimedia and commercial satellite technology. In the case of California's HSEs, the core technologies appear so central to such a wide variety of different future applications, that it seems unlikely they will become obsolete any time in the near future.

The central threat to these HSEs, instead, appears to come from within: as HSEs prosper they almost inevitably become victims of their own success. The wealth and jobs that they generate lead to an increase in the general cost of living, house prices, and negative externalities such as traffic congestion. At some point, these negative factors start to counterbalance the benefits of clustering, leading to a slowing in the growth, if not absolute decline in the size of the cluster (Swann, 1998). While these downsides of growth may hinder the ability of HSEs to attract top talent, they also have positive consequences. For the HSE, it places strong pressure on the enterprises to concentrate on only the most high skill, high value-added activities within the region. When products become more mature or parts of the value chain no longer demand as high a skill level, such as the shift from pilot plants to more custom mass manufacturing, then the operations are often shifted outside the region to new locations. This is already the case in Silicon Valley, where much of the more routine programming and manufacturing is now located in other parts of the US or around the world (India, Russia), where the needed talent is available at a lower cost. Likewise, when the growth in an HSE reaches the stage where it is deterring some new start-ups, this can encourage the development of new clusters in the same sector. This dynamic is already occurring in the US computer, biotech, and multimedia industries, as new clusters have formed both adjacent to Silicon Valley (Santa Barbara, downtown San Francisco), and across the country in other areas that possess leading research universities (Austin, TX, Salt Lake City, Utah, Raleigh/Durham, North Carolina).

Another way in which HSEs risk becoming victims of their own success is because of the high levels of individual expectations they have created. As noted, a large part of the reward packages in these start-ups consists of stock options that can make the employees very wealthy if the firm reaches the stage of successfully going public. Indeed, the U.S. stock markets' appetite for hot technology areas like the internet is so great that companies which were still years from turning a profit, such as Netscape and Yahoo, were able to generate vast amounts of capital and fortunes for their founders through initial public offerings (IPOs). If the stock market experiences a prolonged period of decline, something that hasn't occurred in the entire history of some of these newer firms, then the attraction of these enterprises for many talented individuals may diminish. The roller coaster record of many biotech stocks, however, suggests that even this danger may not be too severe, as the prices of individual companies and the sector as a whole have experienced major ups and downs, while the HSEs have continued to grow and prosper.

VII. HIGH-SKILL ECOSYSTEMS IN THE UK

The U.K. has many of the elements necessary for the generation of HSEs. It has a large and growing supply of high quality university graduates, relatively good telecommunications and a large supply of specialized infrastructure (e.g. science parks) to support start-ups, and a culture and set of free market policies that is generally supportive of new enterprises. Most of all, it has the difficult to replicate competitive advantage of a set of world-class research universities that can act as a strong catalyst for the creation of new industries and technologies. In the biotechnology field, for example, the UK has produced more academic "stars" whose research often serves as the basis for a whole family of new innovations than all except the world's two largest economies: Japan and the US (Zucker and Darby, 1996, Table 3).

This set of factors has helped the UK produce among the most successful HSEs in Europe in computers and healthcare technology. The UK accounted for 45% of all European biotechnology firms in 1994, with most of them clustered around the research universities in Cambridge, Oxford and London (Shohet, 1998). And in the electronics and computers, although the scale of the industry is much smaller in the UK than the US, new research indicates that the extent of clustering of enterprises around is just as great in Britain as in the U.S (Baptista and Swann, 1998).

The weakness of some key elements in the ecosystem, however, appears to be preventing the UK from capitalizing fully on these assets. A clear sign of the underutilization of the research base is that the UK has one of the highest levels of outflow of scientific "stars", with the net migration rate (emigration – immigration/stars ever publishing in the country) equal to one third, a net loss of key manpower exceeded only by Switzerland (Zucker and Darby, 1996). One possible cause of the problem appears to be the weakness of the venture capital industry and opportunities for going public for high tech firms; the UK has a healthy capital market for firms that are already profitable, but a scarcity of funds available for companies in the prior stages of development, where large resources are required to get the first product to market. The relative lack of venture capital funds and banks insistence on collateral for any business loans to new high tech enterprises, means that a heavy share of the risk for new firms falls on the individual entrepreneur. And the potential offsetting benefits are less certain because the efforts to create a new EASDAQ market for start-up firms have not yet taken hold.

The contracts for British university faculty appointments also appear to increase the individual risk of starting a new firm, since it is more difficult than in the US for faculty to get leave or part-time positions, while still retaining their university appointment and benefits. This may contribute to the weakness of individual networks between British academics and industry relative to the US; under 10% of British star researchers have formal ties with a new business enterprise, compared to one third of US stars (Zucker and Darby, 1996).

The UK has also historically had relatively weak institutional linkages among firms and between firms and education and training providers that have hindered the pursuit of collective, high-skill strategies (Crouch, Finegold and Sako, 1998). There have been a wide array of policy initiatives to try to address this weakness; indeed, part of the problem appears to have been too many separate initiatives relating to science, industrial, regional or education and training policy, emerging from different departments, without any overarching strategy for promoting the growth of HSEs in particular regions. These initiatives have generally taken two forms. The first have attempted to build local or regional networks, but generally have had no specific focus on specific sectors or the highest skilled workers. Among these are:

- Training and Enterprise Councils (Local Enterprise Councils in Scotland) -- are charged with building the local skill base, but have, to date, predominantly concentrated on training the unemployed
- Business Links – provides a coordinating mechanism, or "one stop shops," for a bundle of services to small and medium-sized businesses
- Chambers of Commerce – groups of local employers that are often, but not always involved in Business Links and/or TECs

The second set of programs have been national or European efforts at cooperative research:

- The Alvey Program – which fostered collaborative research efforts, but has now largely given way to European cooperative research programs such as ESPRIT and EUREKA
- The Foresight Process – that brought industry leaders and academics together to identify key priorities for future research

Despite the benefits of some of these efforts, the consensus of research on UK's high-skill sectors suggests that weak links between academia and industry and inter-firm networks continues to slow the growth of HSEs (Temple, 1998; Zucker and Darby, 1996; Soskice, 1993).

As indicated at the outset, the UK's capacity to generate HSEs may have been further undermined in the last two decades due to the changes in the research environment. While all of the six largest advanced industrial economies have experienced a sharp increase in the R&D intensity of manufacturing, the UK's relative position has declined, from the second most R&D intensive in 1973, behind the US, to the fifth most R&D-intensive in 1991, falling behind Japan, France and Germany (Temple, 1998).[8] Britain was also the only one of the major OECD nations to have reduced government spending on research in the early 1990s (Sharp and Walker, 1994). The shift within higher education resources from research toward broadening student participation has further weakened the attractiveness of British universities for leading researchers.

VIII. POLICY IMPLICATIONS FOR THE UK

[8] As measured by business R&D spending as a % of total manufacturing value added.

Given the vital role HSEs can play in wealth and job creation and Britain's still strong, if somewhat diminished, research base, there is a clear case for taking policy steps to fill those gaps that may be hindering the growth of HSEs. In attempting to foster HSEs, it is crucial to recognize that the same policies and preconditions that have worked in California cannot be transferred directly to the UK (Finegold et al., 1993). Instead, the policy options outlined below attempt to adapt the more generic lessons from the US to the UK's distinctive institutional and cultural context.

Increase Funding for Basic Research and Pre-Venture Capital

The state has a vital role to play in stimulating HSEs through its funding of research in science and technology. Individual private firms are unwilling, by themselves, to fund basic research at societally optimal levels because of its high risk and public good characteristics. Yet basic research not only generates the innovations that provide the catalyst for new industries, but this research also provides a learning process for highly trained manpower to staff these new industries. When cooperative mechanisms exist for the state and firms to join together to share the costs of this investment, however, the entire industry can benefit. The U.S. semiconductor industry recognized this with the formation of Sematech in 1987 and the more recent launch of a 10-year, $600 million cooperative research program between leading chipmakers, the US Department of Defense and 14 leading research universities to develop the next generation of semiconductor technology (Kehoe, 1998). The Labour Government appears to have recognized the need for renewed investments in Britain's science and technology base, substantially increasing state research funding in its 1998 budget, but more could be done to build true cooperative research partnerships with industry and education.

If Britain is to keep the talented individuals and the innovations generated by this research support, then a vital hole needs to be filled at the next stage of funding for new technologies. The state could establish a pre-venture capital investment fund, chartered to provide seed money to promising new technology innovations that emerge from British universities until they have reached the stage where they have a revenue stream or clearly demonstrated product. This fund could be under private management and invite financial participation from large pension funds and other institutions that are in a position to make high risk, high potential return investments. Like any venture capital fund, it would not be providing grants to these new ventures, but rather investments in exchange for an ownership stake that would be cashed out when a firm goes public or sells out to a larger enterprise. While many of the start-ups would fail to reach this stage, the high payoff to those that do can produce a good return on investment. In this way, the initial state funding should be more than self-sustaining, with profits reinvested in new enterprises. Private venture capital or pre-venture funds would, of course, still be free to compete to fund these new enterprises.

Expand the Supply of Entrepreneurial Skills

There are clear differences among individuals and across cultures in the extent to which talented people have the desire, motivation and capabilities to be a successful entrepreneur. The supply of entrepreneurial skills, however, is not something policymakers have to take as given. There are clear ways in which the government and educational institutions can expand the potential supply of high-tech entrepreneurs:

- *Offer more courses on how to start new businesses to scientists and engineers*. Many of the lessons associated with creating a successful start-up firm are generic and providing training on them can help prospective entrepreneurs save time and avoid costly mistakes. Courses of this type are among the most popular offerings in both Stanford's business and engineering schools. These courses are typically taught in an inter-disciplinary manner, bringing real-world industrialists or small business experts to co-teach with leading technical experts

- *Expand the numbers of foreign students and highly skilled immigrant professionals*. Thanks to the legacy of the British empire, the UK has very strong historical ties with countries like India, Hong Kong and Singapore that contain some of the worlds' greatest supply of engineering and entrepreneurial skills. There is sometimes concern expressed that these highly skilled immigrants are taking the university place or job of native students or that encouraging them to come the UK is siphoning off the most talented people from these developing economies. The evidence from the US HSEs, however, appears to suggest that such international exchange of talent is a positive sum game, fostering growth in US high-skill regions linked to expanding high-tech regions in the students' countries of origin.

Foster Regional Networks

The analysis of California's computer and healthcare technology clusters along with research on other successful models for high-skill industrial districts in Europe confirms the essential role that forums for cooperation among firms and the other key actors in a region can play in the development of HSEs. These cooperative institutions can perform two vital functions: a formal role is to guide strategy and pool public and private investments for goods – e.g. infrastructure, vocational training, applied research – that have positive externalities for all of the members of the HSE. The more informal role is to facilitate the exchange of knowledge and building of individual networks that increase the rate of innovation within the area. The development of an HSE's collective strategic capacity is becoming all the more important in the context of the growing strength of the European Union, which is providing a growing percentage of public funding for basic research and economic development.

The UK would benefit from the creation of regional institutions that can bring together the wide array of competencies and actors to focus on the commercial development of particular technologies in which UK universities have already established or have the clear potential to develop a leading research position. These networks should be open to enterprises which share a common geography and industry focus, as well as to the array of specialized service providers (venture capital, legal and business advice, export marketing) needed to help commercialize ideas. They should also include education and training providers, not only the research universities, but also the colleges of further education that can provide the wider base of technically-trained manpower needed to help test the feasibility and produce new technologies as they move into more commercial applications. Encouraging sub-groups of employer-led institutions such as the TECs to act as hosts for such networks might help shift the TECs' focus from provision of short, low-skill government-funded training for the unemployed to the generation of both a supply and demand for knowledge workers.

Foster Individual Networks

Strengthening employer associations and other intermediate institutions can play a vital role in building regional infrastructure and positioning Britain to operate more effectively in a European context. But the UK's historically weak record in this area suggests that these form of corporatist policy should not be the sole, or even primary mechanism for fostering more high-skill regions in the UK (Soskice, 1993). Rather, the success of the more market-oriented Silicon Valley model, with which the UK shares many important similarities, suggests a complimentary way forward: an individual-based network model.

The research universities, as we have seen, can play a vital role at the hub of such networks. Among the concrete ways in which they can strengthen the ties between basic research and industry are:

- Establishing academic contracts that make it easier for professors and students to take leave or work part-time in industry. This should be a two-way transfer, with leading high-tech entrepreneurs teaching in science, engineering and business school programs, as well as academics spending more time in industry.
- Expanding the offerings of evening, weekend and distance learning courses to shift from the idea that universities are a place for study once, early in a career toward fostering the real delivery of lifelong learning. Just as important, these courses can strengthen ongoing industry-research links and provide key networking opportunities for the participants and their instructors.
- Developing alumni networks for scientists and engineers in particular disciplines that can foster similar networks as continuing education courses, though typically with a more social, rather than academic focus. As US universities have clearly demonstrated, these networks can also play a vital part in fund-raising, as the strong ongoing ties with the institution encourage entrepreneurs to give back to their universities.
- Creating student competitions for the best new business ideas, where the finalists are judged by leading venture capitalists; less important than whether the specific ideas are turned into successful businesses, are the publicity and excitement such competitions can generate to encourage future entrepreneurs and the contacts that are fostered during these competitions within and between the academic and industrial worlds.

All of these above initiatives are small ways that help reinforce the notion of an interdependent ecosystem for the different participants in the system. As one SV venture capitalist who was judging such a competition at Stanford remarked when asked how she could spare so much time to come back to university (Aley, 1997): "I love this. It's all part of a great food chain."

Even if Britain is able to replicate the success of Califonia's HSEs, it will not fully solve the low-skill equilibrium problem. While such HSEs generate numerous high-paying service sector and technician-level jobs, they have also contributed to the general U.S. trend of widening income inequality between college graduates and those with only a high school education. The policy solutions to this problem is not to curtail the HSEs, but rather to redistribute some of the wealth they generate to create living-wage jobs for lower skilled individuals in both public and private service sectors that are in sheltered sectors (see Crouch, Finegold and Sako, 1999 for more details on employment policy options).

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Table 1

OECD EDUCATION PARTICIPATION RATES (SELECTED COUNTRIES (1995)

	AGE 17	AGE 18			AGE 19		
Site	Secondary Education	Secondary Education	Non-University Tertiary Education	University-Level Education	Secondary Education	Non-University Tertiary Education	University-Level Education
NORTH AMERICA							
Canada	69	34	11	17	10	17	25
United States	75	22	14	19	4	17	21
PACIFIC AREA							
Australia	77	32	10	24	20	10	24
Japan	94	2	---	---	1	---	---
Korea	90	23	13	18	3	16	23
New Zealand	74	33	6	18	17	7	24
EUROPEAN UNION							
Austria	88	56	1	6	22	2	12
Belgium	99	54	14	19	31	23	21
Denmark	82	71	---	---	52	---	3
Finland	90	80	1	---	28	4	10
France	91	60	---	---	34	---	---
Germany	93	82	2	1	57	3	6
Greece	56	14	12	22	6	10	29
Ireland	74	46	---	27	12	---	35
Italy	---	---	---	---	---	---	---
Luxembourg	78	70	---	---	54	---	---
Netherlands	91	69	---	13	47	---	23
Portugal	71	45	2	8	27	4	13
Spain	75	43	---	19	26	1	26
Sweden	96	87	---	1	24	---	11
United Kingdom	73	31	4	18	15	6	24

Source: OECD, *Education at a Glance*, 1997.

Table 2

California's Largest Manufacturing Employers

SECTORS	1983	1990	1997
Manufacturing Total	1,927,000	2,068,800	1,913,800
▪ **Durable Goods**	1,312,100	1,357,700	1,186,200
▪ **Non-Durable Goods**	614,800	711,000	727,600
▪ **Computer & Office Equipment**	108,700	100,800	94,100
▪ **Electronic Components**	138,100	138,900	149,400
▪ **Aircraft & Parts**	131,800	162,300	84,300
▪ **Preserved Fruits & Vegetables**	51,400	52,900	45,800
▪ **Women's & Misses Outerwear**	62,400	88,800	107,900
▪ **Commercial Printing**	50,100	62,800	60,600
HEALTHCARE RELATED			
▪ **Measuring & Control Devices**	47,000	69,500	66,700
▪ **Other Instruments & Related**	55,500	52,200	53,100
▪ **Drugs**	19,300	22,900	29,300
TOTAL HEALTHCARE RELATED:	121,800	144,600	149,100
All Heathcare Technology	---	---	209,980 *

Source: California Employment Development Department, web page, 1998
*Includes: Researchers in non-profit institutions and estimate of healthcare-related sales and distribution workers (California Healthcare Institute, 1998)

Table 3
California's High Tech Workforce:
Country of Birth
(1990 Census)

	% Foreign	% US
All Manufacturing	30.4	69.6
High Tech Industries	27.5	72.5
▪ Managers	16.7	83.3
▪ Engineers	31.9	68.1
▪ Scientists	25.9	74.1
▪ Technicians	28.8	71.2
▪ Skilled Craft	45.0	55.0
▪ Operators	54.5	45.5

Source: 1990 Census

Table 4
HUMAN RESOURCE PRACTICES AND PROCESSES

A. During the past year, approximately how many days (half days can also be included) have you spent participating in the following?

B. USEFULNESS: How useful has it been to you in developing skills and knowledge that help you contribute to achieving the company's objectives?
(1 = Not Useful, 2 = Somewhat Useful, 3 = Useful, 4 = Very Useful)

	ALL COMPANIES (AVG 5 C0S)	
DEVELOPMENT ACTIVITIES AND USEFULNESS	A. AVG. DAYS	B. USEFULNESS (MEAN)
• **Attending formal courses and programs**	**8.5**	**2.94**
• **Participating in company seminars, conferences and learning networks**	**4.6**	**2.75**
• **Participating in external conferences and learning networks**	**1.8**	**2.81**
• **Structured on-the-job training**	**3.6**	**2.83**
• **Special assignments (e.g., participation on task teams)**	**9.2**	**2.73**
• **Visiting with customers, suppliers, and partner companies**	**9.9**	**3.17**

Source: Center for Effective Organizations study of "Technical Excellence," publications forthcoming.