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Bharat Trehan — Predicting Contemporaneous Output

Brian A. Cromwell — Does California Drive the West? An Econometric Investigation of Regional Spillovers

Carolyn Sherwood-Call — Changing Geographical Patterns of Electronic Components Activity

Changing Geographical Patterns of Electronic Components Activity

Carolyn Sherwood-Call

Economist, Federal Reserve Bank of San Francisco.

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Some observers have argued that high technology industries are leaving early technology centers, such as Silicon Valley, for lower-cost locations. These assertions are consistent with a world in which early innovations tend to be concentrated geographically, but proximity to the innovating region becomes less important than other costs as the product's market grows and standardized production technologies are developed.

This study finds little evidence of such patterns in electronic components activity within the U.S. In contrast, the U.S. share of the total worldwide electronics market has fallen dramatically, while nations with lower costs and less developed technological infrastructures are gaining market share.

During the 1980s, some observers argued that high technology industries were leaving early technology centers, such as Silicon Valley, for lower-cost locations in the U.S. and abroad (see, for example, Saxenian 1984). These assertions are consistent with the views of some economists, who believe that the factors affecting firms' location decisions may vary during the course of a product's life cycle (Vernon 1966). In this view, innovation in a particular industry tends to be concentrated in a region that offers access to technological expertise, even if the general level of costs in that region is relatively high. As the market for the new product grows and standardized production technologies are developed, proximity to the innovating region becomes less important, freeing firms to seek lower land and labor costs elsewhere. Thus, according to this theory, infant industries may be concentrated in high cost regions, while mature industries are more likely to be located where production costs are low.

Previous studies addressing similar issues (Malecki 1985, Park and Lewis 1991) found that geographical dispersion did not occur within the technology-oriented industries they studied. However, these results are not necessarily inconsistent with Vernon's hypothesis. First, they looked only at changes within the U.S. Vernon's paper, in contrast, discussed these changes in an international context, and the forces suggested by his theory may be more readily apparent by making international comparisons.

Second, they looked for "dispersion," defined as an even distribution of activity across all geographic areas. However, a search for low-cost production sites would not result in an even distribution of production across localities if production moved *en masse* to a region that offered lower land and labor costs. Thus, the level of geographic concentration in the industry could remain constant, even if the location of that concentration were to change. In addition, the geographic areas used for previous studies (census regions and states) may be too large to capture some of the changes that do occur.

An alternative explanation for the empirical studies' results is that the product life cycle theory may not hold for high-tech industries. One possible reason is that the pace of innovation has been so rapid that many products have lifespans of only a few years. In this dynamic environment, the investments in standardized production technology that allow production to move away from the innovation site may never be economically feasible. Moreover, the frequent changes mean that an "industry" as defined by data classifications does not describe a single homogeneous product, but instead includes a series of several distinct products, which substitute for each other over time.

This study examines the issues raised by Vernon's theory in the context of the electronic components industry. The paper is organized as follows. The first section discusses the factors that could cause firms' location decision parameters to change over the course of a product's life cycle. Section II addresses whether the changes described by the product life cycle theory have occurred internationally. Section III addresses the same question within the U.S., using more detailed U.S. data and defining the questions somewhat differently from previous U.S. studies. Section IV draws conclusions.

I. The Product Life Cycle

Vernon (1966) provided a rationale for why firms' location decisions might change during the course of a product's life cycle. Like many stage theories, the stages themselves are somewhat arbitrary, and the events of one stage do not provide a compelling explanation of why events ought to progress to the next stage. Nevertheless, its major points are both plausible and consistent with popular notions of the changes that have occurred in high technology industries. Moreover, it provides a convenient framework for a more general discussion of the changes in the industry's structure.

Initially, production might be concentrated geographically simply because each innovation must take place somewhere. However, some regions are more likely to be seedbeds for innovations than others, since a critical mass of related activity can yield external economies of scale that make each input more productive. For example, a region with a cluster of related activities is likely to have the business service and financial infrastructure in place to serve firms with similar needs. Moreover, workers with appropriate skills are likely to be more plentiful in such a location, and if these skills are relatively unusual in the general population, the location will be particularly appealing to firms. For innovations in which work force characteristics and local infrastructure are critical, proximity to these factors is likely to outweigh other considerations in firms' location decisions at the innovation stage. Therefore, during the innovation stage a cluster of activity could occur even in a location where the general level of costs is high.

After the initial innovation comes a transition stage, in which increased demand for the product makes investment in production technology feasible and the technology of production can be transferred from one location to another. At this point, firms are not tied to the site of the original innovation as closely as they were in the first stage. Nevertheless, the continued need for technological expertise as the production process is refined may lead the firm to confine its site search to a smaller region than it might otherwise explore. Thus, in this second stage, the industry may spread out somewhat from its initial concentration of activity.

The third and final stage of the product life cycle is standardization. In principle, standardization occurs when technological innovations are complete, so the research activities that previously were concentrated in the innovating region are no longer necessary. In practice, some technological inputs may be required even when production is relatively standardized, but in any case, site location decisions should be based primarily on the costs of inputs to a standardized production process. Most interregional cost differences would be expected to result from differences in land and labor costs.

If patterns in the electronic components industry were consistent with the product life cycle theory, and if the initial activity were concentrated in high-cost areas, activity should have left the regions where early innovations took place, and current activity should be most prevalent in areas that offer low levels of production costs for the industry. Wages and other direct costs should have become more important locational determinants over time, while attributes associated with technological expertise should have become less important. These trends should have been especially prevalent in the line production activities, which would require relatively little technological expertise if they were standardized. Moreover, if the product life cycle theory accurately describes changes in the electronic components industry, research and production activities should have become less closely linked to each other over time.

In some ways, these kinds of changes seem plausible for the high-tech industries in general and for the electronic components industry in particular. Personal computers, an important end use for many electronic components, provides an obvious example of a growing market for components during the 1977 to 1987 period.

II. International Comparisons

Table 1 presents various measures of production and costs for the electronics industries in several important producing countries, along with measures of technological sophistication for those countries.[1] The table suggests that, in 1988, the U.S. dominated the world's electronics industry by most measures. The U.S. made 38 percent of the world's electronic products. Japan and the European Community (EC) also contributed significantly to world production, with shares of 26 and 24 percent, respectively. Thus, these three entities accounted for 88 percent of total worldwide electronics production in 1988. Other producers, including India, Taiwan, Singapore, Brazil, and South Korea, together accounted for only 6.4 percent of the world's electronics production.

The U.S. outranks other producing countries by most measures of technological sophistication. The U.S. holds commanding leads in terms of the number of telephones per capita and the number of scientists and engineers. The U.S. also ranks second (to Japan) in the number of scientists and engineers relative to total population.

Gross domestic product (GDP) per capita provides a rough measure of the differences across countries in the cost of doing business. Relatively high GDP per capita reflects the high labor costs in those countries and also suggests that the level of investment in both human and physical capital is sufficient to generate relatively high returns to land and other factors. By this measure, the U.S. ranked second, at $18,393, with only Japan ($19,448) posting a higher GDP per capita. Both the U.S. and Japan have significantly higher GDP per capita than the EC's $13,137, and none of the other producing countries listed in Table 1 has GDP per capita that reaches even half of the U.S. or Japan levels.

There are signs, however, that the U.S. domination of the industry may be waning. The growth rate in U.S. production between 1984 and 1988 was only 1 percent, by

[1] "Electronics" is defined here to include electronic materials and components, software, computers, telecommunications equipment, business equipment (copiers, fax machines, and so forth), and instruments.

Table 1
Electronics Sectors in Selected Countries

	U.S.	Japan	EC[a]	S. Korea	Taiwan	Singapore	Brazil	India	World
Value of Electronics Production ($M, 1988)	186,232	127,208	115,136	9,103	7,890	7,651	3,876	2,314	486,718
% of World Total (1988)	38.3	26.1	23.7	1.9	1.6	1.6	0.8	0.5	100
% of World Total (1984)	43.0	22.5	21.9	0.9	1.1	0.8	0.6	0.2	100
Real Annual Growth Rate (%, 1984-88)	1	8	6	24	15	23	11	23	4
Production/GDP (%, 1987)	3.9	4.6	2.6	6.0	10.0	28.6	1.0	1.7	N/A
Production ($000)/Employment	104.9	105.9	79.2	35.8	40.7	107.8	15.1	11.6	N/A
Total Electronics Employment (000, 1986)	1776	1201	1454	254	194	71	257	200	N/A
Annual Growth Rate (%, 1980-86)	1.3	9.6	1.5	9.8	2.6	−0.2	N/A	N/A	N/A
General Technology Characteristics									
Telephones/1000 Pop. (1986)	791	558	520	186	228	417	84	4	N/A
Scientists & Engineers (000, 1986)	787	575	468	47	42	2	33	100	N/A
Scientists & Engineers/Million Pop.	3,230	4,712	1,443	1,116	2,149	923	230	128	N/A
GDP per Capita ($, 1987)	18,393	19,448	13,137	2,881	3,794	7,654	2,304	326	N/A

Note: "Electronics" is defined here to include electronic materials and components, software, computers, telecommunications equipment, business equipment (copiers, facsimile machines, and so on), and instruments.
[a] EC data exclude Portugal and Greece.

far the slowest growth among the group of countries included in Table 1. Electronics industry growth rates in countries that offer much lower costs were all in double digits—stronger growth than in the countries that dominated worldwide production in 1988. In addition, according to the Semiconductor Industry Association (SIA), the share of U.S. company production in total world semiconductor production fell fairly steadily, from 65 percent in 1977, to 60 percent in 1982, 45 percent in 1987, and 38 percent in 1988 (SIA 1990), before picking up slightly to 40 percent in 1990.[2] It is likely that these numbers understate the movement of semiconductor production outside of the U.S., since U.S.-based companies have moved their own production offshore even as foreign companies have increased their production.

Thus, in some ways, the industry's patterns appear to be consistent with the product life cycle hypothesis. The U.S., a technology-oriented, high-cost country, dominated the industry in its early days, suggesting that the U.S. was the site of early innovations. Between 1984 and 1988, the electronics industry grew fastest in the countries that offered lower production costs. This change is consistent with the industry moving toward the standardization stage, with firms seeking locations that offer lower costs.

Another characteristic that is broadly consistent with the product life cycle theory is that, within the electronics industry, the product mix varies substantially across countries. Korea, for example, specializes in computer assembly, while Japan's electronics industry is dominated by semiconductor fabrication. Differences in product mix and capital intensity are reflected in wide variations in the value of production per worker across countries. In the U.S., Japan, and Singapore, the average value of production per worker is $100,000. In sharp contrast, the value per worker is $40,000 or less in India, Brazil, Taiwan, and South Korea.

Nevertheless, it is worth noting that the U.S. does retain the world lead in some segments of the electronics industry. U.S. producers dominate world production in highly profitable areas, such as processors that are vital to the calculating, graphics, and sound functions in computers. Japanese producers, in contrast, dominate the less profitable market for standard memory chips (Pollack 1992).

In a similar vein, Saxenian (1990) suggests that during the middle and late 1980s, Silicon Valley spawned a new generation of flexible, interconnected firms that specialize in particular aspects of technological development or production. These firms do not attempt to make high-volume commodity chips (as Intel and Advance Micro Devices had in an earlier generation), but instead seek out small, specialized niches in which they can take advantage of their technological expertise and flexibility.

The view that U.S. producers continue to play an important role in the high-tech industries, but not in mass-produced commodity products, also is supported by the pattern of employment growth within the U.S. Between 1977 and 1987, the number of electronic components workers in nonproduction functions (including research and development, headquarters functions, and marketing) grew 88 percent. During the same period, the number of production workers grew by a relatively modest 28 percent. These figures are consistent with a change in the U.S. industry away from mass production and toward custom products with smaller markets.

The overall picture that emerges is one of a very heterogeneous industry, in which different countries have tended to specialize in different functions, and there is still a role for U.S. producers, although that role is different from its role in the past. The product life cycle theory is not strictly applicable to a group of products as heterogeneous as this one. The continued role of U.S.-based firms in developing and implementing the new technologies, and the dominance of the U.S., the EC, and Japan in total worldwide production, suggests that the product life cycle story does not fully capture the dynamics of the electronic components industry. At the same time, though, the rapid growth in assembly activity in Taiwan and South Korea is consistent with the product life cycle theory's assertion that standardization allows production activities to move to regions that offer relatively low costs, even though their technological infrastructures are less well developed.

III. The Electronic Components Industry in the U.S.

Malecki (1985) and Park and Lewis (1991) examined whether the kinds of geographic changes predicted by the product life cycle theory are at work in high technology industries within the U.S. Malecki found that there was little dispersal across four census regions between 1973 and 1983 in the four 4-digit Standard Industrial Classification (SIC) categories he examined.[3] Park and Lewis conducted shift-share analysis using state-level data for three of Malecki's four 4-digit industries, with mixed results.

[2]Note that semiconductors are just one type of electronic component. Semiconductors are a subset of the electronic components category measured by SIC 367.

[3]Those four industries were Electronic Computing Equipment (SIC 3573), Semiconductors (SIC 3674), Medical and Surgical Instruments (SIC 3841), and Computer Programming (SIC 7372).

They concluded that their results did not support the product life cycle model.

Glasmeier (1986) disaggregated employment in 2-digit SIC categories by occupation.[4] She found that the technical and professional jobs were concentrated geographically, but that many of the locations of these concentrations had relatively few production workers in the same industry groups. This supports the product life cycle contention that production and nonproduction activities tend to become more separate as the product's life cycle progresses, although the continued existence of a large cadre of nonproduction workers suggests that production was not yet fully standardized at the end of her sample period.

This section addresses these issues using Census of Manufactures data for the 3-digit SIC industry of electronic components (367). (See Box for a description of the data.) The present study differs from previous work in that it explores the question at the metropolitan area level rather than at the level of the state (Park and Lewis, Glasmeier) or census region (Malecki).

Characteristics of Innovating Regions

Table 2 presents information on various characteristics of the ten Metropolitan Statistical Areas (MSAs) that

[4]These industries are Chemicals (SIC 28), Nonelectrical Machinery (SIC 35), Electrical Machinery (SIC 36), Transportation Equipment (SIC 37), and Scientific Instruments (SIC 38).

Box 1
Census of Manufactures Data

The manufacturing data in this study come from the Census of Manufactures, produced by the U.S. Commerce Department. The Census of Manufactures provides metropolitan area data on such variables as the number of production and nonproduction workers, work hours, and payroll costs. The Standard Industrial Classification (SIC) used for this study is electronic components (SIC 367), which includes electron tubes, printed circuit boards, semiconductors and related devices, and electronic capacitors, resistors, coils, transformers, and connectors. It does not include finished technology products such as computers or scientific instruments.

The number of Metropolitan Statistical Areas (MSAs) for which complete data are available varies among the sample years. Data are withheld for MSAs with only a small number of employers in SIC 367, and for MSAs in which a single employer dominated that MSA's industry. The data set includes 44 MSAs for 1977 and 68 MSAs for 1987.

The MSAs for which complete data are reported leave much of the U.S. employment in the industry unaccounted for. For example, the 44 MSAs for which 1977 data are available account for only 49 percent of U.S. employment in SIC 367. For 1987, the sample size rises closer to 60 percent, but clearly a large portion of the industry remains unreported. This large unreported portion of the industry could potentially affect the empirical results, if many of the industry's changes are occurring outside MSAs or in MSAs that do not report complete data for SIC 367.

One problem with using SIC 367 is that the characteristics of the products classified in this 3-digit SIC category have changed over time. Between 1977 and 1987, the share of semiconductors in the total rose from 30.5 percent to 33.8 percent. The share of electronic connectors also rose, and printed circuit boards were added as a separate category in 1987. (Prior to 1987, printed circuit boards were included in "Electronic Components, not elsewhere classified.") During the ten-year period, electronic capacitors, resistors, and tubes became significantly less important to the entire industry. While going to the 4-digit industry level would alleviate many of the problems associated with changes in the composition of SIC 367, too few MSAs report 4-digit data to allow a meaningful analysis.

Another potential problem with these data is that the manufacturing census is conducted by establishment, and an establishment is considered to be in SIC 367 only if production occurs on the site. Therefore, an establishment engaged only in research and development, sales, administration, or other "auxiliary" functions would not be included in the totals for SIC 367, even if the firm produces nothing but electronic components. This means that the data regarding production activities are likely to be more accurate than the data for nonproduction activities, although the extent of the problem with nonproduction data is impossible to determine.

Table 2

Characteristics of Regions Producing Electronic Components, 1977

MSA	Percent of U.S. Employment: SIC 367 All	SIC 367 Production	SIC 367 Nonprod'n	Total	Per Capita Personal Income ($)	Production Worker Wage ($/Hour)	Nonprod'n Worker Salary ($/Year)	High School Graduates[a] (%)	4+ Years of College[a] (%)
San Jose, CA	10.1	8.1	14.4	0.7	8,865	5.41	19,850	79.5	26.4
Chicago, IL	5.4	5.7	4.8	3.7	8,885	4.63	15,855	67.5	18.5
Los Angeles/Long Beach, CA	5.2	5.7	4.2	3.9	8,473	4.78	19,163	69.8	18.5
Phoenix, AZ	4.1	3.0	6.6	0.6	7,059	5.02	14,053	75.0	18.3
Dallas/Fort Worth, TX	3.7	3.8	3.7	1.4	7,878	5.49	15,233	70.0	20.2
Boston, MA	3.4	3.3	3.5	1.6	7,984	4.86	17,463	77.2	24.7
Anaheim/Santa Ana, CA	3.3	3.4	3.3	0.8	8,968	4.61	19,711	80.4	22.6
Nassau, NY	2.0	2.0	2.1	1.0	8,870	4.81	17,167	75.8	20.9
New York, NY	1.9	2.0	1.6	4.4	8,643	4.61	16,526	63.5	19.2
Philadelphia, PA	1.8	2.0	1.4	2.2	7,844	4.97	17,125	66.0	13.6
Ten MSAs	41.1	39.0	45.7	20.3	8,426	4.97	17,640	72.5	20.3
U.S.	100	100	100	100	7,297	4.83	18,158	68.6	17.0

[a]Education data are for 1980.

accounted for the largest shares of U.S. electronic components employment in 1977. Together, the top ten areas accounted for 41 percent of electronic components employment. By way of comparison, these ten MSAs accounted for about 20 percent of the nation's total employment across all industries.

Of these ten MSAs, eight (San Jose, Chicago, Los Angeles/Long Beach, Phoenix, Dallas/Fort Worth, Boston, Anaheim, and Nassau) are much more strongly represented in the electronic components industry than their sizes would suggest. In contrast, New York and Philadelphia are large metropolitan areas whose contributions to the electronic components industry derive primarily from their large sizes. Their contributions to electronic components employment actually are smaller than their contributions to total employment.

These ten areas accounted for a significantly larger share of the nation's nonproduction workers in the electronic components industry than their share of production workers. They contained 46 percent of the nation's nonproduction workers in the electronic components industry, but only 39 percent of national production workers. The greater concentration among nonproduction workers than among production workers is due to sharp differences in only two MSAs: San Jose and Phoenix. The other important electronic components producing areas were either proportionately represented by production and nonproduction workers, or were relatively over-represented by production workers.

One of the most striking observations from this table is that San Jose clearly dominated the industry. The San Jose area, which accounted for only 0.7 percent of the nation's total jobs in 1977, provided fully 11 percent of the nation's electronic components employment. Moreover, the San Jose MSA had more than twice as many electronic components jobs as Chicago, which ranked second. San Jose's share of the industry's nonproduction jobs was even greater, at over 14 percent. These jobs, which cover functions other than line production, include research and development, sales, and headquarters functions. Thus, nonproduction jobs are more likely to require advanced education and technological training.

In most respects, the characteristics of the San Jose area during the late 1970s were those that tend to be associated with technological innovations. Stanford University, with one of the nation's top electrical engineering programs, is located in the area. The University of California at Berkeley, with another top-rated electrical engineering program, is only about 50 miles away. Moreover, the San Jose area boasts a highly educated population. Of residents over 25 years old, 80 percent had high school diplomas and 26 percent had at least 4 years of college in 1980—much higher proportions than the nation, where the figures among the same age group were 69 percent and 17 percent, respectively.

The San Jose area had high costs by any measure. The average hourly wage for production workers in the electronic components industry was $5.41 in San Jose, compared with $4.83 nationally. The average annual salary for a nonproduction worker in San Jose was $19,850, much higher than the $18,158 national average. Per capita personal income, a more general measure of the level of incomes (and presumably costs) in an area, also was relatively high in the San Jose area, at $8,865 compared to a national average of $7,297. Housing prices are not listed in the table, but home prices also were relatively high in the San Jose area. 1980 Census data, for example, revealed that the median monthly mortgage payment for an owner-occupied dwelling was $475 in San Jose, much higher than the $365 national median. Rents in San Jose also were much higher than the national average, with a median monthly rental payment of $365, compared with the U.S. median of $243.

Venture capital, an important source of funding for high-tech start-up companies, also was more readily available in the San Jose area than in many other parts of the country. While the New York/New Jersey/Connecticut area clearly dominates the venture capital field with over a third of the 100 biggest funds in 1986, Northern California had 20 funds on the list, followed by the Boston area with 15 ("Venture Capital 100 for 1986"). In fact, 73 of the 100 largest funds were located in these three areas alone, with the remainder scattered throughout the rest of the United States.

The overall picture of the San Jose area that emerges is one of a quintessential innovating region. It clearly dominated the industry early on, particularly in the nonproduction areas that require highly educated, technical personnel. The area was near universities with first-rate electrical engineering programs, and had a highly educated population and relatively good access to venture capital. Moreover, the high level of costs in the area, both generally and in terms of labor for the electronic components industry, suggests that if the industry were moving toward standardization during the late 1970s and early 1980s, firms would have had an incentive to move their operations to lower-cost regions.

Most of the other areas listed in Table 2 had some of the characteristics of an innovating region. In particular, nine out of ten had a higher percentage of college graduates than the nation, and seven out of ten had a higher percentage of high school graduates. But the characteristics of the other MSAs are not as striking as those of San Jose. For example, in or adjacent to each of these metropolitan areas there is at least one university with an electrical engineering program. However, the only top-20 programs in areas producing electronic components are in San Jose (Stanford), Los Angeles/Long Beach (UCLA, USC, and Cal Tech), and Boston (MIT).[5] Nevertheless, most of the others have top-ranked electrical engineering departments within a few hours' drive. Anaheim is adjacent to the Los Angeles area and its universities. Princeton is within 50 miles of both Philadelphia and New York. Similarly, Purdue and the University of Illinois at Urbana-Champaign, both top-ranked departments, are within 150 miles of Chicago. Dallas/Fort Worth is almost 200 miles from the University of Texas at Austin. Among the most important metropolitan areas for producing electronic components, only Phoenix does not have a top-ranked electrical engineering department within a few hundred miles.[6]

If there were an incentive to shift activity to lower-cost regions since 1977, costs in these cities would be expected to have been relatively high. Table 2 shows that, for these ten cities as a group, labor costs in the electronic components industry were only slightly higher than the national average. Indeed, the average annual salary for nonproduction electronic component workers actually was *lower* for these cities than it was nationally. San Jose is the only metropolitan area in this group with both production wages and nonproduction salaries higher than the national average. In contrast, personal income per capita, a more general measure of the MSA's level of costs, was substantially higher in these areas than it was nationally. Taken together, these figures suggest that, even if production and nonproduction activities became less closely linked over

[5]According to the author's calculations based on information provided by the Conference Board of Associated Research Councils (1982), the top twenty electrical engineering programs were: MIT (Cambridge, MA), Stanford (Stanford, CA), Illinois (Urbana/Champaign, IL), California (Berkeley, CA), UCLA (Los Angeles, CA), USC (Los Angeles, CA), Purdue (West Lafayette, IN), Maryland (College Park, MD), Cornell (Ithaca, NY), Carnegie-Mellon (Pittsburgh, PA), Ohio State (Columbus, OH), Michigan (Ann Arbor, MI), Wisconsin (Madison, WI), Texas (Austin, TX), Rensselaer (Albany, NY), Princeton (Princeton, NJ), Cal Tech (Pasadena, CA), Florida (Gainesville, FL), UCSD (San Diego, CA), and UCSB (Santa Barbara, CA).

[6]The University of Arizona, in Tucson, is 34th of the 91 ranked electrical engineering departments; Arizona State in Tempe (a Phoenix suburb) ranks 57th.

time, as the product life cycle theory suggests, the potential cost savings from shifting electronic components activity elsewhere may be relatively modest, except in the San Jose area.

Around the late 1970s and early 1980s, the personal computer became an important fixture in offices and universities. With the huge growth in the industry, demand for components increased enormously. Given these changes in the industry, the characteristics of the regions that were important producers of electronic components in 1977, and the discussion of the changes that occur over a product's life cycle, we would expect to see a significant reduction in the importance of the San Jose area over time. In contrast, we would expect to see much less dramatic changes in the patterns among the other technology-oriented areas listed in Table 2.

Changes within the U.S.

To see whether such changes have in fact occurred, Table 3 provides similar data for the ten most important areas in the industry in 1987.[7] Contrary to expectations based on the product life cycle theory, San Jose's share of national employment in the electronic components industry *rose* from 10.1 percent in 1977 to 11.5 percent in 1987. Moreover, San Jose became more dominant in both the production and nonproduction parts of the industry. The San Jose area accounted for 14.4 percent of the nation's nonproduction workers in 1977 and 15.4 percent in 1987; the area's share of total production workers rose from 8.1 percent to 9.0 percent during the same period.

Changes among the other producing cities also were modest. One change is that the composition of the list

[7]Since educational attainment data were available for only one year, the figures in Table 4 are identical to those in Table 2.

Table 3
Characteristics of Regions Producing Electronic Components, 1987

MSA	Percent of U.S. Employment: SIC 367 All	SIC 367 Production	SIC 367 Nonprod'n	Total	Per Capita Personal Income ($)	Production Worker Wage ($/Hour)	Nonprod'n Worker Salary ($/Year)	High School Graduates[a] (%)	4+ Years of College[a] (%)
San Jose, CA	11.5	9.0	15.4	0.8	21,547	11.60	38,701	79.5	26.4
Los Angeles/Long Beach, CA	5.1	5.8	4.0	3.9	17,680	9.39	32,535	69.8	18.5
Phoenix, AZ	4.1	3.4	5.1	0.9	16,064	8.36	32,090	75.0	18.3
Anaheim/Santa Ana, CA	3.7	4.0	3.3	1.1	21,405	9.72	34,458	80.4	22.6
Boston, MA	3.5	3.4	3.6	1.7	20,330	9.44	31,936	77.2	24.7
Chicago, IL	3.1	3.6	2.3	3.0	17,662	8.19	30,360	67.5	18.5
Dallas/Fort Worth, TX	2.9	2.8	3.2	1.8	16,998	9.91	39,406	70.0	20.2
Nassau, NY	2.2	2.3	2.1	1.1	22,139	8.82	34,311	75.8	20.9
San Diego, CA	1.8	1.9	1.6	0.8	16,658	8.98	36,114	78.0	20.9
Minneapolis, MN	1.4	1.5	1.1	1.3	18,205	9.20	36,087	79.9	21.9
Ten MSAs	39.3	37.7	41.6	16.3	18,490	9.71	35,585	75.3	21.3
U.S.	100	100	100	100	15,511	9.32	34,751	68.6	17.0

[a]Education data are for 1980.

varies slightly between the two years. In 1987, New York and Philadelphia moved down to ranks 12 and 11, respectively, while San Diego and Minneapolis moved into the top ten. Chicago fell from number 2 to number six, but other changes in rank within the top ten were small.

Taken together, the top ten MSAs accounted for 39 percent of national employment in the electronic components industry in 1987, down from 41 percent in 1977. The ten cities as a group also accounted for a smaller share of nonproduction employment in 1987 (42 percent) than they did in 1977 (46 percent). This change is consistent with the notion that technological expertise might diffuse or become less important as the product progresses through its life cycle. The change in share for production workers, however, was quite small, from 39 to 38 percent. This small change tends to contradict the notion that firms are moving production activities from their early centers to other, lower-cost locations within the United States.

An additional prediction of the product life cycle theory is that production and nonproduction activities become less closely linked over time, as production processes become more standardized. To see whether this pattern has emerged within the U.S., I run simple correlations between each MSA's share of U.S. production and nonproduction employment for each year, using the entire sample of MSAs.[8] If the linkage between the two has become weaker over time, the correlation coefficient would shrink over time.

In 1977, the correlation coefficient between MSAs' shares of national production employment in SIC 367 and their shares of nonproduction employment was quite high, at 0.914. In 1987, the correlation was even higher, at 0.927. These figures suggest that, within the U.S., the linkage between production and nonproduction activities remains strong. This result contradicts the expectations based on the product life cycle theory.

The Census of Manufactures data run only through 1987, and data for SIC 367 are not available for most MSAs for non-census years. However, many MSAs do report intercensal data on SIC 36, electric and electronic equipment, the 2-digit category that includes SIC 367.

For MSAs in which SIC 36 data are available, the shares of the top ten cities remained relatively stable from 1977 to 1987, following the pattern seen in SIC 367 (see Appendix). The share dropped off sharply between 1987 and 1991, from 34.6 percent to 24.6 percent. However, over half of the drop-off in SIC 36 between 1987 and 1990 occurred in Los Angeles, falling from 8.9 percent to 3.5 percent. Since the Bureau of Labor Statistics (BLS) does in fact report 3-digit data for SIC 367 for Los Angeles, we can check to see if the SIC 367 is responsible for the sharp decline in Los Angeles' share of SIC 36 activity. The BLS numbers for SIC 367 reveal a much smaller decline in Los Angeles' share of electronic components employment, from 4.5 percent to 3.9 percent. Thus, the evidence leaves open the possibility that dramatic changes may have occurred in the electronic components industry (SIC 367) since the 1987 manufacturing census, but the changes probably were not as dramatic as the changes in SIC 36 were.

IV. Conclusions

This paper started with the observation that many are concerned about shifts in electronic components activity away from historical centers such as Silicon Valley. Such a shift is consistent with the views of some economists who argue that the factors affecting firms' location decisions may vary during the course of a product's life cycle.

This study analyzed a variety of data at the international and national level. Consistent with previous work by Malecki (1985) and Park and Lewis (1991), the analysis found little evidence to support the contention that the product life cycle theory explains changes in the location of electronic components activity within the U.S. In particular, the San Jose metropolitan area, which includes the Silicon Valley, continues to play a dominant role in the electronic components industry within the United States.

In contrast, an examination of the international data revealed that the U.S. share of the total worldwide electronics market has fallen dramatically, and that nations with lower costs and less developed technological infrastructures are gaining market share. This finding is consistent with expectations based on the product life cycle theory. Nevertheless, the U.S. does continue to play an important role in the industry, suggesting that complete standardization of the industry either has not yet occurred or will never occur in the fast-changing world of high-tech production.

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[8]The sample includes 44 MSAs for 1977, and 68 MSAs for 1987.

Appendix

MSA Employment as a Percentage of National Employment

	SIC	1977	1982	1987	1991
San Jose, CA	367	10.1	11.7	11.5	
	36	3.9	5.8	5.7	5.1
Chicago, IL	367	5.4	4.2	3.1	
	36	7.7	6.2	5.0	4.9
Los Angeles/Long Beach, CA	367	5.2	5.5	5.1	
	367 (BLS)	4.4	4.2	4.5	3.9
	36	7.1	8.2	8.9	3.5
Phoenix, AZ	367	4.1	4.1	4.1	
Dallas/Fort Worth, TX	367	3.7	3.5	2.9	
	36	2.8	3.3	4.2	3.7
Boston, MA	367	3.4	3.5	3.5	
	36	3.0	3.3	3.3	2.2
Anaheim/Santa Ana, CA	367	3.3	3.8	3.7	
	36	2.7	3.1	3.6	2.1
Nassau, NY	367	2.0	2.1	2.2	
New York, NY	367	1.9	1.6	1.0	
	36	2.4	2.0	1.6	1.2
Philadelphia, PA	367	1.8	1.4	1.0	
	36	2.6	2.5	2.3	1.9
10 MSA Average	367	38.3	39.1	36.7	
	36	30.3	32.2	31.4	21.4

Note: Unless noted otherwise, SIC 367 data are from the Census of Manufacturers. SIC 36 data are from the Bureau of Labor Statistics and are not available for Phoenix or Nassau.

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