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Hidden Innovation:
A Reconsideration of an “Old Economy” Industry
in a “New Economy” Region

by

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by Lifang Chiang

Abstract

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Doctor of Philosophy in Geography

University of California, Berkeley

Professor AnnaLee Saxenian, Co-Chair

Professor Harley Shaiken, Co-Chair

The San Francisco Bay Area's independent machine shop sector, comprised of over 500 establishments, has historically served as an important supplier base for a range of the region's Original Equipment Manufacturers (OEMs). Existing analytical dichotomies would categorize the area's machine shops as part of "old economy" manufacturing in contrast to "new economy" knowledge and service-oriented activities. However, machine shops have been critical to the development of contemporary sectors including green technologies and renewable energy; nanotechnology; biotechnology; and information technology. By supporting virtually every other manufacturing industry, local machine shops are embedded as a critical source of "hidden innovation" at the heart of a dynamic regional economy and regional innovation milieu. The existing "old" versus "new" dichotomy is hence rejected in favor of a more inclusive view which recognizes their enduring interdependencies.

Local machine shops face both opportunities and threats to their continued existence. On one hand, firms, employment and business receipts in this sector have been marked by decline and concentration due to a) a “flattening” world of outsourced OEM supply chain practices; b) shops’ increasingly corporatized business practices; c) neighbors’ “Not in My Backyard” perspectives; and d) difficulties in training and recruitment.

On the other hand, local machine shops have adapted by becoming more collaborative with other shops, growing bigger in size, and taking on a more diversified customer base. These adaptive changes are possible due to a) a strong historical and cultural presence ; b) strategies in cooperation, complementarity and learning between shops themselves and with their customers; c) diversification of shops’ customer base, particularly into emerging innovation waves; and d) skill base maintenance via in-house training, conference attendance, networking and college and vocational training programs.

Key stakeholders have sought to raise public policy awareness about the role played by the machining and overall manufacturing sectors as sources of jobs and of wealth generation. Further consideration is needed of machine shops’ essential role as the industrial foundation of the regional economy, to be prioritized and nurtured as a form of "hidden innovation."

Professor AnnaLee Saxenian, Co-Chair:______________________________

Professor Harley Shaiken, Co-Chair: ______________________________

For Jasper and his generation

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CHAPTER ONE: An Introduction

1.1 Statement of Research Problem

Why does a local machine shop sector persist in a highly competitive, advanced regional economy? Consistently touted as the undisputed leader in both high technology and innovation rankings, the San Francisco Bay Area, California region hosts a disproportionate share of high-technology industries and innovative ideas, products and services. These have been variably measured by numbers of patents issued; volume of business employment and receipts; or by more dubious measures of the presence of a broad class of "creative professionals." And yet, what is largely overlooked or little known is that such an innovation milieu is highly interactive with, and arguably reliant upon, a local supplier base of machine shops, operating in an environment of escalating business costs and fierce land competition.

The enduring presence of machining can be traced historically, even as waves of innovation have come and gone. The electronic component and microwave manufacturing sectors emerged in the 1940s and 1950s, which spawned the subsequent military systems and regional industrial infrastructure that developed throughout the 1950s and 1960. This was followed by the burgeoning semiconductor industry beginning in the 1970s; and later the biotechnology and nanotechnology sectors in the 1990s and 2000s.[i] Each of these waves have been squarely dependent on a local machining sector, with their growth generating the demand for the physical presence of even more local machine shop services. In the early twenty first century, clean energy technologies-- solar, wind, water-- are emerging as key R&D and manufacturing activities which also rely on machining suppliers, and which have been touted as promising sources of emerging "green" and "green collar" manufacturing employment. One of the area's largest machine shops noted it comparative advantage in serving this growing sector:

> "With over 50 years experience in precision machining and having served the semiconductor industry since its inception, it is a seamless and natural progression for D&H to serve the solar and other alternative energy industries."[ii]

Despite its parallel historical and contemporary presence, however, the critical role that machining plays in subsequent waves of regional innovation is little understood and known. Hence, through a combination of iterative quantitative and qualitative methods, I seek to answer the following question: *Why does a local machine shop sector persist in a highly competitive, advanced regional economy?* Specifically:

1. What is the Role of Manufacturing in a 'New Economy' Region?
2, What Are the Regional Dynamics of the Machine Shop Sector?
3. Why Are Machine Shops Still Here?

1.2 Dimensions of the Argument

The structure of my investigation is as follows. The intellectual and empirical precedents and contexts to this body of work is outlined in Chapter Two, followed by an introduction of methods in Chapter Three. An analysis of the magnitude and current state of this local sector relative to its presence in other regions, the state and the Nation is presented in Chapter Four, using both quantitative methods of regional economic analysis and qualitative methods to evaluate these regional economic trends. Chapter Five then posits five propositions for the local presence of machine shops, evaluating whether machine shops serve as a form of "hidden innovation" for the region's dynamism. The final chapter six looks back at earlier chapters and evaluates key assumptions, findings and implications, and includes a discussion of policy and planning implications. I conclude with a summary evaluation of whether or not machining constitutes a form of "hidden innovation" within an increasingly services- and information- driven regional economy.

1.3 Assumptions, Implications, and Methodologies

In understanding the role of machine shops within the region's dynamic economy, I seek to establish whether machine shops can be characterized as a source of "hidden innovation" for high technology and emerging clean technology industries and employment. Here, I refer to that innovation which is not captured or recognized by traditional indicators such as research and development (R&D) spending or number of patents, but which nonetheless are critical to the successful development and deployment of advanced technologies. Originally coined in the 1990s, the concept of "hidden innovation" has been used since in the United Kingdom by an independent policy body which identifies four types of hidden innovation:

- Innovation that is the same or similar to activities that are measured by traditional indicators, but which is excluded from measurement.
- Innovation without a major scientific/technological basis, such as innovation in organizational forms or business models.
- Innovation created from the novel combination of existing technologies and processes.
- Locally-developed, small-scale innovations that take place 'under the radar' and are therefore unrecognized or accounted for.[iii]

The study design draws on an iterative mixed approach of quantitative and qualitative research methods. The quantitative research includes describing and modeling the spatial and historical dimensions of machine shop presence as a function of number of firms, firm size, business receipts, employee wages, and sectoral presence relative to that of other regions. Qualitative cases studies of machine shops include intensive, semi-structured interviews with participant observation in machine shops, local trade shows, and manufacturing conferences, and a business inventory of the numbers and types of customers in these shops. These quantitative and qualitative research methods are framed through the theoretical framework of “hidden innovation” and guided through ideal typologies of “family,” “modern,” “start-up” and “captive” machine shops.

Implicit within the theoretical frameworks, ideal typologies, and quantitative analyses described above are the personal accounts and histories of those working with or within the area’s machine shops. Given a multitude of possible challenges involved in investigating and observing an activity as hidden from plain sight as machine shops, I chose to conduct a localized geographical area, the five-county San Francisco Bay Area, focusing most intensively on those two counties, Alameda and Santa Clara, with the largest concentrations of machine shops.

Those machinists willing to speak about their professional experiences and to provide shop tours proved to be a very diverse group, including Don Bardon, a general manager of a long-standing Oakland family-owned machine shop, long active and a past president in the now-defunct local machining trade association; Jeff and Jim Christofferson, a father-son proprietors of a specialized laser-machine shop in Santa Clara; and Max Ho, CEO and president of a San Jose machine shop, who regularly visits his company’s satellite production operation in Southern China. I also got to know Boris Kessel, a Ukranian immigrant who had built two successful firms in Santa Clara after taking out a sizable loan on his house; Steve Riley, a business manager with D&H Manufacturing, one of the largest machine shops, who had come to the company from one of its key suppliers, Applied Materials; and Ed Guerneville, a Bay Area-born, life-long machinist nearing retirement in Santa Clara, who was increasingly turning his attention from the shop he had founded to his avocation of wine-making.

Among OEM customers, I was most successful in conducting interviews through contacts provided by the machine shops and through attendance at trade shows and conferences. Several OEM representatives spoke about their interactions with machine shops, including Darren Kim, a business manager at Echelon Corporation in San Jose; Red Byer, a laser engineer at Mobious Photonics in Mountain View; Eric Romo, a vice president for finance at San Francisco-based GreenVolts; and Renu Malhotra, an engineer with Hasselgren Automotives in Berkeley . I also spoke withDr. Jon Guice, a co-founder of Blue Mountain Engineering in San Francisco; J.B. Tengo, Public Affairs Manager at Akeena Solar in Los Gatos; and two anonymous executives with SunTech America in San Francisco.

1.4 Section Summary

My research interrogates the presence of a local machine shop sector in a highly competitive, advanced regional economy. I investigate the extent to which the region’s innovation milieu is not only highly interactive with, but also critically reliant upon, a local supplier base of machine shops, operating in an environment of escalating business costs and fierce land competition.

Employing the use of iterative methods of quantitative and qualitative analysis, I first describe model the area's machine shop presence as a function of number of firms, firm sizes, business receipts, and employee wages over time. I complement this regional economic analysis with qualitative investigations of machine shop case studies, and with explorations of why the sector has seen decline in the past two decades. Using the theoretical framework of "hidden innovation" and guided through four ideal types of machine shops, I advance four propositions for the continued existence of the sector. The personal accounts and histories of those individuals working with the area's machine shops are key to the iterative mixed methods employed throughout this investigation.

CHAPTER ONE ENDNOTES

[i] Lécuyer, C. (2005) Making Silicon Valley: Innovation and the Growth of High Tech, 1930–1970. Cambridge, MA: MIT Press.

[ii] http://www.dhmfg.com/client/index.html

[iii] http://www.nesta.org.uk/hidden-innovation-report/ Accessed July 14, 2008.

CHAPTER TWO: A Review of the Literature

2.0 Introduction

This chapter will explore the role of ‘old economy’ manufacturing sectors in ‘new economy’ technology regions of advanced industrial economies. In the early 21st century, attention has increasingly shifted away from protectionist concerns about loss of manufacturing industries in regional and national economies. Attention has instead focused on globalization and the offshoring of a wide array of service and technology-oriented industries and jobs, with much of existing literature on the “new economy” building on costs and disagglomeration.

Yet, what is missing in this paradigm shift is an examination of the critical role that manufacturing sectors play in these ‘new economy’ regions, by spurring innovation spillover and generating economic and employment multiplier effects. What is further missing is an understanding of the many new forms of collaboration which go beyond the standard binary debate between markets or vertical integration of firms and business activity. Much of the current literature does not adequately outline the ways in which, within a “free market,” there are always firms actively instituting the market. That is to say, firms are able to achieve what they want around the world through implementing processes of co-design, highlighting the importance of the relationship between design, manufacturing and services.

This chapter will review the literature pertaining to linkages between advanced technology regions and more traditional, blue-collar industrial production industries. I will seek to describe how various industrial clusters are currently shaping and adapting, and how new forms of collaboration are emerging. In conclusion, the chapter calls for broadening the current focus on job loss in the highly skilled service and technology sectors to an integrated vision of production, knowledge and service sector activity.

2.1 'Old' and 'New' Economies Defined

In order to explore the connection between advanced technology regions and more traditional, blue-collar production industries, it is useful to critically examine theoretical and empirical literature in economic geography and other disciplines. The article is organized into five areas as follows: first, the terms 'old' and 'new' economies are clarified and defined, followed by a discussion on recent perspectives on the 'New Economy.' Then, a historical overview of literature on the importance of manufacturing sets the stage for an exploration of past and current debates on the spatiality of manufacturing in a global era. The discussion then turns to contemporary research on the service industries and jobs. Finally, the article calls for moving beyond the production/service dichotomy by outlining an integrated vision of production and services.

Terms which have been used to describe the old and new economies are summarized below:

Table 2.1: Characteristics of the Old and New Economies

	Old Economy	New Economy
Economy	Stable National	Dynamic Regional and Global
Geography	Dispersed employment and production	Agglomeration of employment and production; clusters
Period	Early –Late 20th Century	Late twentieth century
Industry	Manufacturing Mechanization Capital/Labor Firms Compete	Informational Services Digitization Innovation/Knowledge Alliances and Collaboration
Workforce	Full employment Job-specific Skills	Workforce adaptability Broad skills, lifelong learning
Governance	Regulation	Assistance with Firm Innovation

Source: Adapted from Phelps and Ozawa 2003; Peck 2003: 139; 586; Atkinson and Gottlieb 2001: 4; Harvey 1990: 177-179.

The term ‘old economy’ is employed herein to refer to those traditional, blue-collar production industries and occupations that were the mainstay of a stable, post-World War II era of Fordist mass production (Harvey 2003; Piore and Sabel 1984). It also refers more broadly to the era of late capitalist development beginning in the early 20th century, wherein mechanization and industrial production emerged as the most prevalent form of economic activity in mature regions, having eclipsed a nascent industrial era from mid to late 19th century (Phelps and Ozawa 2003).

Meanwhile, the phrase ‘new economy’ connotes the emergence of a post-industrial era, particularly emphasizing those knowledge and learning regions wherein digitized Information and Communication Technologies (ICT) are most successfully produced and disseminated. This era is characterized by innovation, knowledge, and collaboration between firms (Florida 2002, 2005; Gertler 2004; Lundvall and Johnson 1994; Thrift 2006).

Emerging in the context of an increasingly de-regulated and marketized post-1973 US economy, the beginning of the ‘new economy’ era really took off with the growth of ICTs in the 1990s. A body of literature emerged variably articulating this era as embodying a ‘space of flows’ liberated from territoriality (Castells 1996) and characterized by ‘post-modern hyperspaces’ (Jameson 1991). A litany of like-minded terms were conjured (cyberspaces, network society, informational societies) that heralded the emergence of ICT as a radical innovation in a neo-Schumpeterian sense.

However, the ‘newness’ of the ‘new economy’ phenomena is dismissed by others as urban cliché (Boyer 2004; Smith and Marx 1994; Thrift 1996). Thrift notes the history of electronic telecommunication technologies as ‘evolutionary rather than revelatory’, noting that:

> [W]ith gestation periods, the essential architecture of the computer was first articulated in 1837 . . . with the basic mathematics of digitalization theorized in 1928. Indeed if one were to conceptualise these developments as starting with the physical exploration of electromagnetic phenomena one could say that they had been coming on-stream for the better part of two centuries or even four. (Thrift 1996 2)

Disputing a popularly held view that ‘technology "drives" history, a number of historians of science argue instead that technologies are social products that are not autonomous from societal controls’ (Smith and Marx 1994). Put another way, ICTs are ‘merely the latest in a series of innovations which, since the early nineteenth century, have affected corporate management's ability to manage and transmit information’(Boyer 2004 119).

Hence, the analytical categories of ‘new’ and ‘old economies’ have been delineated and challenged across a range of academic disciplines, ranging from cultural to economic geographers (Harvey, Phelps, Thrift) to sociologists (Castells, Jameson) and historians of science (Smith, Marx, et al. 2000) cited above. However, the use of these terms is slippery at best, and employed with caveats against technological determinism. At least philosophically, the ‘newness’ or distinctiveness of the post-industrial ‘new economy’ is not clearly disentangled as a separate entity from its predecessor and counterpart, the industrial ‘old economy.’

2.2 Recent Perspectives on the 'New Economy'

Much of existing attention in the literature on the new economy builds on neoclassical economic models of costs, technological advancement and disagglomeration (e.g., Friedman 2005; Bhagwati 2004). But in fact, there are many new forms of collaboration which go beyond the standard binary debate between either markets or vertical integration, a la Alfred Chandler. Another, emerging body of scholarship focuses on understanding how industrial districts and firms within them can achieve what they want around the world through deliberately "instituting" the market through implementing both spatial and organizational strategies. Of industrial clusters still in existence, scholars in the early 21st century are focused on how are they are shaping and adapting by describing such phenomena as "relational "modular innovation" and "vertical fragmentation" (Langlois 2002, 2004), "knowledge exchange networks" (Zeitlin 2007), "relational networks" and "transnational technical communities" (Saxenian 2002; 2006); and the skill content demanded by globalization and technological change (Levy and Murnane 2004; Autor, Levy and Murnane 2003).

As Zeitlin (2007: 17) notes, 'successful industrial districts are becoming more conscious and more organized', as well as 'less self-contained and more integrated into global supply chains and knowledge exchange networks. Or, as Sabel aptly notes, those successful regions are those which are "windows on the (globalized) world" rathern than self-contained, miniaturized "worlds in a bottle" (Sabel 2003: 8). Corroborating these general observations are Langlois' empirical studies of Apple Computers and Applied Materials, a major semiconductor suppliers, which notes that rather than a battle of standards, the current situation might best be thought of as a battle of alternative development paths. Here, the greatest benefits are derived from "vertical fragmentation" strategies emphasizing external economies of scope and modular innovation over that of systematic innovation and coordination (Langlois 2004:1). The move away from firm and regional reliance on modularity, however, is nothing new. Langlois (2002) indicates that Apple Corporation has long kept its products non-modular to circumvent the risks of imitation and loss of proprietary control associated with modular organizations. Meanwhile, Saxenian's relational networks and transnational communities cite the "brain circulation" which occurs as a result of migratory patterns of scientific and technical professionals between established (Silicon Valley) and emerging (India, Taiwan, Israel) high technology regions (Saxenian 2005). Such relational networks are long-term, often spatially dispersed relationships rooted in elements of cooperation, trust and long-term relationships, which does not demand spatial propinquity as the foundation of trust'. Such elements of 'cultural embeddedness' contrast with Sturgeon' (2002) more parsimonious description of a "modular value chain" wherein lead firms design and market products and turn-key suppliers provide more routinized production capacities, but are able to swiftly adapt to volume orders as conditions change, thanks to both tacit linkages and to codification of standards and protocols. In Sturgeon's world, such codified inter-firm links and the *generic manufacturing capacity* residing in turn-key suppliers reduces transaction costs, build large external economies of scale and reduce risk for network actors .

The contributions of Zeitlin, Langlois and particularly Saxenian are culturally "thicker" descriptions of the processes of wealth creation in high technology regions, which cast doubt on Sturgeon's empirically "thinner" notion of the increasing presence of "modular production networks" that enable flexible, vertically disintegrated production for fast-changing market niches. Moreover, Bresnahan, Giambardella, and Saxenian (2001) comment on policy prescriptions by noting the institutional and cultural dimensions of success in regional clusters of entrepreneurship and innovation. They found that the economic factors that give rise to the *start* of a cluster can be very different from those that *keep it going* . "Old economy" factors like firm-building capabilities, managerial skills, a substantial supply of skilled labor and connection to markets are particularly crucial for the take off of these 'new economy' clusters (including Silicon Valley 40 years ago). As cluster shape and adapt, Bresnahan, et. al. caution against tendencies towards protectionist policies, which were noted as ill-advised strategies used to further grow entrepreneurialism.

At the level of the firm and worker, Autor, Levy and Murnane's studies (2004, 2003) of the skill content of recent technological changes illustrate the mix of "old" and new economy job skill demands. Using data from 1960 through 1998, they corroborate the notion that shifts in job task content due to technological and global change have contribute to recent demand shifts favoring educated labor, particularly mastery of Expert Thinking and Complex Communication . Meanwhile, industries that have long been intensive in labor input of routine tasks, including manufacturing, have

1) invested more in computer capital;

2) reduced labor input of routine tasks, for which computer capital substitutes, and

3) increased demand for non-routine task input, which computer capital complements.

2.3 Historical Perspectives on Manufacturing Matters

Because it has historically been an integral part of advanced industrial economies, the 'old economy' manufacturing sector has long been regarded as a fount of productivity and innovation, and as offering an opportunity for decent-paying and rewarding jobs (Bluestone and Harrison 1982; Fingleton 1999; Jacobs 1961, 1969, 1985, 2005; Melman 1988; Rosenberg 1963, 1969; Sabel and Piore 1984; Cohen and Zysman 1987). On the other hand, a more recent concern has been that this sector has shed jobs in the past three decades; and that there are higher paying, knowledge- and service-oriented jobs to be had in the new economy (Gilder 1990; Oliner and Sichel 2000a,b; Reich 1992; Ramaswamy and Rowthorn 2000).

'Blue-collar' employment in advanced industrial regions of North America and Western Europe began to decline in the 1960s and 1970s as mass production activity spawned by World War II and New Deal economies gave way to a service-based and financial capital economy (Harvey 2003; Sabel and Piore 1984). In the face of such decline, studies emerged establishing the importance of linkages between remaining ‘old economy’ manufacturing sectors, innovation, and cities. Authors who considered such connections notably include urbanist Jane Jacobs, whose observations regarding manufacturing presence in urban economies span four decades (Jacobs 1961, 1969, 1985, 2005). In her earlier work, Jacobs (1969) traced the history of the Minnesota Mining and Manufacturing Company's (‘3M’) evolution from mining to office products, rising from its humble origins as a “small and obscure company comprised of two proprietors and a few workers engaged in digging, crushing, sorting and selling sand” (Jacobs 1969, 52–53).

Past writings, most notably those of Nathan Rosenberg (1963, 1969), also include analysis of innovation and creativity linkages between earlier technologies and later inventions throughout US history. In contrast to the sequences of parallel and unrelated activities in pre-industrial societies, Rosenberg argued that modern problem-solving, product development, and innovation occur in what he calls a process of “technological convergence”:

> What is important here is an historical sequence in which the need to solve specific technical problems in the introduction of a new product or process in a single industry led to exploratory activity at a vertically ‘higher’ stage of production . . . This convergence exists throughout the machinery and metal-using sectors of an industrial economy. (Rosenberg 1963, 423, 426)

In other words, once a particular problem was solved for a particular industry, the solution became available to technologically related industries. A major historical example of the process of technological convergence is the production of firearms in the latter half of the 19th century which would spawn the later development of sewing machines, watches and typewriters. Relatedly, from the 1850s through the 1870s, the technical requirements of the sewing machine industry played a major role as a source of machine tool innovations, out of which grew the vast boot-and-shoe and men's and women's ready-to-wear clothing industries (*ibid*., pp. 428–429).

In the last quarter of the 20th Century, mass assembly production practices in industries ranging from automotives to semiconductors increasingly shifted to more flexible, ‘just-in-time’ methods that proved to be even more amenable to processes of technological convergence. Sabel and Piore (1984) have described this shift as a ‘second industrial divide’, one that articulated the promise of revitalizing crafts production in an otherwise knowledge and service-based economy, and that resulted in the creation ‘new industrial districts’ found in the declining city centers of advanced regions. Comprised of a geographical cluster of complementary firms often working collaboratively, industrial districts have been lauded for improving the competitive performance of individual firms (Sabel 1989; Scott 1998). This notion of a second industrial divide held the promise for what Luria and Rogers (1999) would later describe as ‘high road’ jobs – those skilled, well-paying, often unionized jobs with career mobility opportunities.

Other scholars in the 1980s and 1990s were considerably less optimistic. Concerned about the loss of a manufacturing base, “de-industrialization theorists” promoted the sector as essential to overall economic productivity and the retention of decent paying and rewarding jobs. They argued that manufacturing was crucial to US economic health for four principle reasons. First, it created the demand for many portions of the service sector (Cohen and Zysman 1987; Fingleton 1999). Second, manufacturing traditionally offered more high-paying jobs than the service sector (Fingleton 1999). Third, a strong manufacturing sector has tended to improve trade balances (Bluestone and Harrison 1982; Cohen and Zysman 1987; Fingleton 1999). Fourth, a virtuous circle of innovation, job growth and productivity occurred when a healthy manufacturing sector is coupled with a healthy high-technology sector (Cohen and Zysman 1987; Melman 1988; Tyson 1992).

2.4 The Globalization of Manufacturing

2.4.1 The geography of industrial production: dispersion or agglomeration?

Despite such compelling benefits of manufacturing, the fact that manufacturing activity has diminished in mature economies is not in dispute. For example, manufacturing and construction comprised 35% of the US employment in 1960. By 2004, only one-sixth of jobs were in such goods-producing industries, with five-sixths in services (Blinder 2005, 4). What is more controversial in the literature is establishing an understanding of both what manufacturing remains, and its spatial and business reconfiguration.

A popular mantra that contrasts with the earlier set of 'deindustrialization' theories has been that manufacturing does not matter in a post-industrial society, and that there are higher-productivity employment opportunities to be had in an increasingly volatile global economy (Gilder 1990; Oliner and Sichel 2000a,b; Reich 1992; Ramaswamy and Rowthorn 2000). Such claims have basis in 20th century neo-classical economic perspectives, inspired by Adam Smith (1776), which explain away the demise of manufacturing in advanced regional economies as a natural process of equilibrium market forces.

Following from this logic, the 'crowding out' of manufacturing by foreign competition, high rents and labor costs is a natural and inevitable process. A case in point is the the United Kingdom's past comparative advantage in textile manufacturing, which then moved to New England, only to have comparative advantage shift once again to the southern United States, and then to Latin America (Blinder 2005; Bonacich and Appelbaum 2000; Sabel and Piore 1984). Current comparative advantage in apparel, and a host of other types of manufacturing resides in China and other less developed countries, and hence the current controversy around what were formerly 'American jobs' (Blinder 2005). Among the most vocal challengers of the comparative advantage thesis include those regions and their workers who have found themselves with eroding wages, or else laid off by plant closures and relocation to overseas locales, and for whom re-training and placement in new trades prove to be difficult if not impossible (Bluestone and Harrison 1982; Clawson 2003).

2.4.2 Empirical Evidence for the Spatial Dispersion of Manufacturing

A contemporary body of work emphasizes the role of economic globalization in hastening further spatial dispersion of manufacturing activity (Borrus and Zysman 1997; Gereffi and Koreniewicz 1994; Lester 2003; Phelps and Ozawa 2003; Phelps and Waley 2004; Sturgeon 2002; Zysman 2002, 2003). The global re-organization of industrial production has been associated with the global re-organization of commodity chains (Gereffi and Koreniewicz 1994), the exploitation of new labor forces (Bonacich and Appelbaum 2000), and the development of global production networks based on regional and transnational institutions (Saxenian 1994, 2002).

Within such a New Economy paradigm, only a minimal threshold of local production is required by original equipment manufacturers for product design and prototyping, with the bulk of routine production possible from distant locales. The emergence of modular production networks has been noted in industries ranging from chip manufacturing to apparel, with a focus on US lead firms' reliance on spatially dispersed suppliers, and an increased adherence to industry standards, to reduce costs and risks (Lester 2003; Sturgeon 2002).

Authors such as Borrus and Zysman (1997) describe the phenomena of modular mass production as one wherein scale production can be spatially separated from innovation, yielding increased cost cutting and time savings. Zysman (2003) examines the place of manufacturing in a new digital economy, and concludes that worthwhile production activity is distinguishable from ‘grimy’, less relevant blue-collar manufacturing. The real issues in a digital era, Zysman notes, surround competitive advantages based on processes of manufacturing and production re-organization, as exemplified in the transformation of the consumer electronics industry. Such advantages are based on a new model of competition that Borrus and Zysman (1997) have labeled ‘Wintelism’ (a combination of Windows and Intel) wherein competition between firms is fought over product and market standards. Within such struggle, control over production matters within the firm, but geography of where production actually happens does not.

Sturgeon (2002) bolsters the latter point through examples of disagglomerated production organized along a mass modular structure, in sectors ranging from apparel to hard disk drives. He describes and theorizes the emergence of a distinctly ‘American’ form of modular production networks as US-led firms increase their reliance on spatially dispersed suppliers, rapid ramp-ups of technology, and an increased adherence to industry standards, to reduce costs and risks.

Other scholars who note the disagglomerating forces of international economic integration point to more complex economic, political, and cultural factors than the more straightforward technological story told by Borrus, Zysman and Sturgeon. For example, Phelps and Fuller (2000) describe the productivity and success of a local Welsh affiliate of a multinational enterprise in producing generators in a greenfield site, initially employing workers in two assembly halls (*ibid*., p. 236). Opportunities for further investment and hopes for an expanded employment base were dashed, however, by a ‘black box’ of intra-firm dynamics and local agencies’ influence. Citing entrepreneurial and allegedly subversive efforts on the part of the multinational enterprise subsidiaries in other localities (in Germany, Mexico, and Spain) to win multinational enterprises’ attention, the Welsh subsidiary saw their chances of further investment sullied by others’ actions to ‘massaging of figures relating to costs and efficiencies by other plants’ (*ibid*.). The Welsh example is one example of what Harvey (1990, 2001) has described as the logic of a ‘spatial fix’ wherein capital is continually relocating geographically in order to maintain its profitability and to take advantage of cheaper costs elsewhere.

Schoenberger (2000) moves even further beyond fixed technological and cost considerations, by analyzing the spatial and temporal strategies employed by firms within the production function. For instance, the Japanese mass production system of prioritizing waste elimination contrasted markedly with the U.S. Fordist practice of producing as much as possible. Hence, machine idle time became more tolerable, while worker idle time was anathema, an exact reversal of US systems of temporal values (*ibid*., p. 328). The Japanese form of time management in turn alters spatial arrangements: in a just-in-time production system, machines are grouped in a ‘U’ around a single worker rather than strung out on a line one machine to a worker. Schoenberger notes that such distinct industrial practices do not ‘naturally’ flow from a culture: they arise from real historical-geographical processes and circumstances (*ibid*., p. 329). Schoenberger's observations regarding the differences in management of space and time bolster the observation that production has become spatial dispersed under globalization. Insofar as industrial agglomerations in old manufacturing ‘cores have not kept up with spatial-temporal practices adapted elsewhere, they are surpassed in production by innovative new clusters’.

2.4.3 Evidence of Agglomeration in Industrial Production

While acknowledging the internationalization of the organization of production, a contradictory body of work points nonetheless to the enduring advantages of established localities and concentrations of expertise geographers and urban planners consistently point to the entrenched advantages of various agglomerations, from the dominance of a few global cities in international finance to the specialization of wine-producing regions (Ernst 2003; Gereffi and Koreniewicz 1994; Harrigan and Venables 2004; Henderson et al. 2002; Sabel 2001; Sabel and Piore 1984; Yeung 2007). Such concepts as industrial districts (Sabel and Piore 1984) and business clusters (Porter 2000) underscore the continued relevance and power of agglomeration and of localities. For all intents and purposes, the two terms are synonymous, yet the latter are a more updated variant that situates such districts within a larger geographic backdrop.

Clusters are a geographically proximate group of interconnected companies and associated institutions in a particular field, including product makers, service providers, suppliers, universities, and trade associations (*ibid*.). Business clusters comprise the heart of global production networks (Henderson et al. 2002) and commodity chains

(Gereffi and Koreniewicz 1994). The latter two terms are processes by which individual clusters or regions are rapidly becoming internationalized, and increasingly dependent on international linkages to import key inputs and to export outputs. Such external linkages cover both tangibles like materials and machinery, and intangibles like finance and knowledge. And yet, conventional theories of collocation versus the ‘flattened world’ of dispersed production are deeply divided. The resolution of this debate may have less to do with a ‘winning side’, as in the need to go beyond broad generalizations and to examine sector-specific, case-by-case characteristics of supplier–customer relations.

In contrast to the dispersion argument and reminiscent of Rosenberg's earlier production–innovation thesis, Ernst's studies (2003, see also Ernst and Kim 2002) in the early 21st century illustrate the continued necessity of collocating innovation with production in sectors such as chip design, where engineers work side-by-side with foundry workers. Ernst notes that developing countries in Asia are becoming more capable of moving up the technology ladder of advanced manufacturing, managerial, and research and development activities. Ernst's observations suggest a geographical ‘collocation of innovation’, as spatial and social proximity is important ingredients in the processes of knowledge production and innovation. This ‘collocation thesis’ directly suggests the important roles played by manufacturing workers in problem solving and tinkering within the R&D process (Ernst 2002, 2003; Rosenberg 1963) as well as the benefit to designers and engineers observing the production process.

Providing further empirical evidence on the Asian newly industrializing economies, Yeung's (2007) recent fieldwork in the electronics industry reveals an analytical framework of ‘triangular production’ underpinning the success and spatial agglomeration of Asian electronics suppliers to global lead firms such as Dell and Hewlett-Packard. Such a triangular production involves (i) the triad of appropriate business strategies; (ii) favourable global production networks; and (iii) supportive home bases (encompassing state-led intervention), which together allow these supplying firms to compete in the global economy. Yeung (2007) concludes that there is ‘a strategic coupling when these three elements are complementary and mutually reinforcing’ (pp. 4–6).

Agglomeration and collocation is likewise a feature of North American advanced manufacturing technologies, based on the findings of Gertler's (1995, 7–11) fieldwork in Canadian firms that combined postal surveys, plant visits and interviews in four of Ontario's manufacturing sectors (aerospace and automotive parts; electrical and electronic parts; fabricated metal products; and rubber materials industries). The study found that spatial proximity and distance mattered: when queried, more than half the firms opined that collocation of original equipment manufacturing customer and (supplying) producer in the same region was important, with the top reason being proximity to service and spare parts (*ibid*., p. 10), along with enhanced flows of information and communication. Moreover, plant visits and intensive interviews revealed that intensive interactions with manufacturing customers allows producers a competitive advantage eliminating the hassles of time zone differences, border and tariff hassles, challenges in translating technical terms, and the like (*ibid*., p. 11).

In some contexts, then ‘modularity’ annihilates the role of space, while in others ‘collocation’ rescues the importance of geography. Moreover, the growing vertical disintegration of some firms means that simple descriptions of the spatial division of production do not capture the increased complexities of global supply chains.

The decision-making processes in setting prices, standards and quality, and in the organization of production at each point along the supply chain are no longer coming from a ‘top-down’ command and control directive but are negotiated at multiple stages in the supply chain node.

Indeed, the contemporary global production networks of firms like Hewlett-Packard, Siemens, or WalMart, who source the majority of their products from branch plants or supplying vendors, might aptly be described as increasingly “vertically fragmented,” with no fixed spatial patterns or locational correlates. They contrast sharply with Alfred Chandler's model of the modern corporation, a la Ford's River Rouge plant or IBM of the 1970s, where all primary and subsidiary operations and materials reside within the company. In summary, the forces of dispersal and agglomeration of production activity can no longer be diagrammed in the simple hierarchical relations of old. In the era of globalized production, the relations of production and vertical fragmentation are increasingly complex, hidden, and difficult to model or to generalize.

2.4.4 Regional Impacts of Manufacturing Decline

With the growth of trade in manufacturing and services, a wide-ranging body of literature points to the ways in which manufacturing increasingly became less attractive for regional and national economies and their workers, particularly in the 1990s (Bardhan et al. 2002; Castells 1996; Froebel et al. 1980; Theodore and Peck 2002).

The spatial logic of globalized production and services has meant a vast spatial reconfiguration of employer–employee relations since the publication of Froebel and colleagues' volume (1980) in the Marxian tradition articulating a 'New International Division of Labor' (NIDL). In that core-periphery system of First World–Third World, the 'NIDL' was the result of multinational and state-restructuring of production while in search of a vast reserve army of Third World labor; a strategic response to the continuous imperative of the accumulation in capitalism. Increasingly, however, the boundaries between economic development and growth in core and periphery have blurred, as have distinctions in production and innovation in the manufacturing process.

Various commentators on the newest round of employment reconfiguration differ in emphasis and outlook on the social and spatial configuration of this reconfiguration of cores and peripheries. Castells (1996) focuses on the role of information-based production and competition in the formation of the 'knowledge economy' encompassing interdependence, asymmetry, and regionalization; and marked by selective inclusiveness and exclusionary segmentation (i.e. occupational, industrial, education systems). The growth of such bifurcation has been particularly bleak for workers in mature regions. For instance, a high percentage (40%) of total job growth in the temporary staffing industry work is comprised of blue-collar manufacturing jobs in the American Midwest (Theodore and Peck 2002). The structural reasons underlying the expansion of the demand for temporary, flexible work began in the 1980s. These included cost suppression and a determined search for enhanced workplace flexibility, both factors paramount to corporate strategy in an era of surge in gross domestic product coupled with strong international competition.

Describing the regional decline of manufacturing in the UK context, Phelps and Waley (2004) note the local economic and political ramifications of the actions by one multinational enterprise, Black and Decker, to close its plants in outlying Wales. Despite the many concessions to corporate headquarters of the local subsidiary, and the intervention of local authorities, Black and Decker nonetheless sought a ‘spatial fix’ by relocating elsewhere. The authors suggest that the tendency is toward continuing international integration to continue, and note that local ‘tactics of resistance’ are limited in their ability to moderate these powers.

Meanwhile, Bardhan and colleagues’ (2002) empirical work on foreign outsourcing by California firms challenges conventional notions of international trade theorists regarding comparative advantage and the zero-sum games of trade. They do so by focusing on one aspect of globalization, the substitution of American unskilled in-house labor with foreign intermediate inputs. Despite the cyclical nature of data, the process of decreasing demand for blue-collar labor through foreign outsourcing is continuing in the high-tech manufacturing downturn and hence, trade plays a role in rising labor market inequality. Although Bardhan and colleagues state that the blue-collar jobs in manufacturing that were exported abroad have gone for good, they also point out that new technologies are adding to the demand for production labor and creating new kinds of blue-collar jobs.

2.5 Contemporary Focus on Exportable Service Industries and Jobs

The geographical and historical fate of manufacturing provides instructive insight for the early 21st century phenomenon of job offshoring in the more highly skilled service and production sectors that have arisen as a consequence of the new technologies. Consequently, academic attention and public policy debates have come to focus predominately on exportable professional service occupations (Blinder 2005, 2006; Florida 2002, 2005; Kroll et al. 2004; Samuelson 2004). However, much of the current literature pertaining to the rise of a services economy altogether overlooks or even dismisses the linkages between old and new economy sectors.

Economist Blinder weighs in on the offshoring question, but distinguishes exportable jobs from those that are likely to stay by focusing on what he terms ‘impersonal service’ jobs:

> Thanks to electronic communications and globalization, the future is likely to see much more offshoring of jobs in what I have called the impersonal services,

> that is, services that can be delivered electronically over long distance with little or no degradation of quality. (Blinder 2005, 30)

Blinder's is at heart a simple supply-and-demand logic, one wherein changing trade patterns will keep most personal service jobs at home (chauffeurs, teachers) while many jobs producing goods and impersonal services (medical transcribers, accountants) migrate overseas. Moreover, as more workers in advanced regions seek employment in personal services, wages will decline. Blinder goes on to say that, despite the political controversy and media attention, 'little of this service-sector offshoring has happened to date', but may eventually lead to a 'Third Industrial Revolution' (*ibid*.).

Meanwhile, Florida (2005) echoes Blinder's concerns about the offshoring of service jobs, but his research differs by focusing primarily on the most highly skilled of white-collar occupations in what he terms the 'creative industries', and on urban quality of life issues. Florida lauds those cities with enough cultural attractions, diversity and tolerance to attractive such a 'creative class' of professionals. Drawing from personal experience, Florida cites the creativity of work done by high-end hair salonists that, despite lower pay and fewer benefits, he establishes as a more rewarding and creative endeavor than what he contrasts as the mundane work by blue-collar machinists (Florida 2005, 4). However, Florida is remiss in promoting a nation of designers, and sellers of services and neglects the importance of proximate 'old economy' manufacturing activities (as discussed above) identified by Rosenberg and others. Most importantly, Florida does not address the importance of innovation linkages between problem solving, product development, and innovation – what Rosenberg earlier termed a process of 'technological convergence'.

In other words, Florida portrays a false dichotomy between 'old' and 'new' economy industries and occupations. Florida's devaluation of machining work does not consider the importance of Dieter Ernst's 'collocation of innovation thesis', resulting from contemporary studies of the chip industry, wherein engineers work side-by-side with foundry workers in designing and producing parts. Such a dichotomization of old and new also cannot adequately account for Gertler and Vinodrai's findings in the design sector, which revealed that over a fifth (21%) of the Ontario design workforce is employed in the manufacturing sector (Gertler and Vinodrai 2004, 13). Indeed, Gertler's (1995) earlier work had illustrated the importance to local advanced manufacturing producers of 'being there' in the same region as their users.

2.6 Section Summary

We live in an era where the lines between successive modes of production are blurring. We have traced the origins and uses of the terms 'new' and 'old' economies, and through the contributions of a wide range of social scientists, have noted that the use of such binary analytical categories are slippery at best. Geographers, including Yeung, Waley, Thrift, Schoenberger, Phelps, and Henderson et al., add important empirical evidence and added analytical understandings of the nexus between 'old' and 'new,' while Langlois, Zeitlin,and Saxenian describe the mechanisms by which firms are deliberately instituting the market through strategies of vertical fragmentation, without set spatial patterning or locational correlates. These studies provide nuance and understanding to the otherwise intractable question of whether global forces have given rise to a further 'flattening' of industrial production in space and time, or whether and how agglomeration and clustering is in fact the defining characteristic of our global era.

Contrary to the view that technological forces drive the spatial dispersion of production, we have explored instances throughout history of the synergistic effects of innovation and industrial production (Jacobs, Rosenberg, Ernst, Gertler and Vinodrai). Meanwhile, Autor, Levy and Murnane's work on shifting job task content illustrates the ways in which many "old economy" industries have reduced routine tasks and increasing demand for non-routine tasks and demand re-structuring of basic education and skills training. These studies illustrate concrete ways in which demarcations of activity into "old" and "new" economies are false. More understanding and insight is needed, then, into the intertwined nature of information systems, organization, and production/ manufacturing processes. Hence, I propose broadening the current focus on job loss in the highly skilled service sectors to an integrated vision of industrial production, knowledge and service industries in an advanced economy.

The most pressing questions are thus, which specific kinds of manufacturing occupations have the best potential to remain in advanced industrial regions, and what are the mechanisms by which workers will be trained and prepared for these jobs? Although generalizations have been made herein about the important role of skilled manufacturing in advanced regions, important details have yet to be explored or worked out. Rigorous empirical studies of specific manufacturing activities (e.g. tooling, machining, welding, foundry, fabrication, and assembly work) and their contributions to ‘new economy’ industries (biotechnology, computer, renewable energy technologies, nanotechnology, semiconductor, and transportation) are lacking in the literature. I believe that addressing this gap is an important starting point if we are to effectively address the overlapping roles of manufacturing and production in what have otherwise been characterized as knowledge and service-oriented, advanced industrial region.

CHAPTER THREE: Research Strategy and Background

3.0 Introduction

The persistence of a local and regional machine shop sector in a highly competitive, very expensive, otherwise service-oriented Bay Area economy is a compelling paradox to be elucidated. In this chapter, I will describe the qualitative approaches used throughout the study, setting the stage for the introduction of four distinct "ideal types" into which existing machine shops are categorized. I also introduce and utilize a range of quantitative methods, drawing from a variety of published business and employment surveys. Finally, I provide a summary of the existing data and literature on the U.S. machine shop sector relative to global machining and manufacturing trends.

3.1 An economic geographer's approach

I begin my introduction of research methods through a brief examination of what distinguishes the sub-discipline of economic geography from other social science endeavors which study economic activity. In essence, the most striking feature of economic geography is spatial concentration of activity; how and where things happen in relation to one another. The distinction is also methodological. Economic geography has a comprehensive set of analytical tools lacking in mainstream approaches to economics or public policy. Countries, regions, localities exist in space – a fact acknowledged by urban and regional economics but all but ignored by international economists. Herein lies the dilemma for such social sciences that focus on quantitative modeling- complex spatial and social relations involved in concentration are far more difficult to model than constant or diminishing returns.

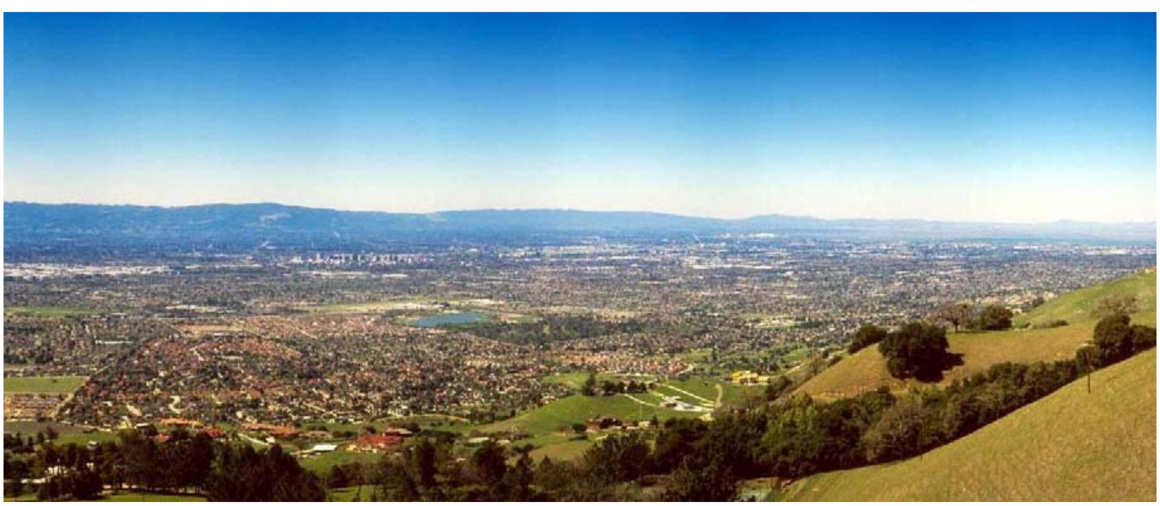
Still, important geographical issues and most importantly, sources of evidence, are absent and excluded from much of the academic contributions to public policy. In his 1991 book, Geography and Trade, geographical economist and NYT columnist Paul Krugman noted that this needs to change, and offered the rare assessment that some of the best works of economics are done in obscure university departments of urban planning and, more often, geography. However, Krugman notes that unfortunately, "Economic geographers . . . may do excellent work, but it does not inform or influence the economics profession." [1]

On the one hand, Krugman's assessment is incomplete because it does not acknowledge the work of urban economists including Edward Glaeser and Brian Arthur. Highly regarded within economics departments because of their abilities to model spatial dimensions, Glaeser's and Arthur's works incorporate the unpredictability of the modern urban landscape by borrowing from a variety of nonlinear dynamic processes in chemistry, biology and physics and combining these methods with those used by the new international trade theorists.[2] On the other hand, I would agree with but extend Krugman's argument to say that economic geography and geographers by and large do not influence the realm of public policy, given that academic studies coming out of obscure departments largely are not translated into plain language for wider audiences. And yet, I argue that the conjunction of a useful analytical approach and a timely and relevant topic, such as the role of manufacturing in an advanced technology region, do indeed lend themselves to such translation and beg the need for a re-framing of the debate and of the data.[3]

3.2 Explanation of Case Study Selection

The Bay Area is a compelling locus of study for a myriad of reasons. Foremost, because I wish to focus my research question on the existence and continuation of industrial production in advanced regional economies, the Bay Area (as home to Silicon Valley, the world's leading region of New Economy technological innovations) serves as the most useful heuristic model and purest "ideal type" of advanced regional economies.

Plate 3.1 The San Francisco Bay Area:



View from Silicon Valley

Moreover, the Bay Area has not only been the world leader in innovation of high technology products; these industries have traditionally been supported by a wide array of local parts suppliers (foundries, metalworking firms, machine shops) for the past three decades. Indeed, the Bay Area began as a manufacturing economy, a past noted earlier in Chapter 1 and documented by many of the area's historians.[4] An examination of the current state of local supplier-contractor relations would hence allow an assessment and evaluation of the growth or decline trajectory of these supplying sectors in an advanced industrial region, providing insight for other regions on the high-technology development path.

In many ways, the demands of the case study approach have been noted to be far greater than that of other approaches, such as experiments, surveys, histories and the analysis of archival information (e.g., economic studies). Ethnographer Robert Yin has commented on the intrinsic difficulties. Too many social scientists, he argues, draw upon the case study approach "because they believe it is 'easy' " (Yin 2003: 50). In actuality, Yin notes:

> "…the demands of a case study on your intellect, ego and emotion are far greater than those of any other research strategy. This is because the data collection strategies are *not* routinized…(nor) analytically boring. Conducting case studies offers no such parallel. Rather, a well-trained and experienced investigator is needed to conduct a high-quality case study because of the continuous interaction between the theoretical issues being studied and the data being collected (Yin 2003: 58).

Despite the disadvantage of time and resource burdens, the case study approach is the preferred strategy when "how" or "why" questions are being asked and when the investigator has little control over the course of events, and when the focus is on contemporary phenomeonon within some real life context (Yin 2003: 13).

3.3 The Uses and Importance of Qualitative Methods of Inquiry

Conducting research has been likened to finding oneself amidst a dense forest, with many possible twists and turns. Given a multitude of possible challenges involved in investigating and observing an activity as hidden from plain sight as machine shops, I chose to conduct a localized geographical area, the five-county San Francisco Bay Area, focusing most intensively on those two counties, Alameda and Santa Clara, with the largest concentrations of machine shops. I conducted a series of intensive, semi-structured interviews with participant observation in machine shops, local trade shows, and manufacturing conferences. I conducted 32 semi-structured interviews and participated in six trade shows and conferences, for a total of 102 hours of interviews and participant observation from June 2005 – August 2007. (Please see Appendix A which details the survey questions asked of interviewees.) To supplement these primary qualitative sources, I also utilize a variety of archival research methods, employing business and trade journals, unpublished dissertations,
and oral histories.

Table 3.1: Fieldwork by Type and Counts

Entity	**#**	**Format and duration**	**Total hours**	**Detail of informants**	**Location**
Machine shops	22	Semi-structured interviews/ shop tours .75 -2 hrs*	48 hours	Owners, managers and employees of machine shops	Alameda, SF, SC counties (6 cities)
Original Equipment manufacturers	9	Semi-structured interviews/ shop tours .75 to 2.5 hrs*	19 hours	OEM engineers, scientists and product managers	Alameda, SC, SF counties (3 cities)
Public & nonprofit	3	Semi-structured interviews	7 hours	Workforce development intermediaries, city agencies	Alameda, SC counties (3 cities)
Trade shows	3	Participation observation in half & all-day events	13 hours	Booth representatives ; participants and journalists	SC county (1 city)
Conferences	3	Participant observation in conference proceedings	15 hours	Speaker, organizers and fellow attendees	SC county (2 cities)
Tally of Fieldwork	39	Combination of interviews/ participant observation	102 hours	Variety of key informants listed above	3 counties and 7 cities (city tallies include overlaps)

3.4 The Complementarity of Quantitative Data Sources

The use of published statistics on machine shops and allied manufacturing activities assists in quantifying their business and employment dynamics through time. The benefits of this approach include increased understanding of the size, magnitude and direction of business and employment activity. To this end, this chapter incorporated a myriad of data sources from state and Federal statistical collection agencies as follows:

Table 3.2: Published Data Sources Ranked By Importance

Data Type	Primary Data Source	Secondary Data Source	Tertiary Data Source
Firms	CA Employment Development Department (EDD) Labor Market Information 2007;	US Census County Business Patterns (CBP) 2005.	Bureau of Labor Statistics (BLS) Census of Employment & & Wages (CEW) 2006, Gardner's Machine Tool Output and Consumption Survey 2007
Business Receipts	US Census CBP, 1999 & 2005	BLS CEW 2000 & 2005	CA EDD Labor Market Information (LMI) 2007, , Gardner's 2007
Employment	BLS CEW, 2000 & 2005	BLS Occupational Employment Statistics (OES) 2006	CA EDD Labor Market Information 2007
Occupation	BLS OES 2006	US Census 1-% Public Use Microdata Samples (PUMS)	US Census County Business Patterns, 1999 & 2005
Age, Gender	US Census 1-% PUMS	---	---

3.5 The Limitations of Existing Data and Further Need for Qualification

On the other hand, the pitfalls or limitations of a quantitative approach include the potential unreliability of published statistics including either under- or over-reporting by firms and individuals (given financial incentives to do so under current programs in unemployment insurance and worker's compensation); a globalizing business environment difficult to precisely categorize; conflicting numbers reported between different datasets; and the lack of comparability between different historical points in time.

With respect to the latter point historical analysis is complicated by a dearth of data: published data sources on machining employment and business receipts before 1997 do not utilize the same North American Industrial Classification (NAICS) industry codes used later, instead using the old Standard Industry Classification (SIC) codes, for which precision machining does not contain an accurate “bridge” across years.

Moreover, what the seemingly precise quantitative figures elucidate about the regional dynamics of growth and decline in the sector are far from clear. One source of skepticism about reliance on quantitative methods are current debates about the nature of productivity statistics versus actual off-shoring activity. In particularly, critiques have been lodged by some economic researchers about published U.S. business and employment statistics. On the one hand, business research in the last decade has consistently reported that manufacturing employment has declined because productivity has continued to increase.[5] Contrarily, more recent concerns have surfaced beginning in 2007 voicing quite a different picture. Here, some economic and business researchers charge that Federal data collection methods report American manufacturing capacity which is vastly overstated, as the U.S. Gross Domestic Product and offshoring data rely on outdated methods of counting which do not capture the realities of an increasingly globalized world of trade and production.[6] Namely, the overseas activities of U.S. multinationals, including subcontracted work, is often counted within US productivity statistics, when actual production and employment occurs abroad. A labor economist at the Upjohn Institute has charged that:

> "outsourcing and offshoring are poorly measured in U.S. statistics, and poor measurement may impart a significant bias to manufacturing and, where offshoring is involved, aggregate productivity statistics. Second, companies often outsource or offshore work to take advantage of cheap (relative to their output) labor, and such cost savings are counted as productivity gains, even in multifactor productivity calculations."[7]

For the purposes of my investigation, the extent of OEM's reliance on foreign machining suppliers may in fact be undercounted, as current reported data may underestimate the extent to which customers are increasingly outsourcing machining products to overseas venues. In other words, there is a discrepancy between the published data and knowledge about potential data flaws, resulting in a gap in knowledge. Thus, qualitative methods are employed in later chapters to further evaluate the claim of the machining sector's critical role in the local economy. Given this kind of limitations with published data on productivity gains, it is important that quantitative research methods are supplemented with more direct modes of field inquiry including participant observation and interviews.

3.6 Identification of Machine Shops by Ideal Type

Through the course of my fieldwork involving data analyses, interviews and participant observation, I developed the following four "ideal types" depicted in Figure 3 as follows, to classify and better understand the characteristics and dynamics of the nearly 900 existing machine shops. I observed, and archival data seemed to bear out, that Machine Shops are comprised of what can be described as the following ideal types:

- Modern Shops
- Small to medium “family” shops
- “Garage” shops which have been spun recently from established ventures.
- These independent machine shops do not include “captive” shops within OEMs

Plate 3.2 A Typical Suburban Machine Shop in A Office Park Complex

Photo by the author, July 2006

Although these categories are mutually exclusive (each shop fits into only one type), Figure 3 depicts interlocking types to characterize their interdependency. That is, the category into which each machine shop belongs may vary over time, as shops grow or decline in capacity, whether adding or losing employees, types and numbers of machine tools, and customers.

Four ” Ideal Types” of Machine Shops

a. Modern Shops   These are the “first tiered” suppliers with whom OEM customers directly have contracts and interactions. Seven “modern” machine shops in the area have shop floors of over 15,000 square ft. each and employ from 100 - 249 workers. Six of the seven are located in Alameda County, including the giant Original Equipment Manufacturer Sanmina-SCI (a key supplier to IBM), which is located in Newark. Only one large modern shop is located in Santa Clara County.

b. Family Shops These are “second-tiered” shops that collaborate with first tiered companies on jobs and often do not interact directly with the largest OEM customers. Comprising the majority (over 80%) of shop, these shops range anywhere from 5,000 - 15,000 square footage and dominate the machine shop universe,. They are dubbed “family shops” because many are owned by two or more family members, often intergeneration, typically father and son proprietors. Many have been in existence for two to three generations. These shops usually employ under 20 workers; the majority of these have been in business for at least 10 - 15 years.

c. Start-up shops: These small, start-up “garage shops,” comprising the third and fourth tiers of contractors’ suppliers, which have spun up in recent years, and typically employ from 1 - 4 workers. New “garage shops” are continually being spun by machinist employees, often leasing under 5,000 square foot of work space. These shops are started by entrepreneurial-minded shop owners who embrace financial risk, like taking a lien on one’s house, or getting personal bank loans, in order to be their own boss. These up-and-coming shops often acquire their first contracts from former employers or former customers.

d. "Captive shops": The above categories do not include "captive" shops which are those housed within within OEMs and do not have a separate NAICS code 332710. There are no known government or private censuses which track the existence of such captive shops. However, interviews with machine shops and their customers revealed that many Original Equipment Manufacturers, research laboratories and universities have their own fully operating, in-house or "captive" machine shops and employ machinists. Large OEMs with captive machine shops range from Hewlett Packard to IBM, and Varian. Smaller OEMs range from Beckman Instruments in Richmond, a major producer of high-speed centrifuges, to Hasselhoff, a race car designer and manufacturer in Berkeley.

3.7 The Existing Data and Literature on Machining

A body of established work already exists on the U.S. precision machining sector, situating the importance of this industry within the larger manufacturing sector and encompasses published data summaries, qualitative case studies, and policy analyses. The U.S. precision machining industry serves as an instructive and illuminating case study of the conjuncture of the changing patterns of employment, of regional economic development, and of shifts in global production. The industry—as with much of traditional manufacturing in the United States—has been shrinking, but its decline is particularly pronounced with a 70% decline in machine orders since 1997 (NTMA 2004). At the same time, however, manufacturing in this sector has been seen as vital to maintaining the U.S. leading edge in innovation, through its forward linkages to more recognizable consumer products.

3.7.1 Machine Shops: SIC 3599 and NAICS 33271

The simple definition of machining is that of "shaping of mechanical parts of machines" (Kelley and Harrison 1990: 1274), involving the use of a wide variety of machine tools to cut or to form material, usually metal, to precise shapes and dimensions. The work consists of cutting away metal chips (Rosenberg 1963: 417). Firms in this sector utilize the full range of machine tools and related equipment, ranging from small automatic lathes for miniature parts, to enormous boring mills (author's fieldwork, 2005-2007)..

Despite considerable diversity within precision manufacturing, the industry is probably the most technologically advanced of all small manufacturing activities (Rosenberg 1963; Sabel and Piore 1984; Rand 1990), and enjoys widespread deployment of computer-numerically controlled (CNC) machines and other computer-aided design and manufacturing (CAD/CAM) techniques. Moreover, the industry supplies the necessary precision tooling and machining parts and services for such vital industries as defense, automotive, aerospace, appliance, business machines, electronics, agricultural implements, transportation, environmental, construction equipment, and many more (NTMA 2004)[8]. Hence, its role in providing necessary intermediary products and parts to a variety of more visible consumer products, renders the precision manufacturing sector a vital "industrial backbone."

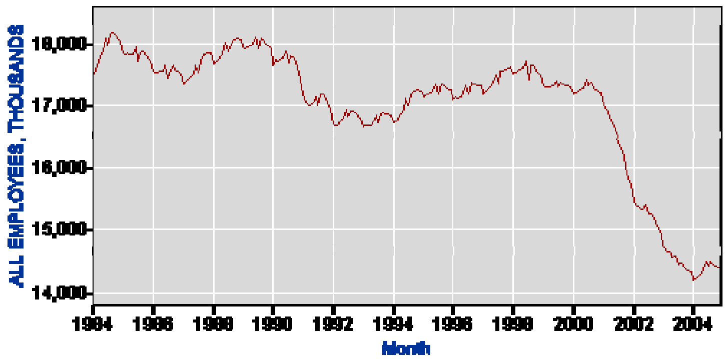
3.7.2 Manufacturing: NAICS 332710 – SIC 3599

Custom precision manufacturing falls squarely within the manufacturing sector, one of twelve overall industry categories captured by national statistical agencies including the U.S. Bureau of Economic Analysis (BEA), Labor Department's Bureau of Labor Statistics (BLS), and the Census Bureau. The manufacturing sector consists of establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products.

Current Employment Statistics estimates in table 3.3 below show annual average employment in manufacturing above 16 million between 1994 and 2000, before declining sharply. During 2003, manufacturing employment averaged 14,525,000, or 12% of all employment.

Table 3.3
Employment, Hours, and Earnings from the Current Employment Statistics survey

Industry: Manufacturing
NAICS Code: N/A
Data Type: ALL EMPLOYEES, THOUSANDS



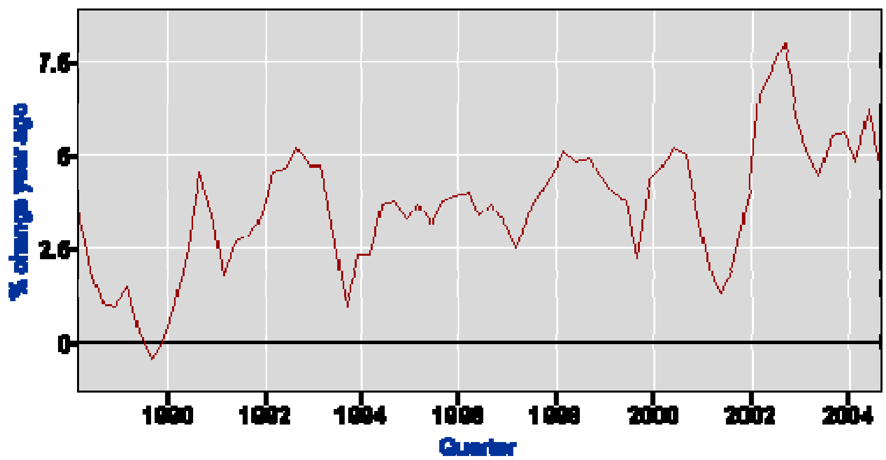
Source: Bureau of Labor Statistics, Current Employment Statistics Survey, 1984 - 2004

Counts from the Quarterly Census of Employment and Wages program show that the manufacturing sector employs many workers, but in a relatively small number of establishments. Over 64 percent of workers in the goods-producing sectors (which includes natural resources and mining, and construction) are manufacturing employees, yet manufacturing accounts for less than 30 percent of goods-producing establishments and 5 percent of all establishments. Much of manufacturing work, then, occurs in large good-producing establishments.

A decline in employment numbers in the last twenty years has been accompanied by a rise in labor productivity (output per hour). As the following graphic illustrates, the change in percentage of yearly labor productivity from a dip of under .5% in 1989 to a high of nearly 8% increase in 2002.

Table 3.4
Major Sector Productivity and Costs Index

Duration: % change year ago
Measure: Output Per Hour
Sector: Manufacturing



Source: Bureau of Labor Statistics, Current Employment Statistics Survey, 1984 - 2004

Importance of Machining

Despite considerable diversity within sectors served by and machines used within precision manufacturing activity, the industry is probably the most technologically advanced of all small manufacturing activities (Rosenberg 1963; Sabel and Piore 1984; Rand 1990), and enjoys widespread deployment of computer-numerically controlled (CNC) machines and other computer-aided design and manufacturing (CAD/CAM) techniques. Moreover, the industry supplies the necessary precision tooling and machining parts and services for such vital industries as defense, automotive, aerospace, appliance, business machines, electronics, agricultural implements, transportation, environmental, construction equipment, and many more (NTMA 2004). Hence, its role in providing necessary intermediary products and parts to a variety of more visible consumer products, renders the precision manufacturing sector a vital “industrial backbone.”

The machining sector is often a springboard for the creation of the breakthrough technologies of the future. Machining is closest to the " heart of an industrial economy." (Levoy 1996) Thus, machine shops can be a" foundation for other manufacturing." (Vartabedian 1993). Nathan Rosenberg's concept of "technological convergence" is appropriate for the machine shops as springboards of technological innovation. Technological convergence arises from the application of industrial methods at increasingly higher levels of production, "exploratory activity" focused on problems, and transmission of the knowledge produced through the "exploratory activity" to other applications and fields. (Rosenberg 1963, p. 426) Technological convergence creates external economies of knowledge and information that are transferred through a common widespread production method like precision machining. (Rosenberg 1963, p. 427) Machine shops can be characterized by relatively low barriers to entry: the production of sophisticated products for high technology can be done with machine tools, which are relatively simple equipment involving only the few basic processes cited earlier by Rosenberg (milling, drilling, grinding, polishing, etc.). Even the latest in CNC technologies are relatively affordable for small machine shops (Machine Design 1997). An experienced machinist can go into business with a small down payment on a $150,000 machining center. Often, a shop can be started with as little as a $10,000 line of credit. ((Vartabedian 1993 and Ascenzi 2000, cited in Charpentier 2001).

Machine shops can play a unique role in the regional economy. First, the precision machining process is ubiquitous in the economy because it produces the machines and parts that are then used to produce the consumer and intermediary goods. Second, machine shops employ a range of different workers-- by one count over 100 different job classifications ranging from machine setter and tenderer, to machinist apprentice. (Kelley & Harrison 1990, p. 1282.). Other functions in the machine shop include non-machining occupations, such as clerical, finance, sales and marketing. Third, the scope of production of machine shops is so diverse that it acts as a hedge against business downturns. If activity in one sector has dropped, machine shops can shift their attention to another (Charpentier interviews, 2001).

3.7.3 Existing Machining Case Studies and Methods

My inquiry into the role of Bay Area machine shops benefits from an earlier body of work in the sector. With regards both method and content, the research stands on the shoulders of past industrial sociology studies of the manufacturing and machining sector. Among influential earlier studies are Donald Roy's (1952, 1955) and Michael Buroway's

(1979) ethnographies of the same piecework machine shop in Chicago, nearly three decades apart. Both researchers found paid employment as machine operators within Roy's Gear Company, a Chicago factory employing hundreds, while covertly conducting participant-observer fieldwork.

However, Roy and Buroway differed vastly in the basic premise under which each was operating. Donald Roy focused on questions of managerial science so prevalent in time and motion studies since the 1930s, namely, "why don't workers work harder"? Pathbreaking in its time, Roy's voluminous publication painstakingly documented the details of life on the shop floor. Contrary to what corporate time-and-motion researchers of the day were concluding about the "irrationality" of workers' failure to meet management's expectations, Roy found extreme rationality in workers' tactics of output restriction via"goldbricking," "quota restriction," and "efficiency and the fix," in the face of Taylorist management practices demanding ever greater efficiencies.

Twenty four years later, Michael Buroway posed an opposite question in his fieldwork at the same site, now a branch of Allied Corporation, "why do workers work so hard?" The latter argued that the myriad games and rule-bending strategies were forms of worker resistance to the overarching hegemony posed by the piece rate system. Burawoy combined rich ethnographical description within a Marxian framework of the capitalist labor process, deliberately analyzing his own experiences in relation to those of Donald

Roy. By trying to understand what he observed to be workers' routine consent to their own exploitation, Burawoy traces the technical, political, and ideological changes in factory life to the transformations of the market relations of the and to broader movements, since World War II, in industrial relations.

Following Roy and Burawoy, later ethnographies of apprentices explored the learning craft aspects of high precision machining in smaller shop settings. In various studies, machinists and apprentices were interviewed and/or observed while they worked (Barrett 2004; Sweet 1994; Madono 1988). The studies varied markedly in their observations and conclusions. On the one hand, each identified socially interactive group learning and problem solving approaches, identified as "communities of learning."[9] Findings, however, varied from one study which emphasized the "dark side" of managerial control and intra-group competition resulting from post-Fordist machine shop practices in four shops (Sweet 1994), to others which were more focused on the positive aspects of co-learning on the shop floor..

In the course of his ethnographic work, Sweet's study notes the loss of workplace democracy which derived from the adaptation of new technologies::

> the "concomitant loss of worker power expanding use of advanced manufacturing technologies, decreasing organizational sizes, decreasing bureaucratization of the work place, and the abandonment of Tayloristic managerial practices in favor of (supposedly) increasing worker participation in decision making processes." (Sweet 1994: 1).

By contrast, along the lines of a "community of learning" model,[10] an earlier study (Madono 1988) found that there were multiple levels of involvement in different aspects of the machine culture. For instance,:

> "experienced machinists were not only fulfilling production quotas, they related their assigned menial tasks to the shared expressive culture of machining: leisure, reciprocal exchange relationships with other artisans, solitary problem solving, participation in technical gossip, focused observation, and appreciation of the aesthetic taste expressed in group problem solving" (*Ibid.:* iv – v.)

This second study emphasized that craft practices that apt apprentices often must master are distinguished by an eschewed dependence on a mentor, learning to struggle with machining problems in solitude (*Ibid.:* 152). Madono combines the importance of various communities of learning with that of solitary learning and idiosyncratic problem solving approach, which together contribute to a process of "backyard-like," seedbeds for cultural transmission of machining practices (*Ibid.:* 4).

The methods of participant-observer employed by these industrial sociologists served to effectively address questions at the shop floor level. However much such participant-observer methodologies might add more empirical depth at the micro-perspective, though, they lack powers of generalizability across sectors, space and time. What's also notable, moreover, is the labor and employee focus of the machine shop accounts cited above: the above studies excluded detailed explanation or accounts of business or managerial account of shops' operations, emphasizing instead the lives of workers on the shop floor.

Critiques of similar nature have been lodged against employing qualitative case study approaches in the manufacturing sector by Appold (1995) and Harrison and Kelley (1990), who instead utilize nation-wide surveys and datasets to test theorems about manufacturing competitiveness and technological innovation in the machining sector nationwide. Harrison and Kelley's (1998) and Appold's (1995) respective research in the metalworking sector discounted the role of local agglomeration in machine shops. By measuring distance to primary customer as an indicator of performance, Appold evaluated a nationwide sample of nearly 1,000 metalworking plants and found that what he termed "collaborative manufacturing" between plants and collaborating shops indeed enhanced performance, but that spatial agglomeration to other firms did not matter.

Appold's and Harrison and Kelley's later emphasis on detailed firm surveys and quantification and replicable findings, however, simultaneously neglects the global and local dimensions of firm behaviors and motivations, which could be remedied by supplementing data analyses with qualitative context derived from interviews and historical investigation.

Such studies as Piore and Sabel's 1984 case study of the New England machine tool industry; Alice Amsden's investigations of machine tool industries in Taiwan (1985), Korea and Japan (1986) and India; and Liang-Chih Chen's 2007 Berkeley dissertation, as well as graduate research conducted by city planner Sean Charpentier (2000 and 2001), utilized more comprehensive, mixed-methods approach of a series of firm and employee interviews as the basis for storytelling and hypothesis testing supplemented by quantitative data analyses.

Chen's dissertation work in the allied machine tool industry, for example, situates the genesis and growth of the Taiwanese machine tool industry within a detailed historical-geographical account of the rise of modern machine tool industries in Europe, including Italy, Germany and France; Asia including Japan, China and Korea; and the Midwestern United States.[11] Chen notes, moreover, patterns of production dominance of industrialized countries, accompanied by emerging activity in East Asian Newly Industrializing Countries.

The production of special purpose machine tools are more sophisticated and specialized, carried out in countries like Germany, Japan, Switzerland, Italy or the US, which have long traditions of machine tool manufacturing and also strong domestic special purpose machine tool using industries, such as automotive, electronics and other heavy or precision metalworking industries. Chen notes further that:

> As for the production of general purpose machine tools, given their relatively lower production thresholds in terms of the requirements of technological capability and domestic demands, latecomers in the machine tool industry, like Taiwan, Korea, China, etc., are allowed to play a role in the world market, which, however, is still dominated by the aforementioned industrialized countries (Chen 2007: 59).

Hence, the existing case study literature on the allied machine tool sector serves as an important body of knowledge and understanding for the U.S. and the Bay Area regional machine shop sector. Indeed, Bay Area machining activity can be viewed as part *multiple* production networks and commodity chains, both as "forward" linkages in the production of machine tools, and as "backward" linkages in production of OEM consumer goods This understanding in turn helps to pinpoint where technology and capital resides in the production and innovation process.

To understand the magnitude of commodity chain activity in the allied machine tool sector, Table 3 below ranks the top ten producers in 2007 of world machine tools:

Table 3.5 World's top ten machine tool producing countries in 2007

Country	Production (US$mill.) P	Import (US$ mill.) M	Export (US$ mill.) X	Consumption (US$ mill.) C=(P+M)-X	Domestic Market Share (P-X)/C	Import Dependence Ratio M/C	Export Share	Trade Balance (US$) (X-M)
Japan	14,443.5	786.0	7,610.1	7,619.4	-81%	10%	23%	6,824.1
Germany	12,725.0	3,694.5	9,167.8	7.252.1	49%	51%	27%	5,473.3
China	10,090.0	6,900	1,600.0	15,390.0	55%	45%	5%	-5,300
Italy	7,273.7	1,990.9	4,207.6	5,056.0	61%	39%	13%	2,216.7
Korea	4,550.0	1,400.0	1,800.0	4,150.0	66%	34%	5%	400
Taiwan	2,069.0	4,253.0	3,408.0	3,785.0	-35%	112%	10%	-845
US	**3,578.0**	**4,253.6**	**1,659.8**	**6,171.8**	**31%**	**69%**	**5%**	**-2,593.8**
Switz	3,323.8	416.5	2,457.5	1,282.9	68%	32%	7%	2041
Spain	1,436.8	666.3	842.2	1,260.9	47%	53%	3%	175.9
France	1,087.8	1,252.0	718.4	1,621.5	23%	77%	2%	-533.6
World	US $ 70,197.5 million							

Source: Author's calculations derived from Gardner 2008 World Machine Tool Output/Consumption Survey http://www.gardnerweb.com/consump/produce.html. Computational methodology adapted from Chen 2007:18.

With a combined US $48 billion in receipts, the top ten producers (Japan Germany, China, Italy, Korea, Taiwan, the US, Switzerland, Spain and France) together accounted for approximately 70% of the world production of US $70 billion. Within these top ten producers, Japan, Germany, China, Italy and Korea were the five largest machine tool exporters. With the exception of China (with a negative trade balance of $5 billion), each of these top producers maintained a large trade surplus in comparison with other major machine tool producing countries. By contrast, at a US $2.6 billion shortfall the U.S. had by far the largest trade imbalance in machine tool exports relative to imports.

Relatedly, an examination of the top ten *consumers* of machine tools globally yielded seven of the same top producers. As depicted in Table 3.6 below, China, Japan, and Germany and the U.S. were the top four worldwide consumers in 2007:

Table 3.6 Shift in Consumption of Machine Tools, 2007 and 2000

	2007 Value	Share	2000 Value	Share	Change in Share
1 China	$15,390.0	37%	$ 3,628	10%%	+27%
2 Japan	7,619.4	18%	$ 2,812	8%	+18%
3. Germany	7,252.1	17%	$ 5,597	15%	+2%
4 United States	6,171.8	14%	$ 7,077.8	19%	-5%
5 Italy	5,056.0 6	14%	$ 3,391.8	9%	+5%
6 Korea	4,150.0	10%	$ 2,328.2	6%	+4%
7 Taiwan	3,785.0	9%	$1,358.8	4%	+5%
8 Brazil	1,822.2	4%	$1,020.3	3%	+1%
9 India	1,774.8	4%	$ 229.5	<0%	+4%
10 Mexico	1,669.6	0%	N/A	<0%	0%
(US $ mill)	$41,793.6	100%	$27,442.6	73.5%*	

Source: Gardner 2008; author's calculations

*Note: The total for the year 2000 does not equal 100%, because India and Mexico were not on the top 10 list of consumers for that year, and France (#7 in 2000) was not ranked in 2007 .Canada was ranked #9 (2.9%) and Brazil was ranked #10 in 2000.

This was a marked shift in consumer share from just seven years ago of the U.S., Germany, China and Japan. In other words, during this time China quadrupled its share of consumption, whereas the U.S.'s consumption fell by US $1 Billion, the only top-consuming nation in 2007 to have fallen in percentage share of consumption since 2000.

Despite its current standing as a top-ten producer and top-four world consumer of machine tools, the world of American machining today suggests that a precipitous decline of machine shop activity within just a few short years. The U.S.'s decline in consumption of machine tools has been even more rapid than its decline in production: In 2001 the U.S. fell out of first position as leading consumer for the first time since 1993.[12]

These machine tool import/export statistics suggests that the focus of my research, U.S. machine shops, are increasingly dependent on imports for their capital expenditures--leaving them at the whims of currency exchange rates during periods of economic downturn.

3.8 Section Summary

Chapter Three has described the regional dynamics of the machining and manufacturing sectors. First, the chapter discussed the utility of a geographical approach, followed by an exploration of the methods of investigation used throughout the study, both qualitative and quantitative. I also introduced my construction of three "ideal types" by which the region's machine shops can be viewed: small family shops, large "modern" shops, and "invisible" contracting shops. Limitations to existing data collection and reporting, including current employment and economic indicators including GDP and import prices which are variably over- or under-reported, further underscoring the importance of qualitative approaches to understanding regional dynamics of machining and manufacturing. Finally, I provided an overview of existing data analyses, case studies and related literature pertaining to the machine shop industry, within the larger manufacturing sector.

Despite their ability to provide in-depth detail, case studies suffer at a more global level. In this era of "outsourcing" and "right-sizing," the worldwide dispersion of tasks demands a commodity-chain approach of the scholar which necessitates interactions with a multiplicity of extra-firm actors: that is, tracing the production process via firm-to-firm interactions; customer-supplier relations; and thus investigation at the machine shop sector as simply a portion of the larger jig-saw puzzle. More appropriate, then, are later industrial studies in related industry, the machine tool sector. Such studies as Piore and Sabel's 1984 case study of the New England machine tool industry, and Liang-Chih Chen's 2007 Berkeley dissertation, as well as unpublished graduate research conducted by city planner Sean Charpentier (2000 and 2001), utilized a mixed-methods approach of a series of firm and employee interviews as the basis for storytelling and hypothesis testing in the machine tool industry, supplemented by quantitative data analyses.

Chapter Three
Research Strategy and Background

In an era of "outsourcing" and "right-sizing," the worldwide dispersion of tasks demand a commodity-chain approach of the scholar which necessitates interactions with a multiplicity of extra-firm actors: that is, tracing the production process via firm-to-firm interactions; customer-supplier relations; and thus investigation at the machine shop level, undertaken by earlier ethnographers (Burawoy, Roy, Madono, Sweet) becomes simply a portion of the larger jig-saw puzzle. At the other end of the spectrum, a host of investigations (Sabel and Piore, Amsden, Chen) in the machine tool sector illuminate the utility of a wider global production network lens. Very importantly, these case studies are anchored in a geographical-historical account of the local genesis and evolution of industry within a transnational and global framework of commodity chain supply-and-demand activity. What's more, such case studies benefit from an understanding of dynamics occurring at the national and global levels, as elucidated through historical trend analysis of machine tool production and consumption datasets.

In order to most effectively make the linkages between these multiple scales of micro- and macro-level activity-- between on the shop floor; at the level of the firm; and with suppliers and customers, I propose an alternate level of study at a "meso" level, namely, in the selection of a targeted, regionally-bounded case study. It is at this level that the remaining chapters will engage the study of the San Francisco Bay Area's existing machine shops.

CHAPTER THREE ENDNOTES

[1] Krugman, P 1991 Geography and Trade Cambridge: MIT Press, PP. 3 – 4.

[2] For examples of spatial modeling see W. Brian Author's work at http://www.santafe.edu/~wbarthur/publications.html and Edward Glaeser's work at http://www.economics.harvard.edu/faculty/glaeser/papers_glaeser (accessed August 27, 2008)

[3] Lakoff G 2004, *Don't Think of an Elephant. Know Your Values and Frame the Debate.* NY: Chelsea Green.

[4] For an exploration of this history, see Lécuyer, C. (2005) Making Silicon Valley: Innovation and the Growth of High Tech, 1930–1970. Cambridge, MA: MIT Press.

[5] For example, see discussions in J. Bivens, "Shifting Blame for Manufacturing Job Loss," Economic Policy Institute, Briefing Paper #149. http://www.epi.org/content.cfm/briefingpapers_bp149 and J. Tatom, Manufacturing employment, productivity and the business cycle," IDEAS, University of Connecticut Department of Economics, http://ideas.repec.org/p/pra/mprapa/4351.html. Accessed June 6, 2008.

[6] Michael Mandel, "The Real Cost of Offshoring," and "How Those Deceptive Numbers Creep In," BusinessWeek cover story, June 18, 2007. www.businessweek.com/magazine/content/07_25/b4039001.htm Accessed June 30, 2007.

[7] S. Houseman, June 2006 Revised April 2007, "Outsourcing, Offshoring, and Productivity Measurement in U.S. Manufacturing, www.upjohninst.org/publications/wp/06-130.pdf. Accessed September 12, 2007.

[8] Customer sectors derived from NTMA San Francisco Bay Area chapter membership list, May 2004.

[10] In contrast with learning as internalization, a "community of practice" is defined as encompasses "learning as increasing participation in communities of practice concerns the whole person acting in the world" (Lave and Wenger 1991: 49). The focus is on the ways in which learning is 'an evolving, continuously renewed set of relations' (*ibid.:* 50).

[12] http://www.gardnerweb.com/consump/country.html#us. Accessed August 26, 2008.

C H A P T E R 4: Regional Dynamics of the Machining and Manufacturing Sectors

4.0 Introduction

The following chapter seeks to measure the share of number of firms, employment and business receipts in machining, relative to its base employment both locally, regionally and nationally.[1] To this end, the chapter establishes a quantitative evaluation of what is happening in the Bay Area machine sector to those in to describes firm, employment and business dynamics in machining, relative to the region's overall economic base, and that of other regions and the U.S.

Moreover, through a qualitative assessment of the sector's spatial and temporal patterns of growth and change, the chapter seeks to understand ways in which the sector contributes to the overall Bay Area region. In particular, it seeks to understand whether skilled machining activity such as machining in fact constitutes a form of "hidden innovation" which is not typically measured in innovation metrics including R&D dollars or patents.

4.1 Spatial Analytics of Machine Shops

In order to further understand the machine shop presence, we complement the aforementioned qualitative methods with the use of published statistics on business and employment trends in machine shops and allied manufacturing activities, in order to understand the dynamics of concentration and decline over space and time.

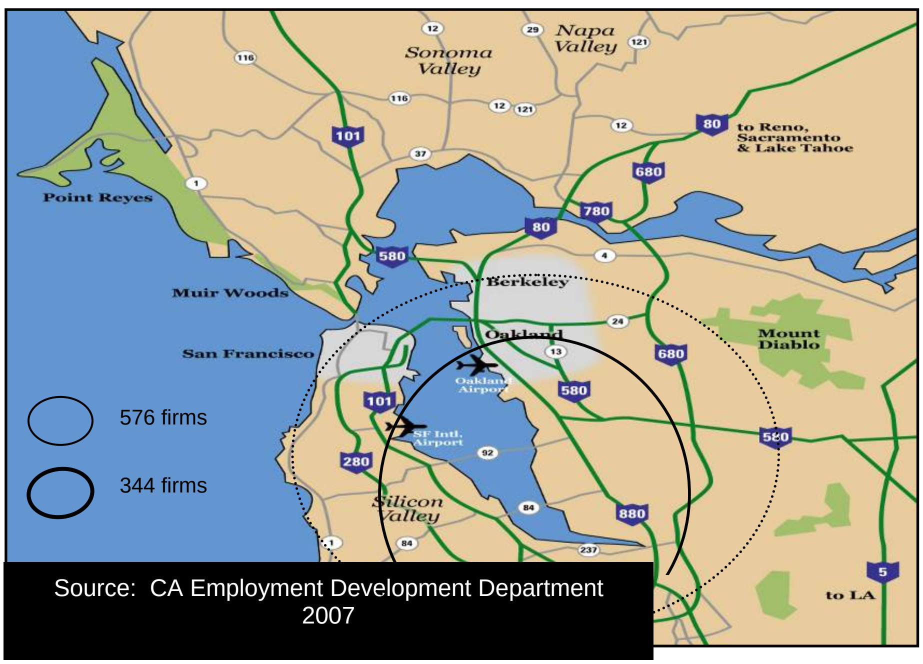
We pose the following questions

- How prevalent across time and space is the regional machine shop presence?
- What are characteristics of the firms (firm employment size, location and business receipts)?
- How does the regional machining presence compare with that in other regions?

4.1.1 <u>Firms are Geographically Concentrated</u>

A geographical survey of firm concentrations shows the presence of 576 firmsL

Figure 4.1 Bay Area Machine Shops, 2007



Source: CA Employment Development Department 2007

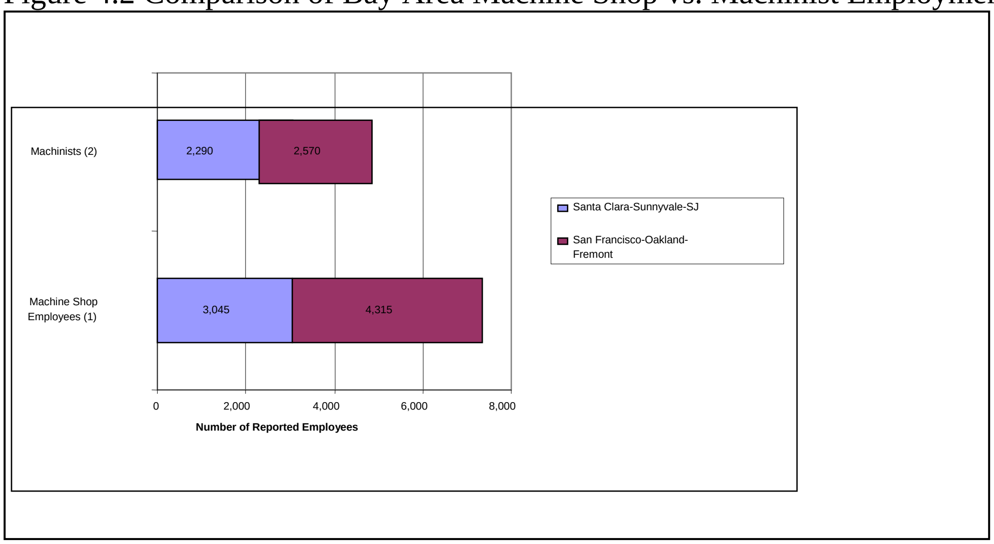
We see that the smallest concentric circle hosts nearly two-thirds of the region's machining firms (344 out of 576), illustrating the fact that innovation and machining are co-located. Located 50 miles south of San Francisco in Santa Clara County and Southern Alameda County, this area is known the world over as "Silicon Valley" encompasses Santa Clara and Southern Alameda Counties and has been aptly referred to as the largest geographical concentration of wealth in history.

4.1.2 <u>Comparing Differences in Machine Shop vs. Machinist Numbers</u>

There is a difference in report numbers of machinists in the Bay Area versus machine shop employment, for two main reasons: 1) machine shops employ an array of other employees and 2) machinists do not work only in independent shops.

Using different employment statistics, we can quantify the difference between the reported size of independent machine shop employment and the reported number of machinists employed in the Bay Area overall in Figure 4.2 below.

Figure 4.2 Comparison of Bay Area Machine Shop vs. Machinist Employment 2005



Sources: Bureau of Labor Statistics Census of Employment and Wages, 2005 and Bureau of Labor Statistics Occupational Employment Survey 2005

We see an approximate difference of 2,500 employees, or a 34% difference between the two reported statistics, which is accounted for by the fact that machine shops generate employment for many occupations beyond that of machining, ranging from machining-related occupations such as machine operator, to shop manager/owner, to marketing, sales and administrative staff. The difference between the numbers, moreover, points to the fact that machine shops are generators of employment for a variety of other occupations.

Moreover, the reported figure of 4,860 machinists cannot be entirely attributed to independent machine shops: an indeterminable number of machinists are employed by large custom manufacturers, related manufacturing and engineering companies, and research institutions. For example, anecdotal and archival evidence discussed in later chapters suggests that such large companies as Hewlett Packard, IBM, and Varian, still retain a handful of in-house machinists, as do national laboratories and universities such as Livermore and U.C. Berkeley. Additionally, public institutions such as the Bay Area Rapid Transit have their own in-house machine and welding shops, and employ machinists to maintain and repair train parts. While such local operations as BART maintenance and repair are arguably not as easily outsourceable, the shift in recent years has been for many of the private OEMs to dismantle in-house shops and increasingly to rely on contracting with independent firms for machining services, a trend discussed at length in the next chapter.

Using the latest Census PUMS and BLS occupational data, I estimate that of the approximately 5,000 machinists in the region, less than 1,000 are estimated to be employed in original equipment manufacturers, research laboratories, and universities and colleges doing research and development work.[2]

An example of a firm which utilizes multiple skilled manufacturing techniques in addition to machining is Haig Precision Manufacturing Corporation in Campbell, CA. Haig has more than 40 years experience in producing precision parts and assemblies for many different industries. Their capabilities cover a wide range of machining services to meet customers' needs, from prototype to fully tooled production. Additionally, though, Haig Precision's manufacturing capabilities also include electro-mechanical assembly, precision sheet metal fabrication, as well as tool and die development, welding, and powder coat finishing. In addition, they offer electronic discharge machining (EDM), stamping, and grinding

Other OEMs have their own in-house machining capabilities. Directed Light is a laser technology company serving the industrial, medical and scientific laser communities worldwide since 1983. Through their two business units, Laser Components Sales and Laser Job Shop, Directed Light serves the automotive, medical device, aerospace, electronics, semiconductor, commercial products, and telecom industries in many ways.

4.2 A Temporal Analysis of Firm Activity

We can employ location quotients, a simple yet powerful regional planning tool, to assess the relative concentration of the machine shop sector relative to its presence in other regions. The formula for location quotients which measures the comparative spatial concentrations of employment in specific industries relative to overall firms, employment or business receipts is listed below:

$$\frac{\text{Local activity in precision machining industry/Total local activity}}{\text{Reference region activity in precision machining industry/Total reference regionactivity}}$$

Because the region was in the midst of the technology boom in the last decade, I wanted to look back in time at least two decades. However, a historical analysis is complicated by a dearth of data: published data sources before 1997 do not utilize the same North American Industrial Classification (NAICS) industry codes used later, instead using the old Standard Industry Classification (SIC) codes. The NAICS codes, 332710 for precision machining, does not have a precise "bridge" with the earlier SIC code, 3599 (miscellaneous job shop).

Within the limitations of historical incomparability, an analysis of machining location quotients since 1987 shows that the Bay Area has remained consistently more concentrated than the United States in machine shop firm and employment activity. However, employment concentration for the region in 2005 declined by around 11% since 1987,. Firm concentration declined even more significantly, dropping from over twice that of the U.S. in 1987 to only 25% greater in 2005.

Figure 4.3 Bay Area Machine Shops
through Location Quotient (LQ) Analysis
1987 through 2005

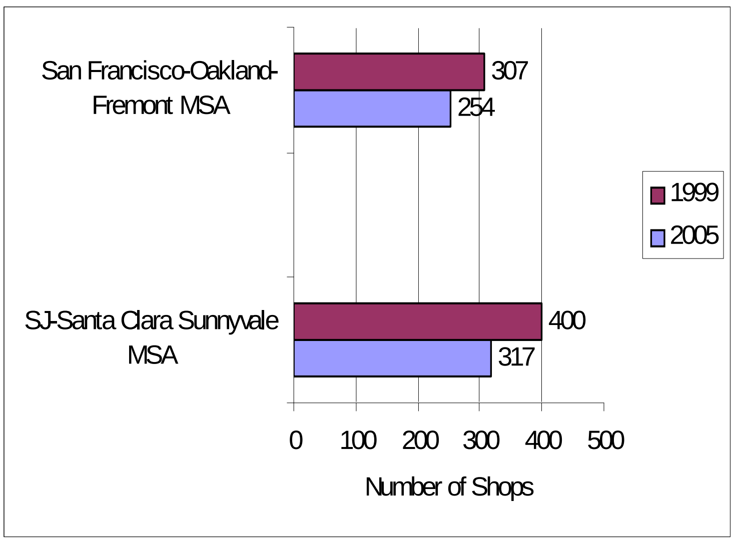
	1987	**1997**	**2005**
Firm L.Q,	2.16	2.11	1.24
Employment L.Q.	1.41	1.97	1.30

source: EDD County Business Patterns, 1987, 1997, and 2005.
calculations by the author

4.2.1 Firms & Employment Declined after Dot-Com Era

An analysis of the five-year period from 1999 to 2005 shows that the total number of machine shop establishments in the five-county region declined to 571 from 707 shops, or a 19% decline since the height of the region's high technology business activity. The steepest decline was in the San Jose Metropolitan Statistical Area (MSA), a decline of 83 shops (21%) in the following Figure 4.4.

Figure 4.4 *Number of Firms Declined 20% in latest 6 year period*



Source: Bureau of Labor Statistics Census of Employment and Wages, 2000 & 2005

4.2.2 Business Receipts Plummeted from 2000 - 2005

Along with decline in the number of shops and workers, the annual business receipts reported by machine shops in Alameda and Santa Clara Counties both fell in the double digits, by 11% and 13% respectively: higher than the U.S. decline of 10% in business receipts.

Figure 4.4 Annual Business Receipts of Machine Shops, 2000 and 2005

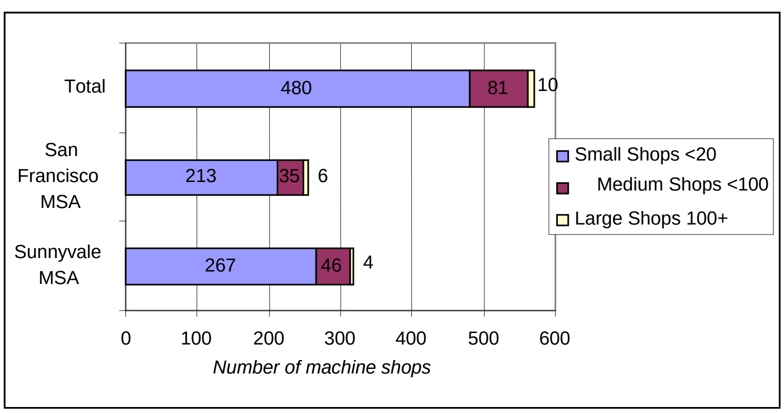
Payroll	1999	2004	% Change
Alameda County	$ 125,732,000	$ 109,824,000	-11%
Santa Clara County	$ 206,122,000	$ 162,390,000	-13%
U.S. total	$ 9,901,950,000	$ 9,445,884,000	-10%

Source: County Business Patterns 1999 and 2004.
calculations by the author

4.2.3 Small Shops Continue to Dominate The Sector

An analysis of machine shops in 2005 reveals that the majority (480 or 81%) are small shops with under 20 employees, illustrated in table 2 below. The remaining one-fifth of shops employ over 50 workers, with only 4%of shops (10) employing over 100 workers. Over half of all shops were located in the San Jose-Santa Clara-Sunnyvale Metropolitan Statistical Area (MSA).

Figure 4.7 Number of Machine Shop Establishments in 2005 by Employee Size



Source: Bureau of Labor Statistics Census of Employment and Wages, 2005.

Interviews with area shops, elaborated in later chapters, reveal that many shops went out of business after the height of the dot-com era in the early 2000s. Whether through shop closures or through layoffs in shops that remain, machine shop employment declined significantly in the five-year period from 1999 through 2004 throughout the Bay Area.

In particular, the San Jose MSA as depicted in Figure 7, saw twice the employment decline of the nation as a whole:

Figure 4.8 Machine Shop Employment in 1999 through 2004

	1999	**2004**	**% Change**
SJ-SC-Sunnyvale MSA	2,913	2,087	- 28%
SF-Oakland-Fremont MSA	4,539	3,520	- 22%
SF Bay Area*	7,452	5,607	- 25%
US	286,833	246,231	- 14%

Source: County Business Patterns 1999 and 2004.
*SF Bay Area is the combination of SJ-SC-Sunnyvale MSA & SF-Oakland-Fremont MSA

4.3 Machining Activity Constitutes A Small But Important Component of Regional Manufacturing

The precision machining sector itself is relatively small, comprising less than 900 shops and under 8,000 employees. In other words, only one in two hundred Bay Area workers is a machinist. A comparison of the size of the area's machinist population with other skilled manufacturing occupations reveal that machining is the most prevalent of highly skilled trades:

Figure 4.9

Machinist Employment Compared to Other Skilled Manufacturing Occupations

Occupation	Total	Percent
Machinist (514041)	**5,260**	**28.8%**
Machine Setters, Operators, Tenderers (514021-514035)	4,670	25.6%
Welders & Related Welding, Soldering, Brazing (514121 & 514122)	3,520	19.3%
Molding, Coremaking & Casting Machine Setters, Operators, Tenderers (514072-514081)	2,250	12.3%
CNC Machine Tool Operator (514011)	1,220	6.7%
Numerical Tool/Process Programmer (514012)	560	3.1%
Tool & Die Makers (514111)	630	3.5%
Total, Selected Skilled Manufacturing Workers	**18,240**	**100%**

Sources: Bureau of Labor Statistics Occupational Employment Survey 2005
Bureau of Labor Statistics Current Employment Survey 2006
calculations by the author

Similarly, an examination of the number of metalworking-related firms and occupations reveals nearly 1,300 shops and 23,000 employees, comprising a nearly 1% share of firms and workers in the 5-county Bay Area. By virtue of its wages and interactions throughout the manufacturing supply chain, machining and metalworking are an integral part of the region's overall manufacturing sector.

Approximately 9 in 100 of all Bay Area workers are engaged in what are classified by the BLS and Census as production occupations (BLS CES 2006): production work employs a wide swath of activity ranging from book binding to laundry worker.

Despite its dominance in the skilled trades, machining and metalwork-related occupations comprise a small portion of manufacturing in the area overall. In fact, most of the 142,000 production workers in the Bay Area (87%) are in non-metalworking manufacturing occupations, the majority of which are lesser-skilled and paid. The following table illustrates the difference in wages by selected production occupations in the Bay Area:

Figure 4.10 Annual mean wage in Bay Area selected production occupation, 2006

Production Occupation	San Jose-Sunnyvale	San Francisco
Bakers (513011)	$26,570	$27,490
Butchers & Meat Cutters	$33,640	$33,890
Bindery Workers	$28,180	$30,700
Job Printers	$45,190	$47,440
Machine Setters	$32,300	$31,570
Semi-Conductor Processors	$40,990	$31,150
Machinist	$43,720	$45,240

Source: Bureau of Labor Statistics Current Employment Survey 2006
calculations by the author

We see that, at $43,720 and $45,240, machinists are the second highest paid of a cross-section of production workers, after job printers, and well above bakers, meat cutters, and bindery workers.

4.4 The Bay Area Hosts a Comparatively Large Machining Presence

Relative to the State of California, the Bay Area hosts a disproportionately high share of employment in machining, relative to its base employment—a concentration 30% higher than that of the nation, and of the State.

Figure 4.11
Comparison of Economic Base Analysis for Machine Shop Employment (NAICS 332710 2004)

	SF Bay Area*	**California**	**United States**
Machine Shop Employment	7,360	29,862	254,418
Overall Employment	2,357,242	12,877,961	110,611,016
Location Quotient	1.30	1.01	1.00

Data Source: Bureau of Labor Statistics, Survey of Wages and Occupation, 2005. *Calculations by the author.*
* San Francisco-Oakland-Fremont MSA
and Santa Clara Sunnyvale-San Jose MSA

A comparative look at employment concentrations in other US metropolitan regions employing the same methodologies reveals the following: the Bay Area hosts a larger and more concentrated employment in the machine shop sector than other regions. The former is twice as concentrated in machining as Chicago and Los Angeles, and over four times that of the Seattle, Washington, respectively. The Rochester, NY area is the real outlier, with nearly 3 times the concentration of machining as the nation as a whole. Bear in mind, however, that both the employment in the sector and the overall employment in that metropolitan area are considerably smaller than the Bay Area:

Figure 4.12
Regional Comparison of Employment Concentrations in Machining

Metro Statistical Area (MSA) Employment	San Francisco Bay Area*	Rochester MSA, NY	Chicago-Naperville-Joliet MSA	Long Beach, CA MSA (LA)	Seattle-Tacoma, WA
Machine Shop Employment	7,360	2,616	10,884	13,062	2,277
All Employment	2,357,242	416,521	3,739,636	4,855,575	1,353,945
Location Quotient	**1.30**	**2.73**	**1.27**	**1.17**	**.73**

Source: Bureau of Labor Statistics, Survey of Wages and Occupation, 2006

Moreover, Figure 4.13 below illustrates that this sector's employment and business location quotients relative to other "innovation regions" (as measured by number of patents) reveal a positive, albeit not linear, association between precision machining and high technology activity as measured by patents. The reason for this association is beyond the scope of this dissertation. Nonetheless, Santa Clara County, at the heart of Silicon Valley, has both the highest concentration of machining employment relative to its overall employment, compared to other regions, including Monroe County, at the heart of the greater Rochester, NY area.

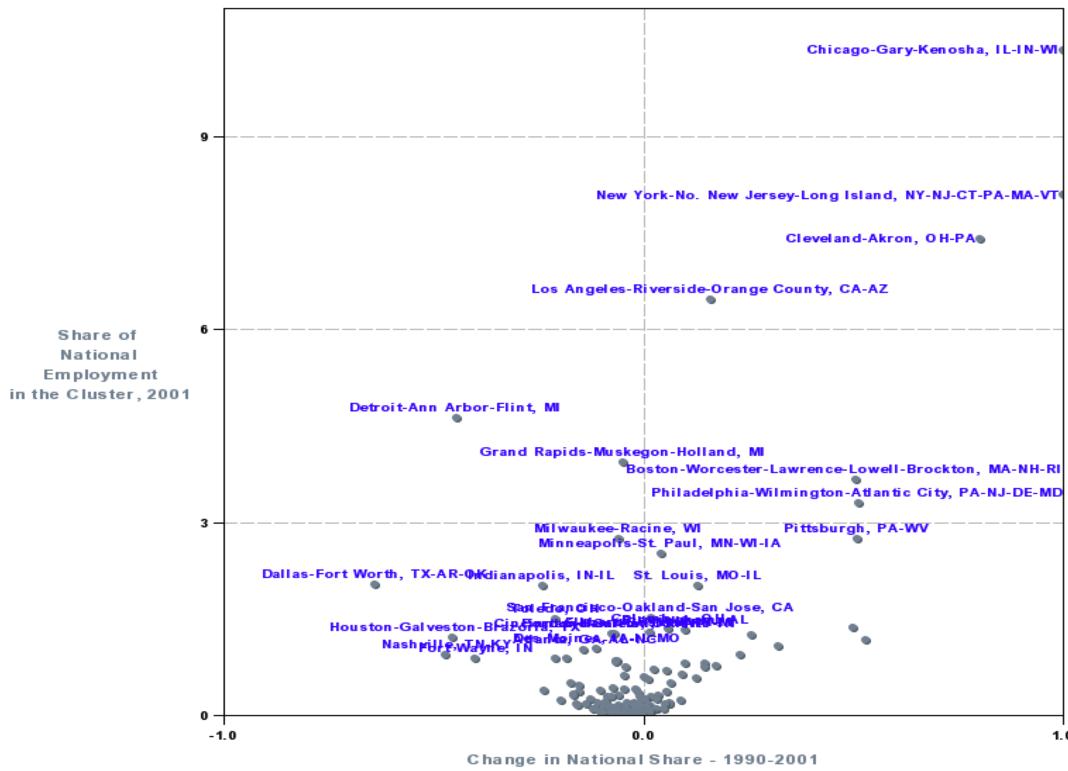
Figure 4.13 Machining Activity by Counties, 2005.

Region	Santa Clara County	Middlesex County, MA	Orange County, CA	Monroe County, NY	Travis County, TX	Durham County, NC
Machine Shop Employment	4,315	2,076	4,251	1,654	313	79
Base Employment	766,343	706,872	1,344,072	332,547	513,107	151,985
Employment Share	0.56%	0.28%	0.32%	0.50%	0.06%	0.05%
Location Quotient	2.45	0.93	1.38	2.16	0.28	0.23
Patents per 100,000 population*	1,654	1.651	1,473	1,358	736	148

Sources: BLS, Survey of Wages and Occupation, 2004. (NAICS 332710) and U.S. Patent & Trademark Office, 1999. *Calculations by the author*
*Note: Patents per 100,000 are employed as a proxy for counties with the highest rate of innovation.

Machining is also a sector which is “exportable” and not tied to its local economic base, unlike such service and retail industries such as barbering or residential realty, or other less skilled but localized manufacturing activity such as electrical wiring. Michael Porter of the Harvard Business School defines such a “traded” industry cluster as one in which manufactured products and services are exported outside of the regional economy, thereby bringing in net revenue to the region. While some machine shops may provide parts and services solely or primarily to vendors in the local area, they are also active participants in extra-regional trade activity. The “exportable” nature of machining, moreover, situates the sector squarely within the increasingly interconnected web of production spanning regions across the globe. Porter’s Cluster Mapping database housed in the Harvard Institute for Strategy and Competitiveness attempts to quantify the extent of this interconnectedness by comparing shares of an array of sectoral clusters across regional economies. The chart below indicates that San Francisco Bay Area (both economic and metropolitan regions) comprises the second largest growth in employment share of Metal Manufacturing clusters in the Western United States: behind only Southern California, and ahead of the greater Seattle-Tacoma region as well as the Portland, Oregon area.

Figure 4.14
Precision Manufacturing Cluster
Change in Share of National Cluster Employment by Economic Area, 1990 - 2001

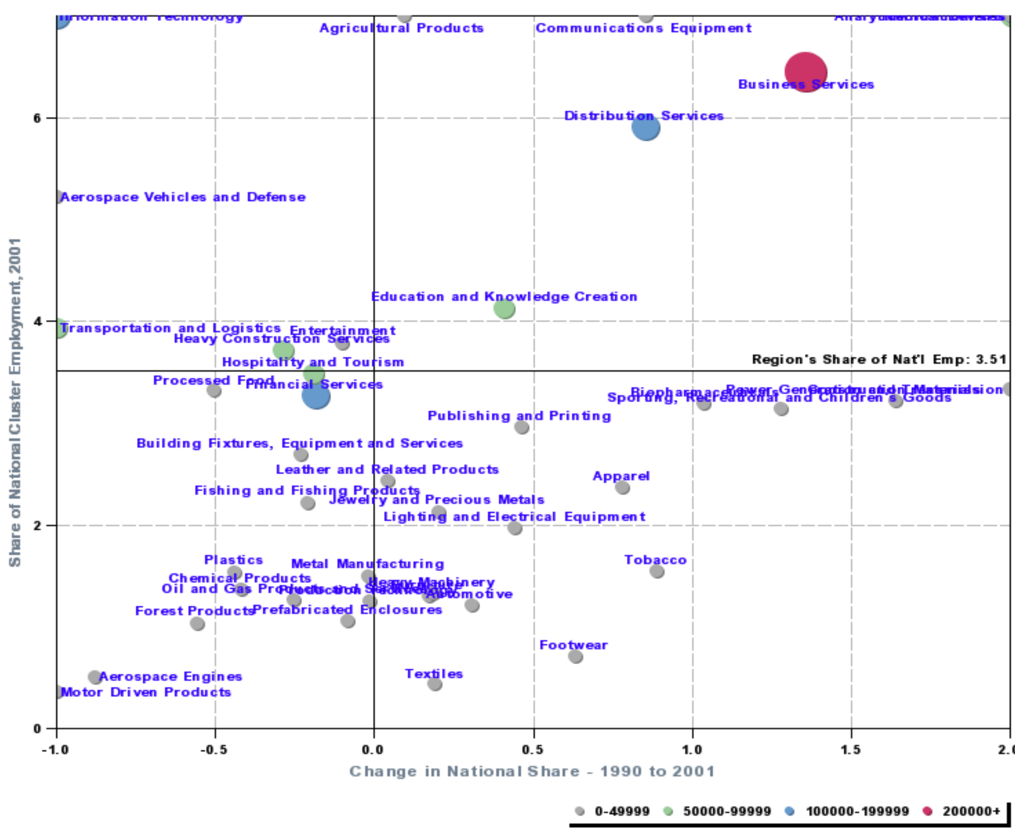


Source: Cluster Mapping Project, Harvard Institute for Strategy and Competitiveness, 2004.

Across regions, the greatest gains in national share of precision machining activity in a recent eleven year period were in the greatest growth in the three state region of Chicago-Gary-Kenosha (IL-IN –WI) hosting the second largest growth nationally, with the defense-oriented economic region of LA-Riverside-Orange County (CA-AZ) leading in employment growth in the Western/Southwestern United States .

Meanwhile, the metal manufacturing captured 3.5% of the nation's entire employment in that employment cluster in a recent 10-year period (Figure 4.15 below), but has not grown as rapidly as the area's activity in business, financial, distribution and knowledge creation services.

Figure 4.15 Change in Bay Area Employment Specialization by Cluster, 1990 - 2001



Source: Cluster Mapping Project, Harvard Institute for Strategy and Competitiveness, 2004.

Despite its relative strength compared to other regions, the machining sector's absolute decline over three decades, is incontrovertible. Therefore, I sought to understand these numerical trends through examining the question of why shops have left the region:

4.5 Four Propositions On Why Shops Are Leaving

Although nearly 600 shops remain in the area, hundreds of others have gone out of business in the last 20 years. Through discussions with shop representatives, I traced four key reasons for shops' departure:

Proposition One: Emerging technologies lessen the importance of local machining;

Proposition Two: Machining Has Grown More Competitive

Proposition Three: Machine Shops Suffer from "Not in My Backyard" Perspectives; and

Proposition Four: The Machining Sector Faces Difficulties in Recruitment and Training

Proposition One: Emerging Technologies Lessen the Importance of Local Machining

Emerging Technologies Lessen the Importance of Local Machining

The emergence of computer assisted design technologies have assisted in the flattening world of machining, a phenomena which is as much a blessing as a bane for regional shops. For example, though San Jose's Laser Machining Center planned a move to Alameda County, it sought to mitigate distance from its supplier base in Silicon Valley by maintaining a comprehensive presence online, and plans a professionally re-designed web page. The move was prompted in part by the relatively cheaper rents in Alameda County, a fraction of the $8,000 a month for a 7,800 square foot property in Santa Clara. In San Leandro, Jim Christefferson, owner/founder of the Laser Machining Center, will be closer to his residence in the city of Alameda, and pay only $2,800 for larger space. Additionally, power is less expensive and small businesses such as his face a lower tax base in Alameda County. Mr. Christeffersen estimates saving about $25,000 a year.

However, Jim Christeffersen also confided his concern about the loss of face to face time with his Santa Clara customers. Given the riskiness of this move, he finds the need to increase his phone interactions with the customer base remaining in Silicon Valley, ranging from Agilient to Boeing and the Valley Transit System. Alameda's business tax rate, also, was noted to be much lower than Santa Clara's. Moreover, despite the latter region's jobless growth recovery of the past three years, commercial rents had not declined commensurately. The other big rationale for the move up north was because of the proprietor's residence was in Alameda. Nonetheless, Jim Christefferson, revealed his nervousness about the physical distance from customers and spoke about being on the phones with them more to offer reassurances.[3]

The downside of emerging information technologies is that shops can pick up and go not only across town, but can in fact be across the country and the world. To illustrate, at Emachineshops.com customers can upload their complex design specifications to a shop in New Jersey, and the parts for things like door signs, motorcycle seats, robot frames, car engine covers, guitar plates and camera parts (whether one or thousands depending on your demand), will come back to you shipped in a timely fashion.[4] The website is but one example of the ability of virtual shops to respond to customer demand by offering very detailed and careful specification selections, and providing timely services at reasonable prices.

Despite the rise of emerging technologies such as improved computer-assisted design, the Bureau of Labor Statistics notes that:

> Technology is not expected to affect the employment of machinists as significantly as that of some other production workers, however, because machinists monitor and maintain many automated systems. Due to modern production techniques, employers prefer workers, such as machinists, who have a wide range of skills and are capable of performing almost any task in a machine shop.[5]

The question is, but where? Despite the assurance that machining services and machinists are still important, these trends serve to illustrate that local machining activity is indeed not irreplaceable.

Rapid Prototyping Technologies Replace "Subtractive" Machining

Another factor lessening the role of machining are new technologies which are supplanting the role of both traditional and new forms of machining. Whereas both traditional and CNC machining are "subtractive" endeavors wherein metal and plastic is shaven away by a machine tool, emerging computer-aided prototyping technologies are "additive" in nature. These new technologies are increasingly being used by a range of OEMs, particularly those who may require less precision parts than offered by traditional and CNC machining. Rapid prototyping is used in building physical models and prototype parts from 3D computer-aided design (CAD) and medical scan data. Unlike CNC machine tools, which are subtractive in nature, these systems join together liquid, powder, and sheet materials to form complex parts. Layer by layer, they fabricate plastic, wood, ceramic, and metal objects based on thin horizontal cross sections taken from a computer model. [6]

The use of rapid prototyping varies widely by specific OEM industries-- for highly precision-oriented industries such as emerging nanotechnology and clean technology, for instance, the exacting tolerance required in parts production does not allow for computer-aided prototyping. Rapid prototyping is typically more popular in larger-scale industries such as automotives.[7] Still, these OEMs may in turn employ individuals with machining skills to do the prototyping work; moreover, the addition of prototyping technologies to the shop floor would add value to the work of machine shops themselves.

Proposition Two: Machining Has Grown More Corporatized and Globalized

Some Shops Have Shifted to Corporate Business Practices

Machinists spoke of the erosion of long-standing customer relations based on trust and history, as both shops and customers have evolved towards increasingly corporatized and globalized business practices. Several machine shops in Santa Clara and San Jose, pointed repeatedly to the bankruptcy of the mammoth Western Tooling Company (on Walsh Avenue), which went out of business in 2005, as an example of an unsustainable business course. The shop was one of the largest players, and present at Walsh Avenue for over 20 years; and was doing double shift at one point, shipping $7 - $10 million dollars of machined products a year.

A number of shops pointed to the corporate ownership of the long-standing shop as a problem: quite simply , the new owners were much more interested in the bottom line of quarterly earnings than the sustained values of good machining and service to customers. The shops regarded the bankruptcy of Western Tooling and subsequent "fire sale" of parts at a local auction, as an example of the greed and short-sightedness of short-term earnings over sustained business practices based on trust and loyalty with clients and employees. Machine shop owners pointed not only to the lack of business savvy on the part of Western, but also to the impersonal ownership of the company by an outside corporation comprised of non-machinists concerned only about quarterly financial statements and the bottom line.

The corporatization of machining is also driven by shop customers. One particular strategy which OEM customers such as Applied Materials have increasingly utilized, and which has drawn the complaints of its vendors, has been to separate their lists of prototype vendors from their volume vendors.[8] This has been a source of consternation and frustration for machine shops. Shops want not only to collaborate with their customers on the design and prototyping of machining parts; they also actively want to land the contract for the first-run and volume production which arises from the initial design and prototype work. Shops confided that they have in the past subsidized the design and prototyping work, deliberately keeping prices low so that they can land the volume contracts; however, this is a strategy that does not pay off in the current OEM strategy of separating vendors by design and volume.

Certainly, though, big players such as Applied Materials are not the only ones rationalizing design and production. Other OEM customers also routinely "play that game" when they are doing larger volume orders: Shops strive to be competitive , so "we find that they often ask whether they should be bidding higher or lower in order to get the job." However, OEM customers generally do not rely heavily on quoted cost: although shops may underbid for the onesie/twosie in the hopes of getting the volume contracts, "there are always (hidden) setup costs."[9]

Shop Competition is Increasingly Global

Aside from corporatized business practices, the other primary challenge that both shop representatives and their OEM customers spoke about was the increasingly "flattened world" of global production and competition. Such well-known and established Original Equipment Manufacturers as Caterpillar, U.S. maker of tractors and combines, are increasingly buying parts overseas from such countries as Italy. One such Italian company, Enterprise, is a big engine company which can provide spare parts for 1,000 large tractors as quickly as any competitor based in the United States.[10]

Meanwhile, in the relentless pursuit of timeliness, quality and cost efficiencies, Bay Area based Sun Microsystems utilizes "proposal-based" bidding system for local machine shops to compete for jobs. Under such a system, shops compete based on a comprehensive package, including the Request for Quotes (RFQ) and Request for Proposals (RFP) procedures. These procedures have grown increasingly more extensive, with comprehensive expectations that bidding machine shops will submit and compete on the basis of a comprehensive statement of work. This is expected to include an outline of very definitive product and parts specifications; quality goals and metrics; product and parts volumes; and team members' resumes, which will help with understanding advantages and can provide identification for possible weaknesses in specific areas.[11]

Sun Microsystems encourages suppliers to propose alternatives to their proposed plan, taking advantage of local, sub tier suppliers and the use of local knowledge, capabilities and materials. Sun's de Millenary characterized manufacturing capacity in developing regions in East Asia (China, Taiwan, South Korea) as "young, talented and able to execute," contrasting these with firms in developed regions (Europe, US) which were "… risk adverse and …may not be as aware of new technologies."[12]

Clearly, the Bay Area must vie with these and other information technology innovations which have made machining services available from virtually everywhere in the world. An OEM or other customer can now put a bid on the Internet, and if a supplier is in Singapore or China, that is where the order will go. According to Darren Kim, head of Echelon's mechanical department, shops in Korea and southern China are as technology-savvy and capable as their Bay Area counterparts, whether in the use of Solid Works or 3D imaging, and in sending renderings electronically.[13] Moreover, IT savvy is combined with the availability of cheap, flexible labor-- according to past president of the Bay Area Chapter of the NTMA Don Burdon, Chinese machine shops are up and running on a round-the-clock, 24 hour basis, with employees living in dormitories nearby.[14]

In this outsourced world, employment and environmental standards are increasingly difficult to regulate. Bonnie Gardiner, the director of ethical sourcing for Hewlett Packard, acknowledges the challenges of assuring conformance, noting that HP's program is mainly focused on its 400 direct, "first tier" manufacturing suppliers, with which the company has contracts.[15] However, the company does not have contracts nor visibility to second, third or fourth tier suppliers, including Oakland's General Grinding, Santa Clara's Adem LLC, or with overseas machine shops, who are selected and managed by such first-tiered companies as Hayward's D&H Manufacturing. Consequently, it is much more complex to monitor and enforce social and environmental responsibility with these suppliers.

In a quest to rationalize costs and efficiencies, Original Equipment Manufacturers have also been increasingly getting rid of their machining vendors, thereby keeping innovation in-house. OEM customers are increasingly conducting their own design work and fanning production out to mass production vendors, a trend counter to the "quality craftsmanship" approach which has been the proud hallmark of the machine shop sector. For instance, Beckman Instruments, a major producer of high-speed centrifuges, has their own in-house machine shop. They also outsource to a vendor, but mainly as a backup.[16] Bay Area machine shop owners noted a concomitant reduction in their workforce, staffing hours, and even in the number of machine shops, given OEM's practice of in-housing machining services.

Proposition Three: Machine Shops Suffer from "Not in My Backyard" Perspectives

Urban Land Competition

Machine shops in Oakland and in Santa Clara complained about 'NIMBY" land use dynamics, wherein their more recently arrived residential neighbors actively complained to local government authorities about noise and activity emitted from the shops. Joseph Grabnow, a shop sales representative from Oakland's Diamond Tool and Die, voiced concern about the land use conflicts with nearby residences and live-work units. Described the long-standing, forty-year history of the firm at its location on 29th Avenue in West Oakland, Grabnow cited complaints among residential neighbors concerned about their property values.[17]

My walk-through of the surrounding West Oakland neighborhood in the Fall of 2006 confirmed the extent of live-work housing versus industry tensions, with brand new residential “lifestyle” lofts sprouting up in a noise- and heavy traffic-filled, predominantly industrial zone.[18] When queried about the role of government involvement, shops expressed skepticism that increased public involvement would do much good for their businesses: shops were viewed solely as private ventures which did not need the encumbrances brought about by government assistance or intervention.

However, there were variations within this general theme. Shop owners’ and employees’ responses ranged from that of proprietor Philip Pham, who was actively involved with the current Governor’s committee on promoting a regulation-free business climate,[19] to the sales manager of East Oakland’s Diamond Tool and Die, Diamond Tool and Die management turned their concern into action by monitoring the price of utilities charged to industries, and voicing concerns to local officials about shop owners’ perspectives on land use conflicts.

Industrial Zoning Policies

High property values in the Bay Area are driving local developers to convert industrial land to housing, retail and office space. Nonetheless, both governmental and nonprofit community groups have been grappling with ways to preserve industrial jobs while promoting other types of development. Figure 4.15, below, illustrates the status of industrial zoning controls in 11 major U.S. cities: all 11 cities, including San Francisco and Oakland, contained industrial protection zoning of some form in its land use regulations. Over half of surveyed cities, including SF and Oakland, permitted zoning controls on office and retail uses. However, none of the cities permitted zoning controls on housing, with only 2 cities permitting such controls provisionally.

The evolution of each cities' land use controls is rooted in particular sets of historical circumstances. In the Bay Area, the City of San Jose's industrial protection efforts came on the heels of 18 years' worth of losses of what planners dubbed "employment land," those uses of land which generated jobs.

Figure 4.15
A survey of industrial zoning controls in 11 U.S. cities

	Industrial Protection Zoning	Housing	Office	Retail
San Francisco	Yes	Not permitted	Not Permitted	Permitted
Boston	Yes	Not permitted	Permitted	Not Permitted
Chicago	Yes	Not permitted	Not Permitted	
Cleveland	Yes	Not permitted	Conditional	Not Permitted
Los Angeles	Yes	Conditional	Permitted	Conditional
Minneapolis	Yes	Not permitted	Permitted	Not Permitted
New York	Yes	Not permitted	Permitted	Not Permitted
Oakland	Yes	Not permitted	Permitted	Permitted
Philadelphia	Yes	Not permitted	Permitted	Not Permitted
Portland	Yes	Conditional	Permitted	Conditional
San Jose	Yes	Permitted	Permitted	Permitted
Seattle	Yes	Not permitted	Not Permitted	Not Permitted

Sources: San Francisco City Planning Department, City of Seattle Planning Department, San Jose City Planning Department.
Modified from: http://communityinnovation.berkeley.edu/presentations/industrial/Laurel-Prevetti.pdf

Cumulatively, SJ planning director Laurel Pravetti estimates between 68,000 - 110,000 jobs lost in this span of time, or roughly 9% of all employment lands.[20] Although San Jose plays a pivotal role in the valley as a “bedroom community,” its loss of employment lands translates into revenue shortfalls.

San Jose’s framework in 2007 for stemming the loss of employment lands includes a strategy to discourage conversion in key employment areas; as well as “sustainability” objectives, including the encouragement of mixed site uses at transit notes and the facilitation of regional solutions.

Fifty miles north in San Francisco, the Board of Supervisors established an advisory board in 2005 on the issue of preserving small and medium businesses, including light industry. The establishment of this advisory board was the brainchild of Supervisor Sophie Maxwell, a local politician long employed as a union electrician,[21] Maxwell’s district covers much of the City’s industrial lands and her office was inspired by the Back Streets Program in Boston as a potential model to help San Francisco resolve tensions around land use issues.[22]

Dubbed the Back Streets Businesses Advisory Board, the committee focused on medium-size industrial or commercial businesses that create products or provide services in manufacturing, wholesale, commercial, logistics, construction, repair and food processing. Such “back street” businesses contrast to “Main Street” office and retail businesses, which typically sell previously prepared materials or provide services directly to consumers. The focus on “back street” businesses is consistent with the Planning Department’s definition of “Production, Distribution and Repair” (PDR). The board’s recommendations for a range of policy and programmatic strategies to retain and expand Back Streets Businesses was submitted to the Board of Supervisors in December 2007.[23]

Across the bay in Berkeley, a coalition of artisanal and manufacturing businesses, the West Berkeley Artisans and Industrial Companies (WBAIC), recently defended the existing West Berkeley plan. Speaking out recently against a proposed tax assessment vis-à-vis a Central Business District/Business Improvement District in that neighborhood, representative Rick Auerbach spoke out at a October 2007 town hall meeting against the profiteering which occurred when properties changed hands and the tax was levied: “This group makes its living when properties change hands for ever-higher land values….the present West Berkeley plan, the lifeblood for industries, artisans and the residential community, is seen by them as an impediment to these efforts.“[24] WBAIC’s position highlights the gap in divergent interests between residents and small businesses on the one hand and the large property owners who would benefit from such a tax assessment.

In the San Francisco Bay Area, then, various efforts at stringent industrial protection zones in the Bay Area have yielded mixed results owing to competing pressures for residential housing and commercial development. The issue of industrial land conversion is driven by urban planning challenges and solutions to balancing supply and competing demands; the industrial land fights also illustrated the inherent politics of and monetary interests involved in converting industrial lands.

Proposition Four: The Machining Sector Faces Difficulties in Recruitment and Training

Anticipating a Wave of Retirements

Machinists are older than the the average Bay Area worker, a difference of seven years. Census public use micro data at the 1% level for the year 2000, the most recent year for which data was available, reveals that machinists are on average 42 years old, compared to the average age of 34 for all workers in the San Jose metropolitan area.[25] Indeed, many of the family-owned shops are proprietors who had been in the business for thirty years or more, and were looking forward to retirement. Ed Guerneville of Bear Machining, who had been working in the trade since he was 18, was already transitioning into semi-retirement, by focusing increasingly on his avocation of wine-making and turning his interests away from the daily operations of the business which he had built. Moreover, Guerneville's children are not following in his footsteps; indeed, only a minority of the machinist-owners I encountered had offspring who were planning to work in the machining industry, let alone inherit the family business.[26]

Retirees Are Not Being Replace

The generational gap between the few young machinists and preponderance of older machinists is apparent. For example, one machine shop employee of a small laser machining company in the South Bay is the college-age son of the proprietor. Noting how seductive it would be to go across the street to work at EBay, the machinist nonetheless noted that machining was a "fun and easy" profession which he wanted to pursue. Nonetheless, his biggest complaint was not being taken seriously as a young person in a profession dominated by aging baby-boomers.[27]

A long-held tradition of children following in their machinist father's footsteps has been quietly eroding, as the youth no longer want to go into the manufacturing trades. Out of thirty shops that I interviewed, I only counted two instances of shop owners' children indicating a desire to take over the family business. Jeff Christeffersen of Laser Machining Center, among this minority of young machinists working with their fathers, noted that he was the only one in his entire high school in the city of Alameda) who was going on to do machine shop work; indeed, many of his college classmates do not understand what machining is and why he would want to pursue it. Jeff's father proudly notes his son's intellectual acumen, noting that in the 1980s, Jeff was recruited as a subject with the UC Institute on Human Development's child psychology program, and identified as "gifted and talented." However much the son enjoys the work and would like to follow in his father's footsteps, however, Jeff shared his pessimistic about his standing as a young person in the machine shop world. He noted that due to his age he often has a hard time being taken seriously by other machinists.

Despite its relatively high wages, it is difficult to compete in salary with other industries, as jobseekers are pursuing more lucrative jobs to afford Bay Area living. Alloy's owner commented that the industry is leaving the city and machine shops are disappearing with it. Other machinists also cited the Bay Area is such an expensive place to do business; and that commercial rents, business utilities, and housing costs are all inordinately high.[28]

Shops indicated, and surveys of the shop floor confirmed, that a significant volume of the machinist workforce is nearing retirement age and is not being quickly replaced. In part, shops are reluctant to quickly hire and then lay off employees, given financial penalties associated with high staff turnover from state income security programs including Worker's Compensation and unemployment insurance. Another source of concern about labor supply is that high employee turnover adversely affects the bottom line. Max Ho of WEMA explains that the firm's biggest worry is balancing cyclical workload against consistent payroll. The firm must pay its employees, even when contracts are not coming in the door; or, it will risk having to lay off workers. Layoffs not only adversely affect the company when work picks up again, and trained talent is lost. The payroll tax system in California is also a disincentive against layoffs during downturns, as the tax rate incrementally goes up each time a worker files for unemployment.

The majority of shops I interviewed spoke with echoed the sentiments of one shop owner in San Francisco, that supply did not meet shops' demands for trained workers. For over 70 years, American Alloy Welding & Machine Co. in San Francisco has carved a niche with specialty welding. Despite having work, the proprietor but he is having a hard time hiring employees because knowledge of the trade is a necessity. "It's hard to come in green….We find we don't have time to teach them. Most of the high schools have dropped machine shop so there is no such thing as trade schools anymore."[29]

Several machinists spoke of their college age children choosing going into professions which were regarded as much more stable and lucrative, particularly in the abundant IT and biotechnology opportunities in the area. The proprietor of Jay's Machine Shop of San Francisco expressed his concern over his son's choice to go into computer engineering, noting that the wave of off-shoring was already underway in that field.[30] Another retired machinist lamented that among youth contemplating a move into production occupations, "driving a forklift at the hardware store" was too often regarded as a visible and easy alternative.[31]

Despite the value provided by machining instruction, the choice of machining as a career path is still not an attractive one. Kathy Werle, Dean of Applied Sciences at San Jose City Colleges, notes the uphill battle:

> "People worry about (the longevity of) their careers, and are increasingly going into (the) health (care sector) because they're afraid of offshoring.[32]

Werle's words offer a supply-side perspective to what is often regarded as a demand-side dynamic (see earlier discussion in Chapter 4, at 4.4.5). Although machining instruction has long been part of the established curriculum at the community college and high school levels, the programs have been greatly cut because of lessened demand on the part of students, which in turn is due to perceptions and fears of offshoring. Another indicator of lessened demand occurs earlier on in the educational pipeline: many high schools in the Bay Area are eliminating shop classes, with only a handful of schools still maintaining a full-fledged machine shop program.

Public Training Funds Have Been Awarded Non-Competitively

The lack of public support for machine shop training is not only a local problem, but extends to national efforts. Despite an increasing focus on machining as a "high growth" area by public agencies including the Bureau of Labor Statistics and the U.S. Department of Labor, the interventions to strengthen the role of machinist training have been ineffective.

On Labor Day 2003, President George W. Bush delivered a speech in Ohio about his administration's efforts to close the skills gap in advanced manufacturing industries before a group of operating engineers:

> "The High Growth Job Training Initiative in this administration is aiming to give workers the skills they need to realize their dreams. It's a collaborative effort to help team up people with the jobs that are needed, to make sure that the changes in our economy don't leave people behind."[33]

To put this approach into action, the High Growth Job Training Initiative identified 14 sectors that fit within the following stated criteria: (1) they are projected to add substantial numbers of new jobs to the economy or affect the growth of other industries; or (2) they are existing or emerging businesses being transformed by technology and innovation requiring new skills sets for workers. The following table illustrates the industries which are targeted by this initiative:

Table 4.16
Industries Targeted by High Growth Job Training Initiative

▪ Advanced Manufacturing	▪ Geospatial Technology
▪ Aerospace	▪ Health Care
▪ Automotive	▪ Homeland Security
▪ Biotechnology	▪ Hospitality
▪ Construction	▪ Information Technology
▪ Energy	▪ Retail
▪ Financial Services	▪ Transportation

Source: The President's High Growth Job Training Initiative: About the Initiative. [34]

A 2007 nationwide audit of the High Growth Job Training Initiative revealed that the three- year program, intended to help disadvantaged youth and workers develop useful skills in the new economy, has instead ended up being awarded non-competitively with little justification. The Congressionally-approved independent watchdog of the Labor Department, the Inspector General, found that over the previous six years, the Employment and Training Administration, headed by a political appointee, Assistant Labor Secretary Emily Stover DeRocco, awarded 157 nationwide grants totaling $271 million under that program. Only 23 grants totaling $29 million were awarded competitively. Fully 87 percent of the funds were handed out without any competition.[35]

The Center for American Progress, a Washington, D.C. think tank, noted that while the High Growth Job Training Initiative represents less than one percent of the almost $10 billion a year budget under DeRocco's control, it also "..appears to represent only a small portion of the total non-competitive grant activity in which DeRocco has been engaged." The Center goes on to state:

> "It is equally disturbing that these practices have apparently been taking place for most of the nearly seven years that DeRocco has served as Assistant Secretary for Employment and Training and are only now being uncovered."[36]

DeRocco, the senior executive identified by both the Inspector General's report, resigned shortly in late 2007 after the publicity surrounding the high growth job training initiative, but defended the administration's non-competitive procedures, noting that they were not required under Federal regulations. DeRocco also defended the administration's efforts in stimulating regional economies and in promoting high-growth jobs.[37]

In my own evaluation of the High Growth Job Training Initiative program, I also found inconsistencies and lack of transparency in the awarding of grants nationwide. Of the 36 nationwide programs awarded High Growth grants, two regional biotechnology training programs received among largest awards of $2 million each, [38] whereas the

National Institute for Metalworking, a Virginia-based non-profit, was awarded $1 million to provide training in machining for the entire nation. This occurred despite emerging evidence that biotechnology job-training programs have failed to find trainees the jobs they expect. As a job placement counselor with the non-profit Unity Council in Oakland, California (one of the locales awarded a $2 million grant), noted with respect to biotechnology , "People are getting training or high degrees in areas that are not supported by the job market." [39]

Moreover, although the Bay Area's biotechnology sector as a whole may be larger than the machine shop sector (68,000 workers) compared to machining (roughly 5,000 machinists, 18k machining-related jobs), 1) the size of the blue-collar opportunities available in biotechnology may not be-- the bulk of biotech work is in research services for highly skilled workers;[40] moreover, 2) lower-skilled opportunities biotech in the Bay Area has been cited for being increasingly outsourced overseas.[41]

True to the Inspector General's independent report, there is no documentation or systematic rationale provided as to how grants were awarded by area, nor proper justification for the amounts provided. Beyond highlighting the potentially inefficient governmental funds, the grant award process also highlights the perception of skilled manufacturing as a lesser career path than careers in what are often regarded as "new economy" industries including biotechnology, despite scant empirical evidence of the latter's success rates in job placements. Greater oversight and strategic planning of public training funds would provide greater overall success in employment training in the skilled trades, including machining-related occupations. Specifically, my review leads me to conclude that more transparency and strategic targeting based on systematic labor demand analysis is needed in awarding discretionary grants with taxpayer dollars.

4.6 Chapter Summary

I began this section by highlighting the paradox of a local and regional machine shop sector in a highly competitive, very expensive, otherwise service-oriented Bay Area economy . My inquiry included the use of quantification and enumeration to analyze a variety of published census and micro data survey. I found that machine shop presence is characterized simultaneously by *concentration* and *decline*, as measured by number of firms, size of employment, and business receipts. Nonetheless, machine shops still have a stronger presence in the Bay Area compared to other regional economies across the U.S.

Quantitative measures of *firm concentration* reveal disproportionately high share of employment and business receipts in machining, relative to its base employment -- a concentration twice that of the nation. Further comparative analyses of this sector's employment and business location quotients relative to other "innovation regions" reveal a positive association between precision machining and high technology activity. In particularly, the data suggests the machine shop sector is an essential, and comparatively over-represented, component of the production sector in the Bay Area compared to other regions. By virtue of its interactions throughout the manufacturing supply chain, machining activity in turn feeds in to the local high technology sector.

Accompanying the spatial dynamics of concentration, however, the data reveals *temporal patterns of decline*, as measured by double digit declines in the number of firms, size of business activity, and number of employees in the most recent five and ten year spans. The precision machining sector has declined significantly since the height of the dot-com era, when measured by number of firms (-19%), employees (-25%), and business receipts (-12%.), respectively. As measured by employment concentration, activity in the sector is significantly lower than (-11%) earlier activity in 1987. The remaining chapters seek to understand why this is so by positing hypotheses for testing. Nonetheless, taking reported data on its face value, the machine shop sector in the Bay Area is still comparatively large, 30% higher than the nation as a whole, and much higher than in other metropolitan regions including Chicago, Seattle, Los Angeles. Compared with other high technology regions including Research Triangle Park, Austin, and Boston Route 128, the Bay Area machine shop sector, particularly in the South Bay, is still over-represented. This suggests that a collocation between innovation and machining, but whether the association is causal or whether there are mitigating factors are questions for further exploration in the following chapters.

In order to understand these shifting patterns and associations, I interviewed and visited machine shops, OEM customers, local government officials, and business and residential neighbors and solicited the reasons for these regional dynamics. I both observed and was provided with a myriad of perspectives which I categorize into five general areas: 1) the logic of globalization and the politics of a "flattening world," wherein relentless technological and cost innovations in logistics management under globalization otherwise permit Original Equipment Manufacturing customers to increasingly turn elsewhere for sources of low-cost, quality customized machined parts; 2) the erosion of long-standing customer relations based on trust and history, as both shops and customers have adopted increasingly corporatized and globalized business practices.3) "Not In My Backyard" attitudes, perspectives and actions of machine shop neighbors, whether residents or other businesses, and local governments who have increasingly shifted land use zones from traditionally industrial uses to "higher and best uses" of scarce urban land; 4) a wave of "baby boomer" retirees in this sector, which are for the first time not being replaced by a traditional source of family members; and finally, 5) evidence that public training monies awarded nationally have been awarded non-competitively and with little justification or systematic analysis, to the detriment of sectors such as machining and advanced manufacturing.

CHAPTER FOUR ENDNOTES

[1] For purposes of discussion, the term "firm" is used as a substitute for the more precise term of "business establishments." Data on machine shop is drawn from the BLS Census of Employment and Wages and EDD/County Business Patterns which report on number of establishments: an employer can have one or more establishments. Each activity in a single physical location is reported as a separate establishment if separate records are kept and the various activities are classified under different NAICS industries.

[2] U.S. Census PUMS 1% data 2000 for San Jose Metropolitan Area; Bureau of Labor Statistics Occupational Employment Survey 2007.

[3] Jim Christoffersen (owner of Laser Machining Center), personal interview, October 10., 2005.

[4] http://www.emachineshop.com/company/about.htm, accessed March 26, 2006.

[5] http://www.bls.gov/oco/ocos223.htm, accessed 10/2/2007.

[6] Wright, Paul K. (2001). *21st Century manufacturing*. New Jersey: Prentice-Hall Inc. and Wohlers, T. (2007). *Rapid Prototyping Terms and Descriptions*, http://wohlersassociates.com/rapid-prototyping.html. Accessed June 30, 2007.

[7] Renu Malholtra (Hasselgren Automotives engineer), personal interview on July 26, 2007.

[8] The OEM business practice of separating its contracts for prototype versus mass production work was mentioned by representatives of three firms.

[9] Red Byer, Engineer, Mobius Photonics, Personal Interview, August 1, 2007.

[10] Don Bardon, Manager, General Grinding/NTMA past president, Bay Area chapter, personal interview, June 11, 2006.

[11] *Ibid.*

[12] *Ibid.*

[13] Darren Kim (Engineering manager with Echelon corporation), personal interview, August 21, 2007.

[14] Don Bardon, Manager, General Grinding, personal interview, June 11, 2006.

[15] Bonnie Nixon Gardiner, Director of Ethical Sourcing for Hewlett-Packard, talk and discussion entitled "From Green to Gold: HP's Social and Environmental Sustainability Program," inaugural lecture of the Graduate School of Business and Center for Socially Responsible Business, Mills College, September 11, 2008.

[16] *Ibid*.

[17] Joseph Grabnow, Sales Coordinator, Diamond Tool and Die, personal interview, June 6, 2006.

[18] Field survey by author of West Oakland neighborhood near 29th Avenue, 94601, June 6 2006.

[19] Philip Pham, Owner, Mission Welding and Machining, Personal Interview, August 2006.

[20] http://communityinnovation.berkeley.edu/presentations/industrial/Laurel-Prevetti.pdf, page 9 of 17.

[21] http://www.sfgov.org/site/bdsupvrs_index.asp?id=4641

[22] Made in San Francisco: Findings and Recommendations by the Back Streets Businesses Advisory Board to the Board of Supervisors and the Mayor, December 2007.

[23] *Ibid.,* pp. 5-7.

[24] http://www.webaic.org/ accessed October 18, 2007 and
"Residents, Small Businesses Oppose Business Tax," Berkeley Daily Planet, http://berkeleydailyplanet.com/article.cfm?issue=10-19-07&storyID=28253 accessed October 21, 2007.

[25] Analysis of 1%PUMS extract for San Jose PMSA, Census 2000.

[26] Ed Guerneville, proprietor, Bear Machining, Santa Clara. Personal Interview, May 2006.

[27] Jim Christefferson, Laser Machining Center, Personal Interview. August 2005.

[28] Bardon 2004; Christefferson 2005; Foster 2004.

[29] Bob Perkins interview, quoted in Made in San Francisco: Findings and Recommendations by the Back Streets Businesses Advisory Board to the Board of Supervisors and the Mayor, December 2007, p. 13.

[30] Y. Lee, Proprietor, Jay's Machine Shop, Personal Interview August 2006.

[31] Anonymous retired machinist, participant at Pacific Machine Tool Expo, November 13, 2007.

[32] Kathy Werle, Dean of Applied Science and Technology, San Jose City College, Speech at the Pacific Machine Tool Expo, November 13, 3:00 p.m. Session 4: Meeting Northern California Machinist Education and Needs

[33] http://www.doleta.gov/BRG/JobTrainInitiative/ Accessed October 27, 2007.

[34] *Ibid*.

[35] High Growth Job Training Initiative: decisions for Non-Competitive Awards Not Adequately Justified
Report No. 02-08-201-03-390 (November 2, 2007)
http://www.oig.dol.gov/public/reports/oa/2008/02-08-201-03-390.pdf

[36] Lilly, S., "Sole Sourcing: Handing Out Tax Dollars at the Labor Department," http://www.americanprogress.org/issues/2007/11/sole_sourcing.html. Accessed December 15, 2007.

[37] Controversial DOL Official DeRocco to Leave Post," Workforce Magazine, December 20, 2007. http://www.workforce.com/section/00/article/25/28/08.html Accessed January 6, 2007.

[38]http://www.doleta.gov/brg/pdf/Advanced%20Manufacturing%20Report%2011.1.05.pdf Accessed December 15, 2007.

[39] Peter Goodman, "Is a lean economy turning mean?" New York Times, March 8, 2008. http://www.nytimes.com/2008/03/02/business/02jobs.html?pagewanted=4&fta=y Accessed April 15, 2008.

40 "Biotech Workforce At-A-Glance," Radford Surveys and Consulting. http://www.biotechwork.org/Region/Bay%20Area,%20CA.aspx. Accessed April 21, 2008.

[41] Bernadette Tansey, "Testing the Offshore waters: Biotech firms experiment with moving work overseas," San Francisco Chronicle, April 18, 2004.
http://www.sfgate.com/cgibin/article.cgi?file=/chronicle/archive/2004/04/18/BUGAI66E7I1.DTL
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Bernadette Tansey, Are biotech jobs next to go? Stronghold of Bay Area economy not immune to trend, San Francisco Chronicle, April 18, 2004.
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CHAPTER FIVE: WHY ARE SHOPS STILL HERE?

5.0 Introduction

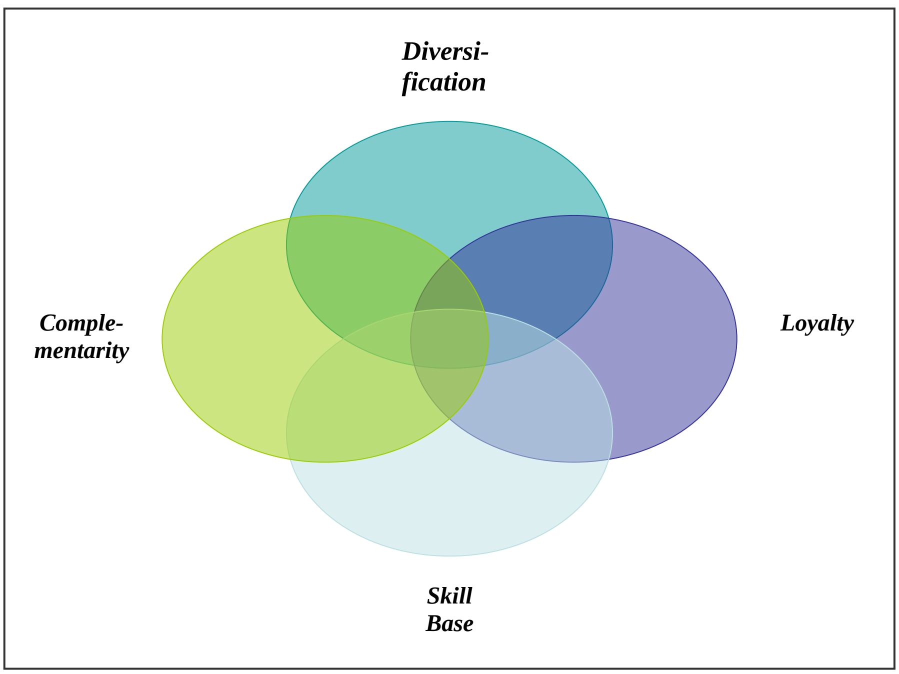
Despite patterns of spatial concentration and temporal decline, the scale and magnitude of the machine shop sector in the Bay Area renders its presence a still-formidable one. Hence, rather than focusing on the sector's overall decline, the more interesting question is the opposite question of why nearly 600 machine shops *remain* in an otherwise high technology and service-sector-oriented economy.

While machining remains a small fraction of the overall regional economy, the 600 existing firms provide critical parts and components for virtually every other segment of the overall manufacturing sector. At an annual average salary of $44,000, machinists are among the highest paid and skilled of production occupations in the region. By virtue of both its high wages and interactions throughout the manufacturing supply chain, the data suggests the possibility that skilled machining activity such as machining constitutes a form of "hidden innovation" which is not typically measured in innovation metrics including R&D dollars or patents, but which nonetheless contributes greatly to the dynamism of the Bay Area region.

Based on my interviews with machine shop owners and employees, observations at local trade shows, participation at manufacturing conferences, and discussions with machine shop customers and also archival materials, I postulate the following four reasons for the continued presence of machine shops in the region: enduring loyalty to the region and to the profession, complementarity of specializations and cooperation between different types of shops, the diversification of shops' client base across customer sectors and the presence of a local skill base.

These four reasons appear below in Figure 16 as interlocking hypotheses; although each distinctly contributes to local machine shops' success, these four factors are also mutually dependent adaptive strategies.

Figure 5.1 Why Are Shops Still Here? Four Propositions



Viewed through the lenses of Marc Granovetter's "social embeddedness" framework[1], [2] and Marx and Smith's assessment that technological change is inherently "value-free,"[3] spatial, technological and cost factors appear to be lesser considerations in the location of machine shops. More important are cultural and historical conditions, social relations and organizational practices. In the case of the machine shop sector, these include a distinct regional history and culture of machining, the evolution of a complex and increasingly fragmented network of supplier-customer relationships, collaborative arrangements among shops and the strategic use of a skilled and adaptable workforce.

5.1 Proposition One: Shops are here for historical, spatial and cultural reasons

5.1.1 Historical and Spatial Factors: Enduring Loyalty to Machining

The first set of events, which I classify as "enduring loyalty," are historical and spatial in nature. Machining in the greater Bay Area had its origins in the city and county of San Francisco: with the Gold Rush, half a dozen machine shops sprang up, serving the development and production of specialized mining equipment. The International Association of Machinists (IAM) was founded in 1888, and the oldest local, the San Francisco Lodge #68, was organized even earlier, in 1885. In 1895 the IAM affiliated with the American Federation of Labor (AFL), which was itself founded in 1881. At the turn of the century the San Francisco and Oakland lodges were notorious for their stridency and regarded as "”stronger and more militant" than their counterparts nationwide. (Nonetheless, IAM did not officially integrate women, blacks, or Asian immigrants until the mid-twentieth century.) [4]

The electronic component and microwave manufacturing sectors that arose in the 1940s and 1950s, primarily in the South Bay, required the physical presence of local machine shops. These sectors contributed both to military systems and to regional industrial infrastructure that, in the 1950s and 1960s, fed the burgeoning semiconductor industry, which to close the circle, demanded even more local machine shop services. Meanwhile, mid-twentieth century Alameda County, including the cities of Oakland, Berkeley, Alameda, Emeryville and San Leandro, continued to host more traditional machining in “older economy” industries. Caterpillar Tractor Company, Aircraft Engineering and Maintenance, Food Machinery Corporation, the Kaiser Shipbuilding Company, Hall Scott Motor Car Company and Morton Salt Company were among large manufacturers employing hundreds of machinists. From 1930 to 1950, both independent machine shops and captive shops of larger manufacturers employed hundreds to thousands of machinists, union membership was extremely active and strike activity occasionally militant.[5]

Babbitt Bearing Company (BBC) is but one example of a small family-owned firm, with under 50 employees, which has been around a half century, and which has continually evolved into serving an array of both “new” and “old economy” customers. BBC was founded in 1945 as an automotive bearing and crank shaft repair shop in San Jose. After a few years, the company began to do machining work for canneries and farmers in the area, which led to larger contracts in the 1960s for a major magnetic tape manufacturer, Memorex. At its present location on 5th Street in San Jose since 1960, the company is among the oldest of the current cluster of over 30 machine shops within a 1-mile radius. From its contract with Memorex in the early 1960s, BBC has been able to concentrate on precision machining and has diversified its customer base to include industries ranging from semiconductor equipment to aircraft parts, food processing components, and printing equipment.[6]

Figure 5.2 Babbit Bearing Company

Babbit Bearing, undated.

5.1.2 <u>Cultural Factors: A Legacy of Craftsmanship and Small Business</u>

Another reason for shops' longevity is a cultural legacy of craftsmanship and small business. Most of the manufacturing firms that were founded in the Gold Rush era have folded; only Levi's Jeans Company, which began as a supplier of mining parts, remains as an enduring legacy of that period. Of large independent machine shops, only Hendy Iron Works remains, wholly owned as a subsidiary of Grumman Northrup in Sunnyvale. Founded in 1879 in San Francisco, Hendy Iron Works relocated after the Great Earthquake to Sunnyvale, when the company was offered free land by South Bay officials eager to develop industry.[5] Other large manufacturers that employed in-house machinists (Hall Scott Motor Company) have altogether folded, left the area (Morton Salt Company) or else evolved into other types of companies—for example, Kaiser, which turned from shipbuilding to an initially auxiliary emphasis on health care. Nonetheless, the legacy of a skill base and industry knowledge was retained via generations of machinists who stayed on and discovered other ways to transmit their talents by following the demand for their skills.

My fieldwork estimates, derived from interviews and inventory of company profiles, suggest that in recent times, approximately forty percent of existing Bay Area machine shops have been in business for at least 15 years. I learned that shops have been handed down over two to three generations and often retained long-standing customers, in many cases even when the customers themselves have relocated out of the area.

The Bay Area's machine shop sector has dramatically declined in the past decade, both in employment and firm size. According to the National Tooling and Machining Association (NTMA) estimates, at its peak in the 1990s the sector numbered approximately 2,000 shops throughout the Bay Area (.Today the region is down to less than half that number of shops, with the balance having either relocated overseas or elsewhere in the United States or gone out of business.) A number of shop representatives noted that there are fewer firms now than in 2001. In their experience, many machine shops have folded, leaving machine tools behind in auctions at fire sale prices. Others have consolidated into a few large firms, as sole proprietors have gone to work for larger, first tier shops.

Nonetheless, when queried about their continuing presence, shop representatives continued to cite the Bay Area as a good place to do business, pointing to non-quantifiable factors such as favorable weather, proximity to customers and inexpensive utilities as particularly good reasons for staying in their current locales.

In the course of interviewing shop employees, I observed that machinists continue to possess a distinct identity and pride of workmanship. Artisan craftsmanship has been a hallmark of this profession. For example, Jeff Christeffersen, a machine shop employee of a small laser machining company in the South Bay is the college-age son of the proprietor, currently with father three days a week while he completes a computer science curriculum at Cal State Monterey Bay. Upon completion of his studies, he plans to join the shop full time. In his words, Christefferson likes the work because:

> "I thought about working down the street at E-Bay" but machining is "easy and fun….I get to really make something instead of just work in front of a computer terminal all day."

Moreover, Christeffersen cited the sense of accomplishment in seeing the machining parts which have gone into the final production of manufactured products; among them, machined parts for the public transit system for the South Bay.

Meanwhile, a number of studies of the Silicon Valley region have highlighted the entrepreneurial, risk-taking nature of the regional economy (Saxenian 1994; Kenney, ed., 2000; Lecuyer 2005). My survey of the area's machine shops indicates that the precision machining sector is no different. Machine shop entrepreneurs spoke time and again of leveraging their own capital to start a shop and to purchase new equipment. All too often, bank loans were not readily available or desirable, due to lack of money for startup equipment.

A case in point is Boris Kessel, an immigrant from the Ukraine with a background as an engineering supervisor, who took on considerable personal risk in striking out on his own by putting a lien on his home to open an independent shop. Kessel now co-owns with a fellow Ukranian a successful limited liability partnership (LLP) machine shop, ADEM LLC, with over 30 employees. In 2006 their company expanded through the acquisition of another shop.[7]

Whether individual firms can survive the volatility of the business cycle, however, is largely contingent on a variety of business factors, including whether a shop owns its own equipment and buildings, and whether it customers pay their bills on time, which enables a shop to avoid machine payments when business has slowed down.

Bear Machining's proprietor, Ed Guenerville, is typical of baby-boomer machinists who have been in the industry for over thirty years and who have progressed from working as a shop floor machinist to branching out on their own. Guenerville started working in the industry when he was eighteen years old, first for a shop called Select Metals and, after a few years, for a shop called Trace It Manufacturing. While working for others, Guenerville began moonlighting in his own garage shop doing tool and die work. He eventually started his own shop and hired workers—building the firm up to thirty people within three years. He did the quoting, running, hiring and firing by himself, moving from a space that had only 3,000 square feet to one with a 9,000-10,000 square foot capacity. He slowly contracted work from bigger machine shops while nurturing his own, very reliable customer base of original equipment manufacturers.[8]

5.2 Proposition Two: Various Shops Specialize and Collaborate with One Another

In the previous chapter, I discovered that the region abounds in small machine shops: four in five shops employ under workers, while only ten out of the over 500 shops employ over 100 workers. My observations through the course of field research reveal that shops of various sizes distinguish themselves by specializing in niches and find both innovative and effective ways to collaborate in an intricate web of business partnerships.

5.2.1 Shops Specialize and Cooperate on A Number of Jobs

In the course of my fieldwork, I observed the whole range of machine tools on the shop floor, ranging from lathes to mills to presses; specialized metrology equipment; laser machines; and specialized equipment for drilling, milling, grinding, and plastics. Shops also specialized in different volumes—from R&D , to first-run production of perhaps one or two hundred parts, to mass production of up to one or two million parts. (In this case, the machine tools would be up and running around the clock, including weekends).

Plate 5.1 A Machined Part Designed in Santa Clara

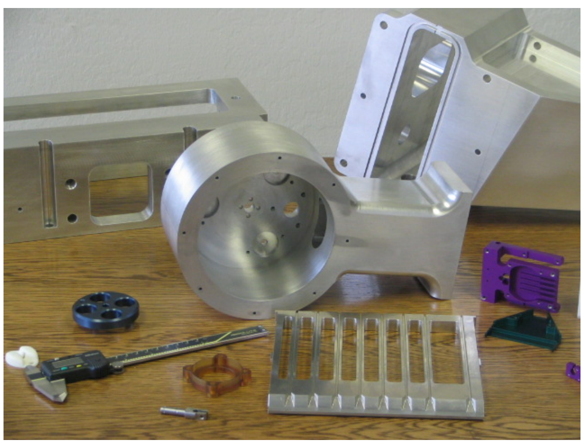


Photo by the author, July 2006

Shop owners consistently explained that their shops interact with one another on jobs for OEM customers:

- Machine shops engage in complementary and mutually reinforcing strategies of prototype and volume production for local OEMs. The collaborative strategies employed by shops to stay in business include a set of intricate subcontracting arrangements in the sector and co-learning among customers, suppliers and supplying partners.

- Assembled teams then bid on contracts. Winning bids owe their success to high levels of professionalism, knowing how to market the team well and how to compile a portfolio of the resumes of each of the team members.

5.2.2 Largest Firms Often Serve as Lead

Seven of the largest, "first-tiered" machine shops employing over 100 workers often take the lead in partnering with other, smaller shops on a family of jobs. As noted in the previous chapter, OEM customers such as HP and Applied Materials interact primarily with this first tier, and only indirectly in most instances with second and third tier suppliers. However, because they may lack specialized expertise on a particular component of the machining process (such as grinding processes or Swiss screwing expertise), these larger modern shops will subcontract with smaller, often "family" shops for such specialized services. For example, a $160/hour job might be charged to the custom manufacturer, for which the first-tiered shop will pay a specialty shop $100 an hour and then pocket the difference as profit.

D&H Manufacturing is one of these large firms. Established in 1956 by the Willis family, D & H currently has shop locations in Santa Clara, Fremont and Austin, Texas, totaling over 85,000 square feet. A machine shop trade magazine recently praised the shop as "one of the most successful shops in the country."[9] The Fremont machine shop is located in a single-story, 30,000 square foot office park building owned by the company. The shop contains over two dozen mostly Computer Numerically Controlled (CNC) machines and employees busy at work on several of the firm's fifty machines located on its main shop floor. At one corner of the shop, two employees labor at workstations, programming computer software, while another employee is in the "clean room" facility located in a side building space. At the height of D&H's busy schedule in the late 1990s, the company was running three shifts. After several years of cutbacks, the third swing shift was recently reinstated. D&H often relies on smaller and more specialized shops, such as Oakland's General Grinding, to provide specialized services.

Customers range from computer manufacturers to makers of medical device and fiber optic technologies. The contracting and subcontracting arrangements are varied and constantly evolving. Large customers such as Applied Materials and Agilent maintain database list of such local preferred vendors from which they draw for precision machining parts.

Shop representatives have variably praised or complained about the inflexible and exacting sourcing requirements that these large contract manufacturers demand of their suppliers; the pricing schemes utilized by these customers get similarly mixed reviews. But the ability to partner with other shops providing complementary skills bolsters the flexibility and capacities of lead shops in the face of rigorous OEM demands.

5.2.3 Medium-Sized Family Firms Are Among the Most Active Collaborators

"Modern" first-tiered shops such as D&H are not the only shops to play a lead in collaborating on contracts. West Valley Precision Manufacturing is one of approximately 200 "second-tiered" "family" shops employing between five and forty-nine employees. West Valley itself has over forty employees, ranging from machine operator to machinist and marketer. As with D&H, the firm is owned by family members—two brothers, one of whom had worked for the firm on and off for eight years. In late 2005 the general manager was departing to open his own machine shop. Despite its small operations, the firm has the technological and organizational capacity to produce a variety of parts, ranging from prototype design to volume production, using Just in Time strategies. West Valley customers range from computer manufacturing to medical device and fiber optic technologies. Once the design and prototype work has been approved, firms such as Agilent will also purchase up to 500 parts at a time from West Valley. What cannot be done in-house is then sub-contracted out to other specialized shops.

5.2.4 Shops Are Consolidating

Specialization is also characterized by the consolidation of firms and services. Adem's president/founder Boris Kessel, as well as WEWA's president Max Ho, attributed the decline in number of shops to shop mergers. For instance, ADEM in 2007 had recently completed the acquisition of another shop, adding manufacturing square footage, employees, and machining capacity.

5.3 Proposition Three: Shops Actively Pursue Diversification Strategies

Ongoing diversification of a shop's portfolio of services and its customer base in the Bay Area and beyond is essential, given the instability of the regional economy since the late 1990s. The intensive specialization in clientele and in niche markets that worked well during the dot-com boom brought some firms to the financial brink during the dot-com bust. Philip Pham's shop, for example, was nearly bankrupted by depending on up to 70% of its contracts on giants such as Applied Materials.[10] Western Tooling, also heavily reliant on Applied Materials, was under the management of a team that had bought out its original owners. Subsequently Western declared bankruptcy and had a huge auction, selling off its machine tools. Subcontractors such as Bear Machining did not recover any money for promised contracts and took nearly two years to recover from the loss.[11] In a third example, a plethora of auction notices about carrier air conditioning parts indicates that many air conditioner manufacturers are going out of business. These bankruptcies will dry up work for machine shops that have depended too heavily on this sector for their business.[12]

My inventory of local shops shows that shops are quite diversified in their customer base,. Of twenty shops surveyed, shops appear to cluster with certain OEM sectors, including computer and semiconductors (nineteen shops), telecommunications (eight shops); aeronautics, electronics and medical/healthcare (six shops each).

4.3.1 OEM demand is industry-specific

Many Silicon Valley manufacturing companies design, assemble and market their products—ranging from automobiles, to computers and electronics, medical devices, laser and optical equipment—but procure the components from the small machine shops. However, OEM demand for machine shop services is very industry-specific; hence, machine shops can diversify strategically only into certain sectors.

Whereas most computer industries (ten of the nineteen shops inventoried above) do require the use of machining services, the use of machine shops by these companies is mostly in the prototype stage of building "onesies" or "twosies." For example, computer industries produce parts comprised primarily of plastic. Only a small portion of those plastic parts are screw-machined. Hence, fewer machining services are required. By contrast, production in the telecommunications and medical device instruments often involves very large, profitable parts per unit (e.g., heat-sinks) that need to be extremely accurate. As a result, these sectors rely much more heavily on local machining.

Under the general category of health and medical technologies, medical device instrument companies are among the biggest users of machine shops, and a sector well-regarded by machinists. "The economy doesn't really matter in the medical industry," says Roland Kamber, owner-president of Campbell, CA's Precision Identity Corporation. Kamber cites two reasons: First, "People don't pay for their medical care; insurance companies and the government pay." [13]Second, "People want to live; if they're sick, and need healthcare, money doesn't mean much. What they want is the best care they can get."[14] Founded in the early 1970s by the proprietor's father, Precision Identity currently occupies a 12,000 square foot facility packed with eleven CNC screw machines, a couple of CNC lathes, several vertical mills and a variety of support equipment. The company keeps seventeen people busy in one shift producing hundreds of thousands of parts annually for fifteen or twenty medical industry customers. "We've been very successful in the medical industry," Kamber says,

> because we found the right formula for keeping our customers happy…. In the medical industry our customers want us to meet or exceed their specifications. They also want their parts to look good. And, of course, in order to remain competitive, we have to be constantly on the lookout for ways to cut our costs and increase productivity. So far we've done all those things. Whenever possible we exceed their tolerances, we always provide finishes better than they expect, and we use the best equipment we can afford to stay productive."[15]

5.3.1 Shops Engage in Active Diversification Strategies

With a diversified clientele and portfolio, machine shops facing a downturn in a single industry such as semiconductor production can choose to emphasize and develop other customers, ranging from medical equipment to computer peripherals, communications or consumer durables. Diversification entails no simple recipe; it does not mean having a certain number or type of customers. Rather, it is an adaptive strategy that involves ongoing flexibility and innovation. Shops must face the reality that despite long-standing customer-supplier ties, customers have the option of exiting at any time.

There is always the danger that customers may stop buying a firm's products, or some long-standing liaisons to the shops may leave the organization. Without constant business expansion, a shop's customer base declines through natural attrition, and with it the shop's revenues and jobs.

West Valley Precision Manufacturing in San Jose is an example of a firm that engages successfully with a variety of customers. The shop does all types of work, ranging from prototype design to volume production using Just in Time strategies. Innovation stems not only from design in the heads of engineer clients but also arises from tinkering in the production process itself.[16] Absent hands-on tinkering and close collaboration with engineering and machinist vendors, designs can be impractical or outright "bizarre,", resulting in modifications and delays.[17]

Given sharper distinctions between shops doing design, prototype and volume production, a number of shop representatives noted that the machine shop sector is under pressure to supply cheap, non-durable machined parts for customers who will find "Wal-Mart" quality elsewhere anyway.[18] At the same time, Bay Area machine shops themselves are increasingly specializing and tailoring their specializations more narrowly away from mass production work.

5.3.2 Shops Stay Current with "Newest Economy" Industries

One particular diversification strategy is to stay current with the latest innovations in manufacturing, by "riding the next waves" of emerging trends in the economy. West

Valley Precision's owner David Madsen uses the "surf" metaphor to capture the need for technological opportunism in the face of business and market vagaries:

> "Since I first incorporated West Valley Precision back in 1986, the company has been lucky enough to find and ride a lot of different technology waves…The Silicon Valley has been a central point where new technologies have been born and, unfortunately, where they sometimes die, too. In our case we've always managed to find and ride the next new wave and that has, by the standards of a lot of people, made us very successful."[19]

Madsen and other firms cite earlier technology waves, such as the hard drive business, which lasted for five or six years but which have now gone offshore, and the fiber-optics business, which peaked in the late 1990s and early 2000s, only to fall victim to over-capacity. These sectors are still in business and employing machine shops, but at a much smaller scale.

To extend Madsen's surfing analogy: firms are now gearing up beyond the currently "hot" manufacturing fields of medical device instruments and biotechnology and thinking about how to catch the next big waves. In Job Shop conferences and manufacturing engineering networking sessions, emerging customer fields include the nascent nanotechnology and instrumentation industries, among others.

Meanwhile, in both the popular media and in local Silicon Valley professional conferences, many manufacturers are increasingly turning their attention and investments away from their fundamental competencies in semiconductor equipment and toward solar energy photovoltaic's and flat screen TVs, which utilize comparable technologies. Forty-five years ago Stanford Professor Nathan Rosenberg noted that in technological innovation, technology transfer moves up the value chain: guns begat sewing machines and the invention of the automobile. Much in the same way, the technologies used in semiconductor equipment are very similar to those in flat screen TV and photovoltaic technologies. Hence companies like multi-billion dollar Applied Materials are eager to develop new technologies in the Clean Tech arena[20].

Indeed, the majority of products designated "cleanses" including water desalination and purification and photovoltaic solar panels—are engineered, manufactured products, rather than designed or electrical engineering/ software-based. These emerging clean technologies are both the fastest-growing and most machining-dependent of emerging environmental technologies.[21]

Traditional semiconductor and computer OEMs including Applied Materials, Intel and HP are all investing heavily in the research, development and manufacture of solar photovoltaics, while General Electric has become one of the largest players in water desalination and purification.[22] Because these OEMs have long been machine shop customers, it has been logical for their emerging cleantech ventures to be serviced by their long-time machining vendors previously working to build machining prototypes for computer components. Meanwhile, these older, more established OEMs have been joined by "new economy" firm Google, which has heavily invested in three companies building potentially breakthrough renewable energy sources including solar, energy and wind.[23] The relational networks being built between these newer ventures and machine shops are less apparent.

5.3.3 Machine Shop Globalization Strategies: The Importance of Far-Flung Partners

Bay Area firms often site their volume production in locations out of state with cheaper labor and real estate overhead. For example, first-tiered D&H Manufacturing in Fremont also has a machining facility in Austin, where its largest customer, Applied Materials, does most of its production work. Engineers at the Fremont location receive exacting design and prototype guidelines from the shop's customers and produce volume parts at its facilities. Likewise, B&Z machine shop, comprise of 56 employees, has a 18,000 sq ft facility in San Jose and occupies another 6,000 sq ft in Arkansas. The company specializes in ultra-precision machining for such companies as Hewlett Packard, Agilent and Honeywell.[24]

Interestingly, companies that have successfully diversified have not done so only through multiple customer sources or out-of-state production, but also through offshoring at least a portion of their operations at cheaper labor cost. San Jose's WEWA does prototyping work here in the Bay Area for its local clients but has a satellite shop in Southern China that absorbs 30% of the company's work, including prototyping and volume production work. WEWA's president Max Ho maintains that he needs to go to China only about once a year to coordinate with his satellite production office there.[25]

Whether or not the most successful firms are able to effectively employ the global strategies used by their customers shapes their own futures as well. Business operations size, capitalization and scale affect a firm's ability to internationalize its operations. (Most of the OEM customers are large, with over 10,000 employees, whereas machine shops average less than 100 employees). Knowledgeable and experienced Bay Area machinists, like their local OEM customers, emphasize the importance of global ties and learning. Implicit, however, is the underlying struggle to control the global production network: rather than be at the whim of a customer's footloose global pricing strategies, machine shops are actively searching for ways to exploit for their own benefit the worldwide resources made available by overseas production.

5.3.4 Social Relations Between Customer and Supplier Are Ingredients in Success

In deciding which shops to contract with, OEMs consider a variety of factors, primarily lead time, cost and type of job. Some machine shops are better than others at different types of work. "Red" Byer, an engineer with a laser company in Santa Clara, noted that he continued the relationship with many of the shops he has worked with in the past at other OEM companies. Both he and other employees bring in trusted firms for whom they have long-standing relationships; one of his current machine shop vendors, for example, was used in the past by one of the firm's newest employees.[26]

OEMS also say that when they seek suppliers, bottom-line factors such as time, cost and type of job matter far less than, in the words of engineer Byer of the Santa Clara laser shop:

> "honesty, integrity, ability to do the work on time and of consistently high quality. We also need good communication and a level of trust, as it is a very important relationship for us."

Time and again, OEMs and shops alike underscored the point that trust and "face to face" are extremely important. If a supplier is late with a part, hundreds of thousands of dollars may be in jeopardy for the OEM If a machine shop is not paid by an OEM or a shop goes out of business and doesn't pay an OEM, there is very little recourse.

Therefore many OEM engineers visit the shops on a regular basis. Byer will often bring a laptop to a shop to show a machinist, and together they'll work out the details. He encourages machinists to call back but notes that "it's hard to get them to squawk." Occasionally he'll get one phone call on a print.

Co-Learning Occurs Between Customers and Supplier

The mutual instruction that occurs between customers and machine shop suppliers is also a function of employment mobility, which is quite common between customers and suppliers. In many instances, after years of close collaboration, a manager at a custom manufacturer has moved over to its supplier or vice versa. Oakland's Diamond Tool and Die manager worked at Stanford Linear Accelerator for many years before moving over to machining work. Currently at Fremont's D&H Manufacturing, manager Steve Riley was for many years employed at Applied Materials, a principal customer to D&H. Not only does such mobility foster greater knowledge and awareness of the exacting specifications of customers; it also provides personal ties, social networks, and a shared language with the engineers and managers of said customers. Not coincidentally, Applied Materials is one of D&H's biggest customers.

A medium-sized family shop, West Valley, emphasized the innovative and collaborative nature of its prototyping work. The orders start with "onesies and twosies designed from paper napkins," wherein the firm's machinists work from the inception of an idea about a new machined part in conjunction with engineers of Original Equipment Manufacturers.

Indeed, some of the Valley's technical innovations, as well as industry information-sharing, also happens through machine shops serving as conduits between various industries, and among themselves. As co-founder Jon Guice of Green Mountain noted, chatter such as "I just heard about a new solar company" might be conveyed from one machine shop owner to another, or else new technological processes used in one sector, such as the emerging use of laser scribing, might be transmitted through the machining process.[27]

The co-learning that occurs in the Bay Area machining sector, between shops and with their customers, corroborate Saxenian's descriptions of relational networks of long-term, relationships rooted in elements of cooperation, trust and long-term relationships. In my observations, however, this co-learning process demanded a level of spatial propinquity as the foundation of trust which is not required in Saxenian's descriptions of "argonauts," those globally dispersed immigrant technical communities.

Relational Networks Are Important

Time and again, firms mentioned the importance of the word-of-mouth ties in establishing customers, affirming Saxenian's "relational networks" framework. OEM customers are sometimes brought in by their engineering staff, who might have previously worked with a job shop on a contract with a previous employer. Rarely did OEMs or firms talk about relying primarily on business White Pages or on advertising through formal channels such as trade journals.

Among established means of networking, however, many firms do prioritize attendance at conventions and trade shows to market machine shop products and services. The most popular among machine shops is the annual two-day Job Shop Show, held every year at the Santa Clara Convention Center and in other manufacturing hubs across the country, with over 100 local shops set up in colorful booths filled with precision machining literature, machined parts and promotional videos. Big machine shop players, including Edwards and Sanmina-Sci, have their inventory laid out on the tabletops, hoping to attract new clientele; they are joined by the smallest, youngest start-up shops.

Many shops have also been actively involved with the Society of Manufacturing Engineers (SME), another longstanding national trade association with a still very active local chapter. SME describes itself as the world's leading non-profit technical and professional society supporting manufacturing education. Through member programs, publications, expositions and professional development, SME promotes increased awareness of manufacturing and keeps manufacturing professionals up-to-date on leading trends and technologies. SME also hosts monthly dinners and six to seven tours a year of a wide range of Original Equipment Manufacturers, machine shops, and related manufacturing firms. Tours have ranged from a medical device instrument company in Palo Alto, Varian Instruments, to tours of Applied Materials and other large computer manufacturing OEMs. In July 2006 the organization held a special, daylong conference on “Global Manufacturing,” where expert speakers from computer and nanotechnology OEMs, venture capital and a research and development consultancy advised local machine shop participants on maintaining business competitiveness in an increasingly outsourced environment.

5.4 Proposition Four: Shops Utilize a Range of Internal and External Skills

My tour of the shop floor confirmed what I had heard from informants, that workers are flexibly trained on the job to work with a range of equipment. The cultural practice on the shop floor seems to be that everyone does everything, from small lathes for miniature parts to enormous boring and cutting machines. There is no assignment of specific worker to specific types of machines; rather, the emphasis appears to be less on what your job is and more on continual learning and multiple communities of practice. Machinists work side-by-side with each other, with supervisors and with shop and customers' engineers on design, prototyping and production specifications. The industry is probably the most technologically advanced of all small manufacturing activities; shops widely deploy computer-numerically-controlled (CNC) machines and other computer-aided design and manufacturing (CAD/CAM) techniques.

5.4.1 Continued Learning Occurs Across Firms and Sectors

Shops have at their fingertips the opportunity to network and to learn from each other through established trade associations and annual events. The National Tooling and Machining Association, a national association of precision manufacturers, had a long-established Bay Area chapter which was very active for many years and had an established machinist training center which, at the height of its demand, was churning out machinists every six months. As of 2005, however, the NTMA appears to be defunct.

5.4.2 Colleges and Non-Profits Fill the Training Gaps Left by the Market

Fifteen colleges in the area have long offered technical training in machining. The demand for new machinists is primarily driven not by independent small machine shops but by large, long-established OEMs such as Honeywell and IBM. Since the 1960s, these OEM companies such as IBM have developed partnerships with academic institutions such as San Jose City College to develop specific curriculum and then hire the graduates.

While for the most part the machine shop sector has neither helped shape training curricula nor hired from community colleges, the latter are very active in training new machinists. Community colleges feed new machinists largely into the OEM sectors that still have a demand for and actively hire new machinists. However, in the words of John Branlund, a machine technology instructor at the San Jose City College who is also a full time machinist:

> *"Machining is not a high-ticket program [at San Jose City College]. Our program is under a lot of pressure; it costs a lot to run and we're just trying to hold on. We continue to offer courses in basic blueprint reading and math, a 18-unit course full time. For students who've already passed the basics, we offer advanced courses in CAD and CAM."*[28]

In part, the difficulties can be attributed to the challenges facing the community college system. Although machining instruction has long been an established curriculum, Braunland noted that community colleges in the area have been facing steep fiscal cuts.

Figure 15 on the following page provides an inventory count of the array of training opportunities provided by local community colleges, universities and training centers, ranging from coursework in basic shop skills and in CNC programming, to apprenticeship and placements.

Among the tally, the area's top research universities, Berkeley and Stanford, offer limited shop courses and product design courses, but these are restricted to graduate students in mechanical engineering and product design majors. Meanwhile, among the most active of community colleges with business partnerships are San Jose City College, which has an active Advisory Board for its certification program in machine technology.

Composed of members of the business and technology community, the SJCC's machine technology advisory board assists in identifying equipment needs, determining course priorities, and monitoring the quality of instruction.. With this advisory board, San Jose City College leads the trend in companies developing partnerships with colleges to include specific curriculum and then hiring the graduates Local employers have reported that students who took classes at SJCC:

> *"After taking your courses, he has a more relaxed attitude toward power tools."*
>
> *"Provided good overall background...learned basic functions of the job."*
>
> *"Learned good skills in lathe and mill work."*
>
> *"Education will allow him the potential to become a leadman."*
>
> *"Attending college shows ability to reach goals...That's important in our line of work."*[29]

FIGURE 5.3

Inventory of Available Training in Machining and Related Manufacturing Skills in 2007
SF Bay Area Colleges, Universities and Non-Profit Agencies

Machining Degree (A.A.)	Metrology	Basic Shop Skills	CNC Programming	Quality Systems - ISO	Electronic Manufacturing	Product Design (CAD)	Entity	City	County
--	--	--	--	--	--	--	Bay Area Industry Education Council (1)	Fremont	Alameda
•	•	•	•	•	•	•	Chabot College	Hayward	Alameda
•	•	•	•	•	•	•	Merritt Community	Oakland	Alameda
•	•	•	•	•	•	•	Peralta Community Colleges	Various	Alameda
		•					U.C. Berkeley (3)	Berkeley	Alameda
•	•	•	•	•	•	•	Diablo Valley College	Pleasant Hill	Contra Costa
•	•	•	•	•	•	•	Las Positas	Livermore	Contra Costa
•		•	•		•	•	Center for Employment Training	San Jose	Santa Clara
•	•	•	•	•	•	•	Occupational Training Center	San Jose	Santa Clara
•		•	•		•	•	DeAnza Community College	Cupertino	Santa Clara
•	•	•	•	•	•	•	Foothill Community	Los Altos Hills	Santa Clara
--	--	--	--	--	--	--	San Jose Job Corps Center (2)	San Jose	Santa Clara
•	•	•	•	•	•	•	San Jose City College	San Jose	Santa Clara
•		•	•		•	•	San Jose State University	San Jose	Santa Clara
		•				•	Stanford University (3)	Stanford	Santa Clara
		•	•		•	•	San Francisco City College (3)	San Francisco	San Francisco

(1) Provides skills assessments and on-the-job placements with 12 cooperating independent machine shops

(2) Provides high school diploma/GED readiness and participants are allowed concurrent enrollment in partner programs which provide machining courses

Underscoring the importance of training, Dean of Physical Sciences Kathy Werle provides a personal example of her own son who completed a training in the aerospace program at California Polytechnic University. He was then sent to intern at a machine shop in the aerospace industry. Then, with no training in machining, he was placed in an aerospace machine shop under dangerous and potentially hazardous conditions. Werle further noted that she gets calls weekly, often daily, from individuals seeking workers with machining experience.

5.4.3 Learning Extends Beyond Machining Skills

Machine shop owners and OEMs alike underscored the importance of more than simply good skills with one's hands and machines: business and communication skills were also extremely important, as were ability to follow instructions and to be punctual. Also important are reading, writing and arithmetic. Given that machining increasingly involves information technologies, most firms spoke of the need for programming and math skills. Indeed, a number of machine shops administered math tests for machinist applicants, in addition to observing them at work with the machines.

Besides quantitative and writing skills, shop owners also noted the importance of communication skills, both oral and written. The head of one shop, Boris Kessel, noted that it was often difficult for OEM customers to communicate with shop floor machinists, and that the company's engineering managers had to intervene and participate in discussions on the technical aspects of machining between machinists and OEM customers.[30]

Fortunately, many of the community colleges offering shop training support broader workforce development. Laney College, part of the East Bay's Peralta Community College system, provides a variety of A.A./ A.S. and Certificated programming through curriculum that complements current labor market trends, including machining technologies.[31] Rather than narrowly focus on training, the community college runs LaneyWORKs, a complementary program that addresses an array of academic and life skills and offers academic counseling, workforce development and job readiness training. The program also provides supportive services such as child care and counseling. Laney and other community colleges, including San Jose City College, also offer work experience based on labor market demands to ensure that students develop the efficient skills and work ethic needed by today's workforce.

5.4.4 Immigrant Labor Force Often Fills the Machinist Employee Niche

Many machine shop representatives noted the prevalence of immigrant newcomers in the industry, in established and in new firms alike. Hiring might be through the *San Jose Mercury News* or word-of-mouth. Often entire immigrant families are employed at the same firm. As Lisa, a front-office worker in a family machine shop noted:

> "One trend I have noticed is that there are many immigrants. 85% of our operators are Vietnamese immigrants in their early 20s; two of them are

> brothers—they tend to bring their families in. When I first started working, the foreman was Hungarian… (When queried about whether she thought immigrants came from manufacturing backgrounds) These immigrants don't have a manufacturing or machining background, they just know where/when to fill a niche; (whereas) young people born and raised here are not interested in taking shop classes or going this route.[32]

Indeed, immigrant newcomers run some of the most entrepreneurial start-ups. Foreign-born machinists from locales as varied as the Ukraine and Vietnam have founded the newest garage shops. The newcomers appear to be well-educated, with many having been trained as engineers and engineering managers in their native countries. For example, Boris Kessel, the Ukranian immigrant who has owned a successful limited liability partnership (LLP) machine shop for over ten years, was trained as an engineer and served a factory manager in his hometown, overseeing the work of over 1,000 workers.

An engineering customer at one laser company commented that many of the shops are immigrant-run. Many machine shop owners, including the prioprietor of one Russian-owned shop, are very successful, he noted, adding that they "drive the best brand of latest model cars--700 series BMW." If shops are good at what they do, he said, machining can be very lucrative, even supporting multi-millionare shop owners.[33]

Such an “up by the bootstraps” perspective on immigrant success in the machining industry, however, masks the many stories of struggle and failure, nor the heavy personal toll exacted on the road to success. With regards the latter, Phillip Pham recounts the multiple barriers he faced upon arrival in the U.S. as a refugee from Vietnam. Trained as an engineer in his home country, Pham started all over again in the mid-1970s by learning on the job as a machinist. However, facing cultural and ethnic discrimination and language difficulties, Pham found it increasingly difficult to work with native-born colleagues, some of whom bullied him despite, or even because of, his machining acumen. Moving from job to job, Pham increasingly found it difficult to support his family of four. Denied Unemployment Insurance, increasingly unable to work due to his emotional health, and unaware of how to seek help otherwise, Pham eventually moved in with his extended family.

It was not until he began to do contract work for a former employer who knew of his good work, that Pham was able, after over a decade of struggle, to open his own shop and eventually grow it into an established machining and welding firm. While Pham ultimately succeeded, success was by no means guaranteed for most or all of his immigrant machinist counterparts. Moreover, his story highlights the multiple barriers--social-cultural, linguistic, emotional, and economic—facing immigrants in a variety of occupations .

5.4.5 A Skills Gap: Machinists Will Continue to Be In Demand

Machine shop owners indicated that they were always searching for machinists. Word-of-mouth, they said, was the most reliable source of new talent, better print or online classified job listings.

The emergence in 2006 of the foundation-funded labor intermediary, Fremont's Bay Area Industry Education Council (BIAEC), suggests continued market demand for skills assessments and on-the-job placements. With the local machining association no longer active, BIAEC plays an important role in filling the industry's demand for skilled machinists and in providing employment to individuals who want to be employed in skilled manufacturing; the participation of twelve local cooperating independent machine shops signals a strong beginning for a relatively recent program.

BIAEC exemplifies those demand-side strategies which are needed beyond the supply-side strategies that firms can utilize to hire and to train its workers. Collaboration takes the form of partnerships among private and public institutions in the region, including schools, colleges, lending institutions, locally elected officials, as well as those clusters comprising the customer base of OEMs.

Projections at the national level suggest that greater demand for skilled manufacturing workers may yet be on the horizon. While U.S. manufacturing employment overall has declined over the past decade, most jobs that have been lost involve repetitive, labor-intensive, and lower-skilled work that can be performed more cheaply in other countries. Meanwhile, millions of skilled manufacturing jobs remain and will continue to remain in the United States. The BLS notes:

> The decline in manufacturing employment does not mean that the manufacturing sector is disappearing from the U.S. economy. Output of manufacturing industries (sales of produced goods to final users and also to other industries) is expected to grow at a healthy 3.5-percent annual rate over the projection period, with the declines in employment explained by the offsetting high growth in manufacturing labor productivity.[34]

5.5 Emerging Trends in "Reverse Globalization" Patterns of R&D and Production

In a process of "reverse globalization, the Bay Area and Silicon Valley are being actively shaped and adapted by overseas OEM firms, resulting in a return to local mass production and spurred machining demand in the Bay Area. This phenomena appears a culmination of a number of factors including 1) the decision by manufacturers to be closer to their markets, spurred in part by the rising costs of fuel and transport and 2) an indication the politics of firm location, decision-making and production are constantly negotiated and culturally "thicker" ever. In interviewing OEM representatives and conducting walk-throughs of the operations of the emerging solar energy sector, it has become clear that along with increased R&D in solar photovoltaic cells and panels, more routinized manufacturing and machining work is being established at the site of consumer marketplaces in the U.S..

The OEMs cited the desire to be closer to their markets, particularly as the Bay Area is regarded as a region with reliable and heavy demand for renewable energy sources.[35] A sourcing manager with one local OEM recently spoke about the "flattened world of production," but did note that that logistically there was still a distinct difference between domestic and foreign locales from a time and cost perspective.[2] As illustrated below, the East Coast of the U.S. is still the only major source of machining parts and services within a day of Bay Area OEMs:

Figure 5.5 A Logistical Comparison of Time Differentials

Air	Hours from Bay Area	Shipping	Days and Weeks
Hong Kong	13	Express	3-5 Days
Taipei	12	Express	3-5 Days
London	11	Sea	4-6 Days
Boston	6	Express	Overnight

Source: Bill DeMeulenaire, Engineering Manager, Sun Microsystems

Their strategy is increasingly making sense in a world of rapidly increased transportation costs. According to a May 2008 study, the cost of shipping a 40-foot container from Shanghai to the United States has risen to $8,000, compared with $3,000 early in the decade. . The study, calculates that the recent surge in shipping costs is on average the equivalent of a 9 percent tariff on trade, concluding that:

> "In a world of triple-digit oil prices, distance costs money. And while trade liberalization and technology may have flattened the world, rising transport prices will once again make it rounder."[36]

The increasing cost of transport challenges the rationality and cost-efficiency of Sturgeon's "modular" production systems, wherein geographically dispersed R&D and manufacturing is seamlessly negotiated through codified knowledge and rapid ramp-up of technology. My discussions with various solar start-up representatives suggest that locational decisions were very much socially and culturally negotiated. For instance, SunTech America chose to locate in San Francisco in 2008 due to a myriad of reasons including the temperate climate, the ready availability of Mandarin speakers, and the proactive courting of and incentives offered by local city officials, allowing that city to win out over dozens of other U.S. cities under consideration. SunTech America is a subsidiary of SunTech Power, Incorporated, based in China with offices in the U.S. and Europe and the largest producer of solar photovoltaic cells and solar modules in the world.

A senior executive with SunTech America explained that while R&D activity was exclusively in Wuxi, that increasingly manufacturing activity would occur in San Francisco.[37] While its downtown headquarters along the Embarcadero is focused entirely on sales and marketing activity; however, the company is also in discussions with San Francisco city Mayor Gavin Newsom and Chief of Economic Development Jesse Blout to locate and develop a significant presence in the Hunters Point Shipyard's planned CleanTech campus. Although the city's vision is of high-skilled, innovative R&D, in fact SunTech's business model suggests mass, routinized manufacturing to meet Northern California's large and growing market for renewable energy.

SunTech's globalized business strategy may not differ significantly from that of other foreign manufacturers operating in the Bay Area. Two other global manufacturers, the Germany solar company Millenium located in Berkeley, and the Canadian company Opti-Solar of Hayward, are both rapidly growing foreign OEMs with sales and distribution and planned manufacturing facilities in the Bay Area. Invariably, a sizable portion of the emerging green manufacturing in the Bay Area will be primarily assembly-based: solar modules, many of which will be produced elsewhere, will be shipped to the U.S. and most of the labor required will be lower-skilled than machining, including parts assembly and installation of modules. However, while machine shops working on the cutting edge of OEM design will continue to constitute a significant threshold in the area, the important role of both specialized and routinized machining work, including laser machining and mass production, is seeing a revival, as evidenced by the contract solar machining work done by Fremont's D&H Manufacturing, one of the largest, first tier machine shops in the region.[38].

Despite potentially ominous implications of a "reverse globalization" process suggested by these foreign OEMs, those concerned about keeping innovation and co-design in the region can look to hundreds of Bay Area renewable energy start-ups who house R&D, manufacturing co-design, and the entire production process within the Bay Area. As with CleanTech in general, the globalization strategies within the solar industry vary from firm to firm. As of yet, no clear pattern has emerged to suggest that the Bay Area will not be an innovation leader in the emerging and vital CleanTech sector: the SunTech model suggests only a possible but by no means definitive re-configuration of innovation and manufacturing. Nonetheless, the foreign OEM presence in this emerging market cannot be discounted: SunTech itself is among the largest and most successful solar photovoltaic and module producer in the world, with both the fortunes of the company and its multi-billionare founder built entirely on successes in cornering a large share of the rapidly expanding solar manufacturing industry.[39]

The case of CleanTech does, moreover, illuminate particularly in ways in which global firms are constantly and deliberating instituting the market, through continual innovations in spatial and social divisions of labor, particularly in the face of global economic downturn and challenges to previously cheap labor and transport availability. Foreign OEM's strategies of siting production in the Bay Area constitutes a form of "reverse globalization." Not only is the highest value-added R&D is going overseas, the first-world/innovation --third-world/manufacturing dichotomy is inverted. Here, the "hidden innovation" of machine shops is not germane to a large volume of machining activity which may return to more routinized, mass production and assembly in the Bay Area.

5.6 Summary Remarks on Why Shops Are Still Here

Contrary to conventional wisdom about the "flattening world" of global production, the regional machining presence, particularly in Silicon Valley, can be characterized as a form of "hidden innovation" that endures due to the four interlocking reasons outlined above. More important than cost or technological considerations in driving the fate of the industry are cultural and historical conditions and social relations and organizational practices. Applied to the machine shop sector case, these include the important role of a distinct regional history and culture of machining; the evolution of a complex and increasingly fragmented network of supplier-customer relationships; collaborative arrangements among shops; and the strategic use of a skilled and adaptable workforce.

Beyond the critical role that machining plays in the co-design of area technologies, however, my observations bore out the presence of volume machining beyond a "critical threshold" for R&D. This includes the emerging potential of "reverse globalization" trends in manufacturing, wherein machining presence increasingly owes to foreign OEMs locating sales, marketing and production facilities in the Bay Area. This volume production by foreign firms will not be on the cusp of design innovations, but will instead involve the mass production of parts for local use.

Together, these propositions challenge “de-industrialization” theories, based in neoclassical economics, that manufacturing does not matter in a post-industrial society, and that there are higher-productivity employment opportunities to be had in an increasingly volatile global economy (Gilder 1990; Reich 1992; Oliner and Sichel 2000 a, b; Ramaswamy 2000), as well as a contemporary body of work emphasizes the role of economic globalization in hastening further spatial dispersion of manufacturing activity (Borrus and Zysman; Gereffi 1994; Sturgeon 2002; Lester 2003; Borrus and Zysman 2002; Phelps and Waley 2004; Phelps and Ozawa 2003).

In Chapter Two, I discussed the increasing attention paid in academia and the media to globalization and the offshoring of a wide array of service and innovation-oriented industries and jobs. This prevailing paradigm generally disregards the critical role that manufacturing sectors play in these "new economy" technology regions: spurring innovation spillover and generating business and employment multiplier effects. Indeed, the very existence of nearly 600 machine shops in the Bay Area calls into question the globalization paradigm of “flattened production” set forth by commentators such as Gereffi (1994), Lester (2003), Borrus and Zysman (2003) and Phelps and Ozawa (2003), the last of whom allows for only a minimal threshold of local production required by OEMs for product design and prototyping.

Instead, the continued presence of skilled manufacturing activity such as machining points to a high-technology economy’s enduring need for “hidden innovation” services.

The “hidden innovation” relationships between machine shop suppliers, their local OEM customers and each other, bolsters observations made by Langlois, Zeitlin, Saxenian and others of firms’ increasing vertical fragmentation. These complex but virtually “hidden” relationships elucidate the ways that firms are actively “instituting” the market through implementing spatial and organizational strategies . Whereas machining is typically disregarded in innovation metrics, including R&D dollars or patents, this critical but unacknowledged, sector contributes greatly to the dynamism of the Bay Area economy.

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C H A P T E R VI. Synthesis of Findings and Afterword

6.0 Introduction

We live in an era where the lines between successive modes of production are blurring. We have traced the origins and uses of the terms "new" and "old" economies, and through the contributions of a wide range of social scientists, have noted that the use of such binary analytical categories are slippery at best. This dissertation is intended to add to the body of critical empirical studies about the continuing transformations of the "new economy" as most recently articulated by such commentators as Levy, Langlois, Sabel and Zeitlin, and Bresnahan, et. al. I sought to understand whether my localized case study provided evidence that global forces have given rise to a further "flattening" of industrial production in space and time, or whether in fact agglomeration, clustering and vertical fragmentation are the defining characteristics of the current era. Most importantly, given the sector's continued presence in the region, I sought to understand whether the cluster of nearly 600 existing Bay Area machine shops continue to serve as an essential, albeit unacknowledged, driver of the regional innovation economy.

.1. Key Findings, Assumptions and Implications

Key Findings

I have endeavored to weave in theoretical discussion with empirical findings in the last five chapters, according to the following sequential structure: the introductory chapter presented a statement of the research problem and the significance of its study: Why does a local machine shop sector persist in a highly competitive, advanced regional economy? Consistently touted as the undisputed leader in both high technology and innovation rankings, the San Francisco Bay Area, California region hosts a disproportionate share of high-technology industries and innovative ideas, products and services. These have been variably measured by numbers of patents issued; volume of business employment and receipts; or by more dubious measures of the presence of a broad class of "creative professionals." And yet, what is largely overlooked or little known is that such an innovation milieu is highly interactive with, and arguably reliant upon, a local supplier base of machine shops, operating in an environment of escalating business costs and fierce land competition.

In Chapter Two, the literature and theoretical overview, I posed the most pressing questions as, "which specific kinds of manufacturing occupations have the best potential to remain in advanced industrial regions, and what are the mechanisms by which workers will be trained and prepared for these jobs? " Contrary to the view that technological forces drive the spatial dispersion of production, I found instances throughout history of the synergistic effects of innovation and industrial production (Jacobs, Rosenberg, Ernst, Gertler and Vinodrai), with firms increasingly operating in a vertical fragmented manner (Langlois, Zeitlin, Whitford, Sabel, Bresnahan, et. al.), without set spatial patterning or locational correlates yet intentionally instituting both proximate or spatially distanced practices to their advantage.

I introduced my research strategy of employing a mixed-method approach of quantitative and qualitative analysis in Chapter Three: given the limitations of and gaps in published data about or accounts of local machining activity, these methods were employed iteratively to complement the other's shortcomings. In this chapter, I introduced both a background review of empirical and ethnographic studies of machining which have been published in the last decade, as well as the research framework through which I approached my own study-- including an introduction of four "ideal types" through which shops are evaluated. I also provided a summary of the existing data and literature on the U.S. machine shop sector relative to global machining and manufacturing trend. With a trade imbalance between consumption and production of over US $2.6 billion, Bay Area and indeed US machine shops are at the whims of currency exchange rates during periods of economic downturn.

Through application of this iterative mixed-methods approach, I conducted a detailed empirical study of the Bay Area's machine shops in Chapters Four and Five, eliciting the spatial and temporal extent of this sector's contribution to "new economy" industries (biotechnology, computer, renewable energy technologies, nanotechnology, semiconductor, and transportation). I found firms, employment and business receipts in this sector to be marked by decline and concentration in the past two decades--the concentration of machining firms in the region is less than 40% what it was in 1987, while the sector's employment concentration has also declined by a tenth. The data revealed and my interviews supported the trend of many shop bankruptcies, with remaining and emerging shops more collaborative with other shops, often bigger in size, and taking on a more diversified customer base.

In the course of my fieldwork, I observed both opportunities and threats to the continued existence of this sector: on the one hand, the world of machining is increasingly part of a "flattening" world of outsourced production; the sector is largely perceived as a private good not in need of public intervention; residential and business neighbors regard machining with NIMBY perspectives; and the persistent difficulties of training and recruitment.

On the other hand, the sector is alive and well due to a) its strong historical and cultural presence in the Bay Area; b) the successful strategies in cooperation and complementarity between shops, with first-tiered, large shops often acting as lead supplier to OEM customers, with family-run "second tiered" and specialty, often newly established "third tiered" shops joining forces and often recombining on a family of jobs; c) shops' diversification of shops' customer base, and particularly their ability to latch onto the next innovation waves; and d) due to both individual shops' and the region's abilities to maintain a skill base via in-house training, attendance at conferences and through informal networking, and through the availability of a well-established training and college programs in the region.

Key Assumptions and Implications

I chose to focus my empirical investigation by moving beyond the nostalgic question of "why and where has manufacturing/machining gone?" By instead exploring in detail the nearly opposite question, "why are machine shops and machinists still here?" I gained insight into the survival and future prospects for this sector. Moreover, *contrary* to the view that technological forces drive the spatial dispersion of production, the Bay Area machine shop case study adds to the body of evidence which points to the synergistic effects of innovation and industrial production (Jacobs, Rosenberg , Ernst, Gertler and Vinodrai).

By virtue of a very specific and focused set of research questions, this investigation makes a number of assumptions which beg re-consideration when viewed through a wider lens. Most centrally, by assuming that industrial production and regional economic growth is a good thing, this study of machining does not address two underlying problems which afflict advanced regional economies and their nation-states: 1) the effects of over- accumulation of capital and 2) the ecological consequences of mass over-consumption. Namely, the assumption that industrial production will aid in both economic growth and long-term economic health does not address or challenge the problems inherent in a production-oriented solution. Solely focusing on production without examining the forces of consumption, misses the fundamentally uneven nature of geographical development, and accumulated capital's constant need and search for new markets, what has been termed by geographer David Harvey to be a "spatial fix".[1]

Just as it was in the early 1930s, the US in the early 20th century suffered from surpluses of commodities, manufactured products, manufacturing capacity and money. In the early 21st century, the US is also faced with a surplus of labor (as evidenced by its unemployment rate at the highest in decades), yet the two surpluses, as before, cannot be profitably matched. Since the oil crisis of 1973, policymakers have tried every available means of solving it and, by doing so, maintaining US global dominance over markets and countries alike, including occupation of foreign lands.[2]

One remaining option to maintaining the current dynamics of production and consumption has been noted to be war; however, a more sustainable direction, one which holds more promise for future generations, has been articulated through emerging social movements focused on fair trade, livable wages, and sustainable consumption which encourages taxation of fossil fuel consumption by individuals and companies alike. As consumer awareness and political campaigns make their way into corporate practices, manufacturers are beginning contribute to such environmental solutions. The degree of their success should be marked by their ability to reduce carbon emissions and promoting fossil-free products and services. By virtue of the growth of CleanTech and nanotechnologies, and their concomitant use of machining services, one can safely say that independent and "captive" machine shops alike are beginning to contribute to such an urgently needed, environmentally responsible direction.

The next wave of technological innovations in renewable energy and clean power are global in dimension—the U.S. has no clear advantage in these emerging industries—and yet, both the policy dialogues and the private strategies to encourage their growth, have not acknowledged the foundational role played by the machining sector as a form of "hidden innovation."

6.2 Steps Beyond Research: Policy and Planning Directions

Beyond the confines of academic scholarship, the larger question of the role of the researcher within the formulation of public policy is highly debatable. Is our intellectual responsibility simply a question of knowing versus acting? Such is a dichotomy of false necessity, in the words of critical legal scholar and Latin American political advisor Roberto Unger. A more nuanced and critical view of geography tell us that the study of human and spatial phenomena transcends neutral principles. Roberto Unger offers a geography of hope which highlights the necessity of transformative action versus intellectual solipsicism:

> *"The most important thing to remember when confronted by scepticism and the sense of despair is that hope is the consequence of action, not its cause. We should act in order to hope. By doing little things we acquire the life and energy to do bigger things."*[3]

In the course of my fieldwork, I encountered several of the key players—machinists, machine shop owners, OEM customers, as well as urban planners, former and current elected officials, civic leaders who, through their visions and efforts, inspired me to grapple with issues of policy. Many of these players have convened recent public forum, such as UC Berkeley's Workshop on Industrial Land in November 2007 and a Roundtable on Industry planned in May 2008, which have sought to raise public discussion and debate about the role of manufacturing. Such discussion and debate have focused on how to strike a balance between more laissez-faire attitude of an "invisible hand" of supply and demand and globalized outsourcing, with a more prescriptive view of precision machining as the "industrial heart" of a regional economy, to be valued and prioritized as source of jobs and of wealth generation.

Within the discussion of public policy, the important role of machinists within the so-called "knowledge," "high technology," and "clean technology" economies cannot be overemphasized. Despite the attention and hype around "green" jobs and "green collar" manufacturing jobs, there has been little to no attention in the literature or in the popular press about the critical role of machining. For instance, "green collar" manufacturing jobs generally refer to such manual processes as solar panel assemblers or construction of “green buildings,”[4] without regard to the “hidden innovation” advantage provided by machining skills. Greater understanding of this sector will promote not only the continued staying power of a well-paying occupation with career paths, it will also ensure the continued dynamism of the entire region.

6.3 Concluding Thoughts and Summary

By virtue of its role in making possible the existence of virtually every other manufacturing industry, machining is indeed essential to and embedded as the industrial “heart” of an increasingly services- and information- driven regional economy. In the past six chapters, I have documented the historical trajectory of this long-standing sector, inquired as to the current state of business, employment and training in the sector, and postulated future directions for firm and worker opportunities in the Bay Area machine shop sector.

This investigation was intended as but one step in a much-needed collection of empirical studies of specific manufacturing activities beyond precision machining (e.g., tooling, welding, electrical wiring, and foundry work) and their contributions to “new economy” industries (biotechnology, computer, renewable energy technologies, nanotechnology, semiconductor, and transportation) More understanding and insight is needed, then, into the intertwined nature of information systems, organization, and production, manufacturing processes.

Through offering a detailed empirical study of the relationship between machining design, production and services, I have sought to address this knowledge gap by focusing on what I have found to be a critical role played by the Bay Area's independent machine shop sector in the dynamics of the region. Indeed, machining is the industrial heart and indeed, the lynchpin source of "hidden innovation" in what has otherwise been characterized as the world's premier knowledge and service-oriented, advanced industrial region.

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US Census 1-% Public Use Microdata Samples (PUMS)

US Census County Business Patterns, 1999 & 2005

Acronyms

BLS	Bureau of Labor Statistics
CAD	Computer Assisted Design
CEW	Census of Employment and Wages
CNC	Computer Numerically Controlled
DOL	Department of Labor
GED	General Educational Development
MSA	Metropolitan Statistical Area
NAICS	North American Classification System
NAM	National Association of Manufacturers
NTMA	National Tooling and Machining Association
OEM	Original Equipment Manufacturer
OIG	Office of Inspector General
SIC	Standard Industrial Classification
SOC	Standard Occupational Code

<u>Appendix B</u> Selected Data Charts and Tables

Figure 1 Number of Machine Shop Establishments in 2005 by Employee Size

Machine Shops	Small Shop (1-19 employees)	Medium Shops (20-99 employees)	Large Shops 100+ employees	Total # of Firms (e)
Sunnyvale MSA	267	46	4	317
San Francisco MSA	213	35	6	254
Total	**480**	**81**	**10**	**571**

Source: Bureau of Labor Statistics Census of Employment and Wages

Figure 2 Total Number of Machine Shops, 2000 and 2005

Machine Shops	2005	1999	# (+/-)	% (+/-)
SJ-Santa Clara Sunnyvale MSA	317	400 (1)	-93	-21%
San Francisco-Oakland-Fremont MSA	254	307 (2)	-53	-18%
Total	**571**	**707**	**- 146**	**-19%**

Source: County Business Patterns 2005 and 1999

Figure 3

Occupation	San Francisco-Oakland-Fremont	San Jose-Santa Clara-Sunnyvale	TOTAL BAY AREA
Machinist (514041)	**2,850**	**2,410**	**5,260**
CNC Machine Tool Operator (514011)	460	760	1,220
Numerical Tool/Process Programmer (514012)	180	380	560
Machine Setters, Operators, Tenderers (514021-514035)	2,580	2,090	4,670
Molding, Coremaking & Casting Machine Setters, Operators, Tenderers (514072-514081)	1,660	590	2,250
Tool & Die Makers (514111)	500	130	630
Welders & Related Welding, Soldering, Brazing (514121 & 514122)	2380	1,140	3,520
Total, Selected Skilled Manufacturing Workers	**10,710**	**7,530**	**18,240**

Figure 4
Precision Machining, Related Metalworking, Machining and All Manufacturing Establishments and Employees in 2005

	# Shops	**% of Regional Share**	**Average # Employees**	**% of Regional Share**
Machine shops	571	.35%	7,360(1)	.05%
Fabricated metal product manufacturing	1,293	.78%	22,865	1%
All manufacturing	7,298	4.4%	226,587+	10%
All firms and employment	165,085	100%	2,357,242	100%

Bureau of Labor Statistics Current Employment Survey 2005

Figure 5
Share of Machinists within All Production Workers

Occupation	San Francisco-Oakland-Fremont	San Jose-Santa Clara-Sunnyvale	TOTAL BAY AREA	
Machinist (514041)	2,850	2,410	5,260	3.7%
Metalwork-related Workers	10,710	7,530	18,240	12.85%
Remaining Manufacturing Workers	78,030	45,570	123,600	87.15%
All Production Workers	88,740	53,100	141,840	100%

Bureau of Labor Statistics Occupational Employment Survey 2005

Figure 6
Machinists' Hourly and Annual Wages

Occupation: Machinists (SOC code 514041)
Period: May 2006

Area name	Employment(1)	Hourly mean wage	Annual mean wage(2)
San Francisco-Oakland-Fremont, CA	2850	21.75	45240
San Francisco-San Mateo-Redwood City, CA Metropolitan Division	710	21.96	45680
San Jose-Sunnyvale-Santa Clara, CA	2410	21.02	43720

Footnotes:
(1) Estimates for detailed occupations do not sum to the totals because the totals include occupations not shown separately. Estimates do not include self-employed workers.
(2) Annual wages have been calculated by multiplying the hourly mean wage by 2,080 hours; where an hourly mean wage is not published, the annual wage has been directly calculated from the reported survey data.

SOC code: Standard Occupational Classification code -- see http://www.bls.gov/soc/home.htm

Data extracted on November 9, 2007

Figure 7
Machinist Wage by Sector

Occupation: Machinists (SOC code 514041) Period: May 2006			
Industry (NAICS Code)	**Employment(1)**	**Hourly mean wage**	**Annual mean wage(2)**
Sector 23 - Construction (23--24)	1130	18.65	38790
Sectors 31, 32, and 33 - Manufacturing (31--34)	307900	17.34	36070
Sectors 48 and 49 - Transportation and Warehousing (48--50)	6210	19.47	40490
Sector 99 - Federal, State, and Local Government (OES designation) (99-100)	4570	23.29	48440
Footnotes: (1) Estimates for detailed occupations do not sum to the totals because the totals include occupations not shown separately. Estimates do not include self-employed workers. (2) Annual wages have been calculated by multiplying the hourly mean wage by 2,080 hours; where an hourly mean wage is not published, the annual wage has been directly calculated from the reported survey data.			
SOC code: Standard Occupational Classification code -- see http://www.bls.gov/soc/home.htm NAICS code: North American Industry Classification System code -- see http://www.bls.gov/bls/naics.htm Data extracted on November 9, 2007			

Appendix C
Interview Guide

I. Questions for <u>Machine Shops</u>

General

- Please describe your own career path. How and when did you get into machining?
- Do you know how many machine shops there are in Silicon Valley?
- Do you think that the number of machine shops in Silicon Valley is increasing or decreasing?
- The firms appear to be getting larger. What explains this trend?
- Would you say that business has been improving or getting worse in the last five years? The last ten years?
- What type of firms use the services of the machine shops most often?
- What type of high tech firms would use the services of the machine shops most often?
- Do any of the high tech firms have internal machine shops, or do they contract out?

<u>Relations with Customers</u>

- How do firms contract the services of the machine shops?
- Are the contracts advertised?
- If so, where?
- Do people find out about contracts through informal relationships?
- Do the large firms that contract the services of the machine shops pressure the machine shops to cut costs?
- Do you sell your products/ services outside the Bay Area, State or Country?
- Do you sell your products to retail outlets, or are most of the products capital goods?
-

<u>Relations With Other Shops</u>

- Do different machine shops cooperate and compete with each other?
- When do you/they cooperate?
- How often do machine shops cooperate to complete a contract?

<u>Business Formation</u>

- What are the factors that are made when a machinist makes a capital investment in new equipment?
- Are there particular banks that loan to machine shops?
- How do machinists raise funds to start a shop or improve a shop?

Employees

- How many employees do you have?
- Where do you seek and obtain your employees?
- What are their ethnic, age and gender make-up?
- Are there changes that reflect greater demographic shifts?
- How experienced and well trained are they when you hire them?
- Do you conduct On the Job Training? What does this entail?
- Do you know how many machine shops there are in Silicon Valley?
- Do you think that the number of machine shops in Silicon Valley is increasing or decreasing?
- The firms appear to be getting larger. What explains this trend?
- Would you say that business has been improving or getting worse in the last five years? The last ten years?
- What type of firms use the services of the machine shops most often?
- What type of high tech firms would use the services of the machine shops most often?
- Do any of the high tech firms have internal machine shops, or do they contract out?
- Please describe your own career path- how did you get into machining?

Technology

- Do most machine shops have a research facility?
- How do machine shops conduct research?
- What percentage of the machining tools used are CNC tools?
- What percentage of the machine shops use AutoCad?
-

II. **Questions for Contract Manufacturers (Customers)**

General

- What does your company manufacture?
- Are the products made locally generally prototype and first-production run work, or do you do mass production onsite?
- Where are your company's design and production processes sited?
- Do you employ the services of local machine shops? If so, what do they make for you?
- Who are the machine shops you contract with? How long have you worked with them?

Business Relations

- How does your firm, and other firms to your knowledge, contract the services of the machine shops?
- Are the contracts advertised?
- If so, where?
- How do you decide which ones to contract with?
- What are requirements that you look for in seeking suppliers?
- Please rate the importance of the following factors in seeking suppliers:
- A. cost, B. proximity, C. quality, D. timeliness factors.
- Do people find out about contracts through informal relationships?
- Does your firm, or other large firms that contract the services of the machine shops, apply pressure the machine shops to cut costs?

Technology

- Do the machine shops you contract with have their own research facilities?
- How do you transfer your research and development capacities to your machine shop suppliers?
- What percentage of the machining tools used are CNC tools?
- What percentage of your machine shop contractors use AutoCad? Programming?

III. Questions for Public/Private Partnership (Workforce Development) Officials

- What are the relevant organizations, groups and players in advanced manufacturing workforce development?
- Do you work directly with private sector machine shops in placing or training people?
- Are there (other) programs which assist individuals in getting jobs as machinists?
- Are there countywide or regional organizations that represent the machinists or machine shop owners?
- Is there an organization that lobbies for the interests of the machine shops/machinists at the local, federal or state level?
- How many people graduate from workforce training programs for machinists each year?
- How many union machinists are there?
- What does the machinist training curriculum consist of? Are computer abilities, such as CNC, CAD and programming, required for graduation from your programs?