Innovation and High-Technology Producer Services: Evidence from Twin Cities Firms

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Abstract

Economic development researchers and practitioners have shown substantial but largely separate interest in the growth of high-technology and producer service sectors over the past two to three decades. Many producer service sectors are very technologically-intensive, fast growing, and represent a key part of regional high-tech economic bases. The prevailing perspective is that high-tech producer service firms represent only indirect sources of innovation within regional and high-tech economies, but recent work on entrepreneurship suggests that they should be likely to exhibit innovative, entrepreneurial tendencies. Interviews with high-tech producer service firms in the Minneapolis-Saint Paul metropolitan area confirm this entrepreneurial impluse and show that firms in this sector can be classified in terms of their technological specialization and entrepreneurship characteristics. They are also tied historically and presently to key regional industry clusters, show relatively few tendencies toward being locationally footloose, but are largely out of touch with economic development initiatives, high-tech and otherwise. Federal, state, and local strategies for high-tech economic development should begin to target high-tech producer service firms to unlock their entrepreneurial potential for innovation and regional development.

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I. Introduction

Researchers and practitioners interested in processes of regional development are intently focused on understanding the scope and geography of the "high technology economy." This attention is well deserved, since the innovation and new ideas that underlie high-tech activity are catalysts for regional and national growth through the development of new industries and rejuvenation of old ones. The countless studies, books, task forces, and economic development strategies devoted to high-tech are evidence of this interest within the academic, policy, and practitioner realms.

This widely-shared interest in high-tech is obscured by the ongoing lack of consensus about what precisely constitutes "high-tech." Early expositions focused primarily on high-technology within the context of fast-growing, "sunrise" manufacturing industries (Markusen, Hall, and Glasmeier 1986), reflecting an interest in how new technologies were shaping and re-shaping the industrial landscape. Since then, definitions of high-tech have commonly been limited to electronics and electrical equipment, software and information technology (IT), and communications services (AEA 2002; Cortright and Mayer 2001; Atkinson and Gottlieb 2001). Broader definitions, including those based on criteria such as research and development (R&D) intensity and science and technology occupational content, have frequently included advanced manufacturing and producer service industries (Chapple et al, forthcoming; DeVol 1999; Hecker 1999). The dearth of consensus on the scope of high-technology activity – and indeed, the imperative to draw boundaries around "high-tech" – is only consequential insofar as it serves to distract from ongoing structural changes within the economy that potentially transform the way in which high-technology activity affects regional development paths.

One such change is the shift from goods- toward service-producing sectors. The role of technology-intensive producer service industries within the broader high-tech economy remains largely unexplored. As Bill Beyers points out, producer service industries were once considered "the new economy" well before the growth of the IT industry in the 1990s led to the term's reassignment (Beyers 2002, p. 2). The fast growth of industries like engineering, research and testing and management services has been driven primarily by the growing need for specialized technological expertise on the part of other firms and sectors in the economy, allowing them to operate and innovate more effectively. Yet we know little about whether firms in these sectors represent active agents for high-technology development. This uncertainty casts a shadow on the inclusion of producer service industries within discussions, strategies, and policies for high-tech.

This paper seeks to address this perceived gap by exploring the connection between high-tech producer services and innovation. I begin by discussing the growth of producer service industries and their under-explored connection with high-technology activity. I then review perspectives from recent economic development literature on the relationship between high-tech producer services and innovation and propose an increased emphasis on these firm's entrepreneurship potential. Second, I propose a framework for analyzing innovation in high-tech producer service firms based upon four typologies relating to their specialization and entrepreneurship features. Third, I offer evidence from in-depth interviews conducted with a cross-section of high-tech producer service firms in the Minneapolis-St Paul metropolitan area, including four brief case studies. Through these interviews I find that many high-tech producer service firms exhibit substantial, but often latent, entrepreneurial potential. They also possess a number of characteristics that make

them attractive targets for economic development interventions. I conclude by addressing the implications of this research for regional economic development policy and planning. My primary thesis is that high-technology producer service firms represent an underappreciated and underutilized source of innovation within regional development and that high-technology economic development policies and programs should place more focus on high-tech producer service firms.

II. Producer Services, High Technology, and Innovation

Despite being somewhat less glamorous than high-tech activity, producer services have garnered almost equal interest within regional development circles over the past two decades. The rapid growth of producer service industries (along with the service sector in general) in the 1970s and 1980s compelled economists, geographers, and other regional development scholars to explore the underlying causes and nature of this ongoing structural economic shift. Demand for producer service functions, which some viewed as part of either a "deindustrialized" or "postindustrial" (Bell 1973) economy, was found to be fueled by increasingly complex systems of production that required specialized expertise both internal and external to firms (Beyers and Lindahl 1996a). Homogenized national and international markets allowed for growing product differentiation, which placed increasing emphasis on non-production (service) activities such as planning, product development, market strategy, and administrative control (Stanback et al 1981). This caused some observers to characterize the notion of the "service economy" as less of a transformation in *what* the economy produces (i.e. industries) than *how* the economy produces (i.e.

occupations), implicating a changing division of labor toward service functions, even within traditional industrial sectors (Gershuny 1978; Gershuny and Miles 1983; Walker 1985).

A series of subsequent empirical analyses of the producer service sector identified tangible linkages to regional development. Surveys of producer service firms found that many – especially those engaged in specialized, non-standardized activities – were highly export-oriented, defying traditional conceptions of service functions as being primarily local-serving (Beyers and Alvine 1985; Harrington et al 1991). Empirical evidence indicated strong positive relationships between the presence of producer service activities and productivity and per capita income growth in metropolitan areas (Hansen 1990). This relationship, which could be attributed to the role of producer service functions in expanding the division of labor among and within firms, is consistent with theories of increasing returns proposed by economists such as Allyn Young (1928). The salutary impacts of producer services on regional growth led some to speculate about the potential for organizing development strategies for peripheral and underdeveloped regions around these industries (Coffey and Polese 1989; Glasmeier and Howland 1994).

Producer Services as High-Tech

Producer services encompass a broad range of functions for intermediate use by other firms in the economy, from advertising and public relations to accounting and finance. Many of the functions of producer service firms are related to science and technology, helping their clients to complete technologically-intensive tasks such as engineering, research and testing that they could not accomplish in-house. Despite this, producer services are often overlooked as high-technology sectors.

Nonetheless, the empirical evidence on the growing importance of producer service sectors to high-technology activity is quite striking. Producer service industries are among the most highly concentrated in science and technology (S&T) occupations, a human-capital based measure of "high-techness" (Chapple et al, forthcoming). Computer programming

Table 1. High Tech Industries, Ranked by Share of S&T Occupations, 1998

SIC	Description	1997 U.S. Employment	S&T Occs % of Industry Total
376	Guided Missiles And Space Vehicles And Parts	76,808	42.7
737	**Computer Programming, Data Processing Services**	**1,425,663**	**40.7**
381	Search, Detection, Navigation, Guidance Equipment	185,888	34.1
871	**Engineering, Architectural, And Surveying Services**	**938,469**	**30.5**
357	Computer And Office Equipment	277,495	30.1
873	**Research, Development, And Testing Services**	**491,699**	**26.7**
366	Communications Equipment	294,531	20.8
372	Aircraft And Parts	415,022	17.0
482	Telegraph And Other Message Communications	815,427	16.4
131	Crude Petroleum And Natural Gas	100,333	15.9
386	Photographic Equipment And Supplies	63,738	15.9
367	Electronic Components And Accessories	613,875	15.8
283	Drugs	198,946	15.6
382	Laboratory Apparatus And Analytical, Optical,	370,257	15.3
489	Communications Services	122,339	15.3
899	**Other Business Services**	**192,001**	**15.1**
211	Cigarettes	21,302	14.6
286	Industrial Organic Chemicals	109,618	14.1
874	**Management And Public Relations Services**	**929,903**	**11.9**
281	Industrial Inorganic Chemicals	130,746	11.8
282	Plastics Materials And Synthetic Resins, Synthetic	114,931	11.2
348	Ordnance And Accessories, Except Vehicles And	38,482	10.9
351	Engines And Turbines	250,051	10.5
355	Special Industry Machinery, Except Metalworking	282,581	10.4
148	Nonmetallic Minerals Services, Except Fuels	1,623	10.3
671	Holding Offices	125,829	10.1
631	Life Insurances	561,385	10.1
493	Combination Electric And Gas, And Other Utility	667,403	9.7
384	Surgical, Medical, And Dental Instruments And	312,396	9.5
601	Central Reserve Depository Institutions	66,733	9.0

Source: Chapple et al, forthcoming, "Gauging High-Tech and I-Tech Activity."
Data from BLS, Occupational Employment Statistics, 1998. "High Tech Industry" defined as industry with greater than three times U.S. concentration in high tech scientists and engineering occupations.
Employment data from Economic Census, 1997. As published in Chapple et al, forthcoming.

and data processing services (SIC 737) had more than two of five jobs (40.7%) in S&T occupations as of 1998, ranking it second only to guided missile production (42.7%) in S&T concentration. Engineering, architectural and surveying services (SIC 871) and research, development, and testing services (SIC 873) were both close behind, at 30.5 and 26.7 percent of their workforces, respectively. "Other" business services (SIC 899) and management and public relations services (SIC 874) also make the cut of high-tech industries (Table 1). Data from national industry-occupation matrices indicate that the concentration of S&T workers within these industries grew by about one-third during 1990s, suggesting that high-tech producer service industries have grown in technological intensity during recent years.

High-tech producer service industries exhibited robust growth in the 1990s relative to high-tech industry overall (Table 2). High-tech (R&D-intensive) service industries showed employment growth of 45.6 percent from 1988 to 1996, compared with only 4.9 growth for all high-tech industries, and negative 10.4 percent for high-tech manufacturing industries (Luker and Lyons 1997). Consequently, the proportion of all science and

Table 2
High-Tech Producer Service Industries:
Employment Growth and Science and Technology (S&T) Occupational Share, United States, 1989 and 1998

		Employment		Growth (%)	S&T Share (%)	
SIC	**Industry**	**1989**	**1998**	**8998**	**1989**	**1998**
73	Business services*	5,628,800	9,783,200	73.8	6.0	9.9
871	Engineering and architectural services	770,300	905,200	17.5	24.9	26.9
873	Research and testing services	522,100	614,000	17.6	21.2	22.7
	Services	35,964,700	47,528,400	32.2	2.2	3.4
	Total, All Industries	120,544,530	138,454,100	14.9	2.4	2.9

Source: Bureau of Labor Statistics, National Industry-Occupation Time Series Matrix, 1983-1998

* note: "Business services" includes computer and data processing services (SIC 737), management and public relations services (SIC 874), along with advertising, personnel supply services, equipment rental and leasing, etc. BLS aggregated these industries together due to data inconsistencies that make the employment estimates not strictly comparable across the time period.

technology workers that were in high-tech producer service industries grew by over 50 percent from 1989 to 1998, with more than one in three engineers, computer/IT professionals, life and physical scientists working in these sectors as of 1998 (Markusen and Schrock 2001). In other words, the increased presence of high-tech workers within producer service industries can be understood in terms of both the *fast growth* of the industries themselves, but also shifts toward greater S&T content *within* the industries.

For many metropolitan areas, high-tech producer service industries have come to represent a substantial share of their high-tech employment base. As of 1997, high-tech producer services comprised approximately 40 percent of total high-tech employment nationally, but employment in metropolitan areas such as Washington DC (89.7%), New

Table 3
Metropolitan Employment Specializations in High-Tech Producer Service Industries, 1997

High-Tech Producer Services	**LQ**	**R&D, Testing Services (SIC 873)**	**LQ**
Washington, DC	3.37	San Diego	4.22
San Jose	2.31	Washington, DC	3.94
Boston	2.08	San Jose	3.17
Denver	1.72	Raleigh-Durham	2.77
Dallas	1.58	Boston	2.55
Computer and Data Processing (SIC 737)	**LQ**	**Management And PR Services (SIC 874)**	**LQ**
Washington, DC	4.01	Washington, DC	2.93
San Jose	3.56	New York	1.85
Boston	2.53	Dallas	1.75
Dallas	2.32	Chicago	1.69
Denver	2.04	Boston	1.68
Engineering Services (SIC 871)	**LQ**		
Washington, DC	2.67		
Houston	2.50		
Denver	1.81		
Boston	1.73		
San Jose	1.72		

Source: 1997 Economic Census, among 30 fastest-growing metropolitan areas from 1991 to 2001.

York City (64.0%), and Denver (62.3%) was much more weighted toward high-tech producer services. In terms of concentration, Washington DC had the highest relative concentration of high-tech producer services among the 30 fastest-growing metropolitan areas in the 1990s, at greater than three times the national average (3.37 location quotient, or LQ). Silicon Valley was second (2.31), followed by Boston (2.08), Denver (1.72), and Dallas (1.58) (Table 3).

By looking at the concentration of specific producer service industries across metropolitan areas, interesting patterns of specialization can be detected. Washington DC (4.01 LQ), Silicon Valley (3.56), and Boston (2.53) dominate the computer and software services industry (SIC 737), although much of this is likely attributable to software *product* activity as much as software *service* activity. Washington DC also leads in engineering and architectural services (SIC 871) with an LQ of 2.67, but its margin over Houston (2.50) and Denver (1.81) is somewhat smaller. Research and testing services (SIC 873) shows a very high degree of specialization in certain metro area, with San Diego (4.22), Washington DC (3.94), Silicon Valley (3.17), Raleigh-Durham (2.77), and Boston (2.55) leading the way. Management and public relations services (SIC 874) were most concentrated in Washington DC (2.93), New York City (1.85), Dallas (1.75), and Chicago (1.69). Other than Washington DC, which excelled in all four major high-tech producer service industries[1], the data indicate a variegated landscape in which metro areas specialize in particular parts of the high-tech producer service sector.

[1] The high location quotients for Washington DC may be partially explained by a compositional effect due to the general lack of industrial activity in the region, which would decrease the employment base and thus the denominator in calculating location quotients.

Perspectives on Innovation and High-Tech Producer Services

The link between high-technology and innovation is relatively straightforward: firms, institutions, and individuals engaged in high-technology activity create, commercialize and apply new technologies that are (eventually) embodied in new and innovative products and processes. Firms that create high-technology products such as semiconductors, computer software or cardiac pacemakers are viewed as playing a direct role in this process. But what about high-tech producer service firms, whose efforts are often more intangible or indirect? What role do these firms play in innovation?

The prevailing perspective is that high-tech producer service firms are primarily *enablers* of innovation and technological progress. MacPherson (1997) finds that manufacturing firms who draw upon external advice from technical consultants experience higher rates of product and process innovation than firms that do not. Such evidence about the importance of technology-based producer services offers justification for federal and state manufacturing extension programs that provide technical services to small- and medium-sized manufacturing firms (Shapira 1990; Rosenfeld 1992).

A slightly more sophisticated interpretation of high-tech producer services' indirect role is that of "knowledge cross-fertilizer." Antonelli (1999, 2000) argues that knowledge-intensive business service firms represent an innovative form of industrial organization that helps to transmit localized technological knowledge across industry sectors. According to Antonelli, new information and communications technologies allow knowledge producers to apply their knowledge in ways that allow them to retain higher degrees of proprietary control. This enhances their incentives to produce new knowledge while engaging in opportunities to diffuse their knowledge broadly. Knowledge creation takes place when

existing stocks of codified knowledge are applied to new contexts. Through consulting opportunities, high-tech producer service firms are involved in processes of tacit learning (i.e. learning-by-doing) that allow new knowledge to remain localized within the firm and its workers for future exploitation. This is consistent with empirical evidence showing that tacit knowledge exhibits strong localization tendencies due to its embeddedness within individuals and organizations (Audretch 1998; Jaffe et al 1993).

But are high-tech producer service firms innovators in their own right? Recent studies of entrepreneurship from the field of strategic management (Shane 2000, 2001) strongly suggest that high-tech producer service firms should be exceptionally well-positioned to identify and exploit entrepreneurial opportunities[2]. Drawing on theories of Austrian economics regarding the idiosyncratic and asymmetrical nature of knowledge and empirical evidence from MIT technology entrepreneurs, Shane (2000) shows that the existing knowledge possessed by would-be entrepreneurs conditions both the identification of entrepreneurial opportunities and the exploitation of those opportunities. Given a particular technology, in this case three-dimensional printing (3DP™) technology, individuals identified entrepreneurial opportunities that reflected their prior knowledge about markets, related technologies and customer needs. While Shane stops short of examining whether entrepreneurs with higher levels of prior market knowledge are more successful than those without, his findings are suggestive that individuals who are better situated to identify market opportunities for technological knowledge are more likely to carry those ideas into entrepreneurial ventures. High-technology consultants, who by the

[2] I wish to thank Professor Harry Sapienza from the Carlson School of Management for introducing me to this strategic management and entrepreneurship literature.

nature of their jobs are constantly seeking new clients (markets) for their knowledge, should therefore be considered prime candidates to identify and exploit entrepreneurial opportunities.

By drawing upon recent entrepreneurship literature we can begin to see the relationship between high-tech producer service firms and innovation from a new direction. Because of the combination of technological and market knowledge that high-tech producer service firms often possess it is expected that they would be directly involved in the process of innovation and not just indirectly through the clients with whom they interact. This hypothesis about the innovative and entrepreneurial nature of high-tech producer service firms represents a key point of departure from existing perspectives on this sector and the basis for the research presented here.

III. Framework For Studying Innovation in High-Tech Producer Service Firms

But are all high-tech producer service firms equally inclined toward entrepreneurial ventures? What important distinctions exist among such firms that would condition whether and how they innovate? This section presents a hypothesized typological framework for studying the innovation patterns of high-tech producer service firms.

Figure 1. Four Typologies of High-Tech Producer Service Firms

		Technological Specialization	
		Low	High
Entrepre-neurship	Low	Outsourcers	Experts
	High	Parlayers	Tech Stars

Previous studies of producer service firms have focused on specialization as the most important distinguishing characteristic among firms in this sector (Lindahl and Beyers 1999; Beyers and Lindahl 1996b; Goe et al 2000). While firms providing more routine services to a local client base play an important role in expanding the social division of labor, specialized firms have been understood to represent a more generative source of regional development. These "high flyer" firms enjoy competitive advantages due to their specialized (usually technological) expertise, which allows them to command substantial premia above industry averages in terms of sales per employee and to add to the region's export base by serving non-local clients. To the degree that specialized knowledge within producer service firms is localized around particular industry clusters and agglomerations, such as medical technology in the Twin Cities, it helps to perpetuate established technological and industrial specializations across regions and metropolitan areas.

Taking a firm's degrees of specialization and entrepreneurship as key characteristics relating to its innovation patterns, a two-by-two matrix is formed. This matrix corresponds to four proposed typologies of high-tech producer service firms: *outsourcers*, *experts*, *parlayers*, and *tech stars* (Figure 1).

Outsourcers are high-tech producer service firms with relatively low degrees of specialization and entrepreneurship compared to other firms in this sector. Outsourcers tend to serve local markets with relatively routine technical services that their customers simply would not be able to provide internally due to demand infrequency or lack of expertise (Beyers and Lindahl 1996a). Because the services they offer are more standardized their base of competitors is relatively large, which makes factors such as cost, proximity, and customer service important competitive factors among outsourcers. Because of tendencies

to serve local markets, outsourcers would be likely to exhibit central place location characteristics, settling in urban agglomerations that maximize their local market area. While contributing nonetheless to regional development through the expansion of the social division of labor, outsourcers face barriers to innovation and entrepreneurship through their lack of specialized technological knowledge.

Experts are firms with relatively high degrees of specialization but low levels of entrepreneurship. They serve highly specialized markets – frequently across great distances – for their technological expertise which along with professional reputation represent their primary source of competitive advantage. Because of their specialized and differentiated knowledge they have fewer and more distant direct competitors. The specialized knowledge that experts possess typically relates to a particular industry or technology segment, meaning that patterns of localization that mirror industrial or knowledge-based concentrations should be expected. Experts contribute to innovation indirectly through their clients, who may or may not be involved in high-technology product areas. The high premium that experts command for their knowledge represents a disincentive for them to engage in entrepreneurial activity that changes the nature of their business, especially for highly established firms.

Parlayers are firms with relatively low degrees of technological specialization, but higher degrees of entrepreneurship. These firms resemble *outsourcers* in that they tend to be locally-serving and provide relatively standardized services, and many if not most firms in this category actually begin as outsourcers and continue to compete against them. They distinguish themselves, however, in their ability to "parlay" insight from their customer interactions toward the development of innovative and often proprietary ways for applying

broadly available technologies. Parlayers' entrepreneurial energy – and the differentiated product and service offerings that result from them – represent their primary source of competitive advantage relative to competitor firms.

The final proposed category of high-tech producer service firms are *tech stars*, which exhibit high levels of both specialization and entrepreneurial energy. Like experts, tech stars work from a technological knowledge base that is cutting-edge in nature and serve markets well beyond the regional economy. Tech stars exhibit an ability and propensity to identify and pursue opportunities to translate their specialized knowledge into new product and service offerings for the marketplace. Tech stars are similar to parlayers in their utilization of market knowledge and learning to innovate but at the same time are very different due to the specialized nature of their technologies. Whereas parlayers generally

Figure 2. Features of high-tech producer service firms, by typology

	Outsourcers	Parlayers	Experts	Tech Stars
Degree of technological specialization	Low	Low	High	High
Number of competitors	High	High, although lower if market niche is identified	Low	Low
Market scope	Local-Regional	Local-Regional	National-Int'l	National-Int'l
Location dynamics	Urbanization	Urbanization	Localization	Localization
Tendency for entrepreneurship	Low	High	Low	High
Source(s) of competitive Advantage	Cost, proximity, customer service	Differentiated products and services	Technological knowledge, reputation	Technological knowledge; innovation
Contribution to innovation	Indirect, through expanded social division of labor	Direct, through innovative product and service offerings	Indirect, through client interactions	Direct, through innovative products and services; pioneering new technologies

apply existing or standardized technologies to new opportunities, tech stars are more likely to be engaged in pioneering new technologies altogether. Because of their tendencies toward new and innovative technologies in products and services and substantial export activity, tech stars can be considered the most generative of innovation and regional development among the four types of high-tech producer service firms.

The four typologies proposed here are intended to represent a stylized framework for understanding how high-tech producer service firms engage in innovative behavior. To the extent that the typologies are based upon characteristics that can be measured in terms of continuous variables (i.e., each observation can be categorized from low to high), the typologies can be considered exhaustive and mutually exclusive. In the section that follows, I will compare this hypothetical framework against evidence from in-depth interviews conducted with a cross-section of high-tech producer service firms in the Twin Cities metropolitan area.

IV. Evidence from Twin Cities high-tech producer service firms

Interviews conducted with a cross-section of firms in the Minneapolis-Saint Paul metropolitan area offer evidence toward the hypothesized framework for high-tech producer service firms. Firms with primary or secondary industrial classifications in engineering services, research and testing services and management consulting services were sampled randomly from a directory of high-technology firms published by the Minnesota's technology-based economic development agency.[3] A total of 191 firms fit the

[3] Information technology firms with primary classifications in SIC 737 (computer and data processing services) were not included in the sample, due to the tendency for firms in this industry to be involved primarily in software products, not services. Nonetheless, several firms interviewed were cross-listed in this industrial category.

sampling criteria; interviews were completed with a total of sixteen firms. Although the sixteen firms were selected on a random basis, the sample is too small to be considered representative of the population of firms in these industries. Nonetheless, it is sufficient for illustrating the potential for the proposed framework.

In-depth interviews were arranged with the highest-ranking person in the firm, which was typically the president, founder, chief executive officer, and / or office manager. The intent was to find individual with the broadest knowledge of the firm, including its history, markets, location factors, etc. Interviews were conducted in-person or by phone and generally lasted between 30 and 60 minutes. The interviews consisted primarily of open-ended questions about the firm's history, service and / or product offerings, customer base and markets, competitors, location factors and relationship to economic development programs. The use of open-ended questions allowed for substantial probing and follow-on questions and was conducive to the collection of rich qualitative detail in addition to basic quantitative data. A complete list of interview questions is provided in Appendix B.

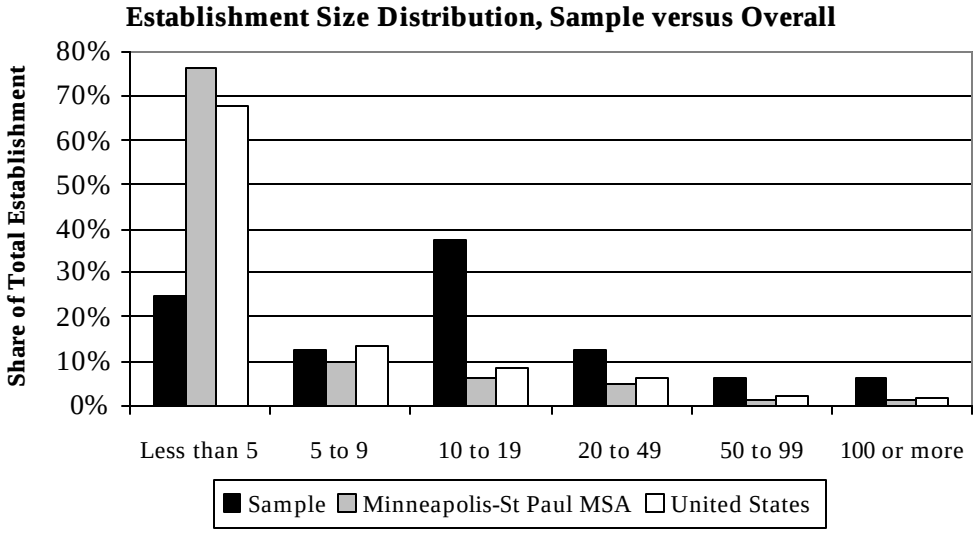
Characteristics of Firms Interviewed

The sixteen firms interviewed can be analyzed in terms of several key characteristics. Nine of the sixteen had primary or secondary industrial classifications in engineering services (SIC 871), six in management services (SIC 874), six in computer and data processing services (SIC 737), five in research and testing services (SIC 873) and two in personnel supply services (SIC 736). Ten of the sixteen were listed in multiple industries. In terms of sectoral focus to their customer base, three of sixteen were focused primarily or exclusively on the medical device / medical technology industry, a major high-technology sector in the Twin Cities. Two were focused on the food processing industry, another key

local cluster (i.e. Pillsbury, General Mills), while one was a biotechnology firm oriented toward the pharmaceutical industry. The remainder served diverse industry bases, although only three of the sixteen had their primary customer base outside of the manufacturing sector.

In terms of firm size, the sample was less heavily represented by very small (less than 5 employee) firms but more represented in small (10 to 19 employee) firms compared to the population of high-tech producer service firms in the United States and Twin Cities (Figure 3). Overall the majority of firms were relatively small, with only four of the sixteen employing 20 persons or more, four with five persons or less, and two single-person establishments (both consultant engineers). The largest proportion (6 of 16) was in the 10 to 19 employee range and the largest firm interviewed employed 100. Total employment in the 16 companies interviewed was 344, for an average of 21.5 workers per company.

Figure 3



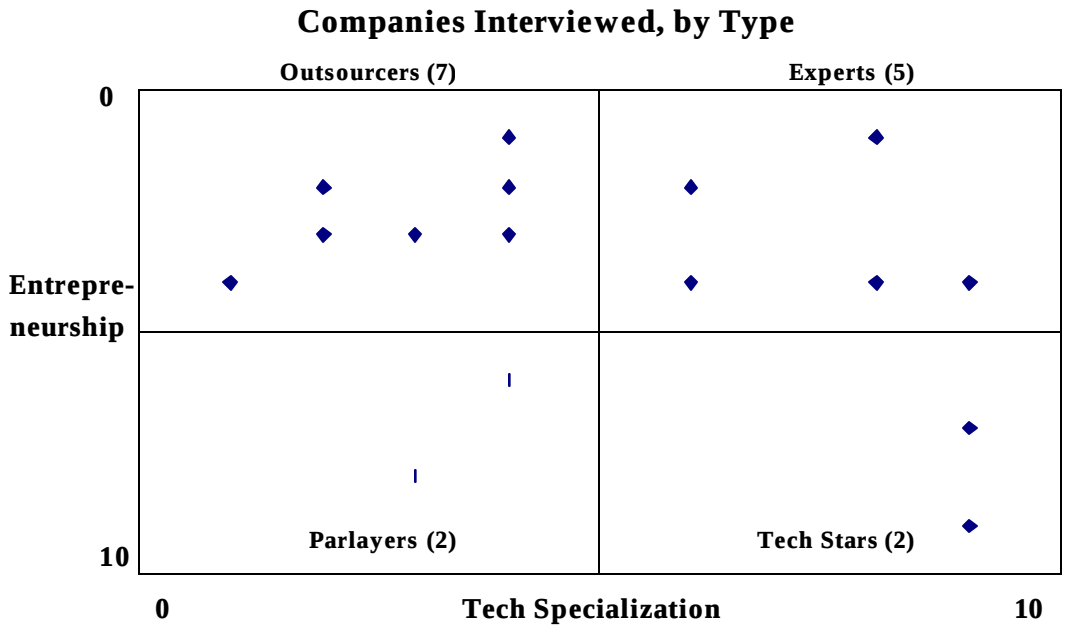
Data Source (MSP and US): Census Bureau, County Business Patterns, 2000; NAICS codes 5413, 5415, 5416, 5417

Twelve of the sixteen were either single-establishment firms or headquarters of multiple-establishment firms. Two of the remaining four were branches of multi-establishment firms with headquarters outside the Twin Cities, while the other two were subsidiaries of related local firms. In terms of date of establishment, the largest share (eight of sixteen firms) were founded during the 1980s, compared with five during the 1990s, and three prior to 1980. None of the firms interviewed had been in operations for less than three years.

Findings: Specialization and Entrepreneurship

As expected, the firms interviewed sorted themselves into the four types of high-tech producer service firms. The sixteen companies interviewed consisted of seven "outsourcers" (low specialization, low entrepreneurship), five "experts" (high specialization, low entrepreneurship), two "parlayers" (low specialization, high entrepreneurship), and two "tech stars" (high specialization, high entrepreneurship). The

Figure 4



distribution of these firms along a two-axis chart is depicted in Figure 4. The placement of the marks along the 0 to 10 axis along the left and bottom axes is indicative of the relative specialization and entrepreneurship ratings assigned to each firm based on the information collected in the interview.

In terms of technological specialization the sample was split almost evenly with nine firms with lower degrees and seven with higher degrees of technological specialization. The metric for assigning the company's specialization rating was the degree to which its core competencies and knowledge base revolved around non-routine (i.e., not widespread or widely diffused) technologies. This was measured as the number of competitors in the same market. Of the seven more highly technologically specialized companies, five derived the majority of their revenue from outside the region and all were active in national or international markets. By contrast none of the nine less specialized companies had more than 40% of its revenue from outside the Twin Cities region.

Technological specialization was not analogous to industrial specialization among the companies interviewed. Of the seven more highly specialized companies only four focused on specific industries, while three of nine less technologically specialized companies had an explicit industrial focus for some or all of their service offerings. Highly specialized companies without an explicit industry focus tended to possess knowledge of basic technologies with multiple applications, suggesting the potential for cross-fertilization of potential applications among industries.

In terms of entrepreneurship the sample was split less evenly. Only four of the sixteen companies interviewed exhibited relatively high levels of entrepreneurship, which was measured in terms of the firm's history of developing differentiated and/or proprietary

product and service offerings. However, a larger proportion (8 of 16 companies) had either already developed a proprietary product, were engaged in some stage of product development, or expressed an explicit goal of developing proprietary products. Still, only three of the eight were deriving substantial revenue from the products they had developed. In most of the other cases the products were either peripheral endeavors for the firm (e.g. related to one project or client) or still in pre-commercial or conceptual stages.

Not surprisingly, the primary source of new product ideas tended to be their clients. Typically, firms that provide engineering, research and design services are brought in to help other companies and organizations develop their own proprietary products. Often, however, new and unintended ideas and discoveries happen along the way. In other words, the individuals and companies providing specialized technological expertise encounter potential applications of their technological knowledge that fall outside the bounds of those identified by their clients. The fact that the generation of new entrepreneurial ideas generally occurs tangential to client interactions is important due to intellectual property concerns. In cases where new product ideas stem directly from specific client interactions, firms must work with those clients to determine appropriate compensation for their role in the process. In cases where the relationship between the entrepreneurial discovery and specific clients is less direct, this is less of an issue.

The motivations for high-tech service firms to engage in product development are relatively straightforward. As one respondent noted, "as a consultant you get tired of chasing your dinner." The revenue growth of service-based firms is almost inextricably linked to the number of workers employed and hours logged. By contrast, the development of new products offers the prospect of faster sales growth without the concomitant need to

add personnel. In the case of a biotech firm, the need for product offerings was even more pragmatic. The product it sells, a fairly routine testing kit, helps to cross-subsidize the firm's research and development efforts to produce cutting-edge assays for the pharmaceutical industry. In other cases, though, the process of cross-subsidization within high-tech service firms works somewhat differently. Firms use revenue from their consulting contracts to underwrite research and development – often informal in nature – for new products.

There may be a couple of potential explanations for why there were a relatively small number of companies that fit the more entrepreneurial categories of "parlayer" and "tech star." The first and perhaps most obvious one is that such firms simply constitute a minority among the overall population of high-tech producer service firms. This is a strong possibility but purely speculative without a more systematic sampling of high-tech producer service firms. Another possibility is that highly entrepreneurial firms in this area eventually abandon service-based work altogether to focus on the manufacture of products they have developed through their service work. An interesting test of this hypothesis (which is well beyond the scope of this work) would be to survey product manufacturers to determine the extent to which those companies had been previously involved in service-based work.

Case studies

In this section case studies are presented of four Twin Cities-area firms relating to the four high-tech producer service firm types: outsourcers, experts, parlayers, and tech stars. The four cases were chosen because they illustrate many of the hypothesized characteristics of their respective typologies. Illustrative case studies are helpful for

"amplifying a more systematic presentation via the realism and vividness of anecdotal information" (GAO 1991, p. 39).

Outsourcer: Northstar Laboratories

Northstar Laboratories[4] is a commercial testing laboratory that employs 15 persons in the northern suburbs of the Twin Cities. The company was started in the late 1980s as a subsidiary of a company producing water treatment chemicals. The owner of the chemical company, which had just moved into a large new facility at the time, started Northstar as a semi-independent entity that would both serve the company's testing needs and at the same time to generate revenue to underwrite the cost of the expensive testing equipment by selling services to outside clients.

Northstar began with a focus on bacteria and nitrate testing of residential wells but soon expanded into discharge testing for municipal wastewater and industrial clients. Environmental regulations that allowed a ten-year window for investigating and remediating leaky underground storage tanks provided a major source of growth during the 1990s. As that market began to subside in the late 1990s, Northstar merged with two small laboratories that were going out of business, including one that focused on food nutritional and safety testing. This service area, which utilizes much of the same testing equipment and expertise, has helped to diversify the company's customer base and tap into the region's strength around food processing. Within that industry, Northstar's services are primarily targeted toward smaller or medium-sized food processing companies who would not have sufficient demand to require such equipment in-house. Overall, the company's markets are highly localized in nature, with approximately 80 percent of its revenue coming

[4] The names of the companies profiled in this section have been changed.

from a 50 mile radius of the Twin Cities. And the company's competitors are also local, with approximately 15 Minnesota firms of various sizes active in similar areas as Northstar.

Northstar's entrepreneurial potential is somewhat limited at present. The company does not currently engage in any research and development toward new technologies or applications of existing technology. Environmental testing, which remains the primary source of the company's revenue, allows relatively little room for innovation since most of the methods are prescribed within regulatory frameworks. The food testing and product safety market, on the other hand, offers far greater potential for cultivating niche markets and technologies. Northstar's general manager indicated that this is an area of potential interest for the company, but that they simply had not identified what that niche might be. Doing so would offer the company opportunities to develop a more differentiated service or product line, moving it from being an *outsourcer* to a *parlayer*.

Expert: Horizon

Horizon is a British multinational engineering design and construction firm. The Minneapolis office is the firm's global center of excellence for food and beverage process and facilities design and is presently ranked nationally in the top five of this category by *Engineering News-Record Magazine*. The Twin Cities establishment, which currently employs 100 people, was originally formed in the early 1950s by an engineer who had worked for locally-based General Mills. The company focused on the food processing industry from the beginning, providing design services for elements such as grain elevators and import-export terminals. Since then the company has been acquired by Horizon and has expanded to offer an array of food facility design services to industry's top companies, such as Pillsbury, General Mills, Kraft, Nabisco, and Cargill, as well as expanding into areas like specialty

chemicals and Nutraceuticals. Although many of its key clients are based in the Twin Cities, where a substantial concentration of food processing companies exists, Horizon provides services around the world at the sites for the facilities it designs. Because of the specialized nature of its work in this area, Horizon competes directly with only three or four firms on a national basis. Although the Minneapolis office also offers more basic environmental and construction management services, its knowledge base around food facility design is extremely specialized.

But while Horizon's Minneapolis office has been successful in establishing a solid reputation as an expert in the field of food process design, they have been less involved in exploiting new ideas and technologies encountered through their work. Such new ideas and breakthroughs do occur on occasion, according to the branch's office manager, but in many cases intellectual property agreements dictate that the clients receive proprietary control of the new technologies developed through their consulting relationship. Nonetheless, Horizon is in the process of filing for a patent on a food processing technology that represents a compilation of the company's internal expertise and experience with a wide range of industries. It is uncertain how Horizon might choose to commercialize the new technology - i.e. whether they would build the products themselves or license it out to other companies, whether they would pursue it internally or spin it off. What is certain, though, is that Horizon will continue to be focused primarily on the provision of engineering services and not shift substantially toward a focus on proprietary products. While the company's status as a branch office likely restricts its decision making in this regard, the firm's established reputation as a consultant is likely also an important factor. If Horizon developed an explicit focus on developing proprietary products it could experience

difficulty finding clients who are willing to share information with them, which would undermine the core business of the firm. This is likely a common barrier to entrepreneurship among expert high-tech producer service firms.

Parlayer: WebMetrics

WebMetrics is a Human Resource Internet Instrument firm located in Minneapolis that offers IT-based human resource development tools to business clients. WebMetrics was started in 2000 as a spin off from a management consulting company that was started in 1994 by a husband and wife team, one with a background in human resource management, the other in information technology and computer software. The company employs six people and is co-located and closely linked to two related establishments, one a consulting group specializing in organizational assessment, the other an interactive media company. Together the three entities offer a range of complementary products and services.

WebMetrics is an "application service provider," in that they have developed a Web-based medium for conducting employee and customer satisfaction surveys, performance goal setting and appraisals, skill and organizational assessments, on-line training modules, etc. that run on their Internet servers. Their customers need only an Internet access to use their tools. WebMetrics' online product offerings will allow it to generate increased revenues per employee by reducing the labor intensity of their client interactions. But also it gives the company an advantage in targeting "geographically challenged" companies – companies with multiple and far-flung sites and branches or are located in remote locations, such as manufacturing firms or healthcare facilities. WebMetrics' primary competition comes from more traditional (i.e. not technology-intensive) human resource and management consulting firms that would be considered "outsourcers." WebMetrics is a

member of local and national human resource trade associations. At present almost all of WebMetrics' customers are based in the Twin Cities area, but their ability to utilize online service delivery means that they have the potential to serve clients over far greater distances than most of their competitors.

Neither the human resource management expertise nor the information technologies that propel WebMetrics are particularly specialized in nature. What makes WebMetrics noteworthy is that its founders identified a niche for parlaying both areas of expertise toward the development of a proprietary product that gives them a competitive advantage. This kind of entrepreneurial activity separates WebMetrics from other "outsourcer" producer service firms.

Tech Star: Techscape Systems

Techscape is a small information technology and environmental services firm based in Saint Paul and employing 20 people. Techscape was founded in 1989 by the lead supercomputer architect for Twin Cities-based supercomputer giant Control Data Corporation and co-founder of its later subsidiary, ETA Systems. The company was founded in the wake of the crash of the Twin Cities' computer industry, when a number of scientists and engineers were laid off from places like Control Data, Cray, and Univac. Techscape's founder, like many computer engineers in the Twin Cities, had extensive knowledge about supercomputer technologies and their potential applications.

Techscape started out pursuing consulting opportunities that drew upon their specialized supercomputer knowledge and served as something of a "job shop" for displaced engineers transitioning from the computer industry into new areas such as medical technology. Soon the company began to develop highly specialized visualization

tools for transforming complex datasets into a three-dimensional graphical interface. This led Techscape into the area of environmental services, where clients like the U.S. Department of Energy and Environmental Protection Agency sought their services to model impacts of events such as hazardous waste spills. The specialized nature of the services offered by Techscape led it to rely very little on a local customer base.

Eventually Techscape found a new niche for its visualization technologies that would transform it from a service- toward a product-oriented company. In early 2002 Techscape launched a Web-based portal that transforms massive publicly-available weather datasets into three-dimensional images that can be integrated with clients' external data, which is targeted toward "weather sensitive" industries such as utilities, air transportation and logistics. And more recently Techscape has introduced a software product for the fast-growing wind power industry, which uses archived weather data and sophisticated models to forecast resource potential and expected wind power energy production. While it received small amounts of venture capital in the later stages of the research and development process, Techscape developed and refined the product's core technologies primarily through its service and consulting opportunities.

According to the company's current CEO, Techscape has always been about "technologies that went looking for a solution." Yet it is unlikely that the company's founder could have envisioned all the possible applications of his specialized knowledge without being compelled to search them out in a consulting context. What makes Techscape a "tech star" is its capacity to learn from the new knowledge it creates by applying its existing knowledge to new consulting situations and the willingness to use that learning to transform the company's product and service offerings.

Comparisons and Cross-Cutting Issues

The four cases presented here illustrate the differing origins, orientations, and trajectories of high-tech producer service firms. One is an integral, innovative part of a competitive "low-tech" industry cluster within the Twin Cities region (Horizon); one provides more routine services to that cluster and other sectors (Northstar); one is the legacy of a once-competitive high-tech industry (Techscape); and the other draws upon the region's past and current strength as a corporate center (WebMetrics). Each, however, constitutes an active and dynamic piece of the Twin Cities high-tech economy. The cases illustrate how lenses of specialization and entrepreneurship can illuminate the way that high-tech producer service firms engage in process of innovation.

One interesting observation is that both highly entrepreneurial firms profiled here (Techscape and WebMetrics) began within the corresponding category of technological specialization. Techscape was an *expert* and WebMetrics was an *outsourcer*, and their entrepreneurial efforts moved them to being a *tech star* and *parlayer*, respectively. This suggests that firms have more control over their degree of entrepreneurship than of specialization, and that to the degree that they move between categories, they move along the entrepreneurship rather than the specialization axis. How specialized a firm's technological knowledge base is seems to depend on the background and prior experiences of its founders and key employees. For example, Techscape likely could not have chosen to focus on supercomputer-based visualization technologies had the firm's founding employees not been deeply involved with them previously. But exploiting entrepreneurial opportunities does not seem to be incumbent on having highly specialized technological knowledge, as the case of WebMetrics suggests. Rather, the ability to be a "learning

organization" – to recognize market opportunities, cross-fertilize knowledge from one application to another – is a more important precondition.

Still, it should not be assumed that all high-tech producer service firms will be inclined toward entrepreneurial pursuits that dramatically alter their strategic focus. For smaller firms involved in fields like consulting engineering, the decision to remain service- rather than product-focused represents a lifestyle choice. For others it means simply foregoing an unnecessary risk if their present status as an outsourcer or expert is successful. For larger, more established experts like Horizon, an explicit focus on developing and commercializing new proprietary technologies could potentially deter clients from working with them, a high risk for efforts that would likely not supplant consulting as their primary revenue source.

General Findings

In addition to addressing the specialization and entrepreneurship patterns of high-tech producer service firms, the interviews provided a wide range of useful information about the origins, location patterns, and connection to public policy and economic development initiatives among companies in this sector.

Firm Origins

There appeared to be no clear pattern guiding the creation of the firms interviewed. Most, however, owed their presence to the efforts of one or more individuals who had previously worked within the Twin Cities region. Even in the two cases where the local establishments were branches of national or multinational consulting firms based elsewhere, both could be traced to locally-based individuals. The motivations behind the establishment of these consulting firms varied, although most were driven by the desire to work outside of

the larger corporate settings where many had developed their knowledge base, and in many cases, which had brought them into the Twin Cities initially from other places. Especially for individuals working in technical, R&D-oriented positions, staying within the corporate environment meant increasing levels of managerial duties and relatively low levels of job security. While only one firm interviewed was the direct consequence of industry downsizing and restructuring, several respondents noted that the decline of the Twin Cities computer industry (Cray, Control Data, Unisys) in the 1980s and subsequent declines in defense-related employers like Honeywell led many local scientists and engineers to begin working as consultants. The high proportion of very small (1-4 employee) Twin Cities high-tech producer service firms relative to the national average (Figure 3) may be indicative of an ongoing effect in this regard.

Location Factors

The interviews provided evidence that challenges the notion that high-tech producer service firms are locationally "footloose" due to their smaller size and general lack of physical capital (Markusen and Schrock 2001). While the ability to work and communicate with distant clients (especially for highly specialized firms) make firm migration a possibility, in reality other barriers tend to be equally high if not higher. For one, the founders of these firms are typically well-established, mid-career professionals with strong industry ties within the region. Consequently they face substantial disincentives to establishing their consulting firms elsewhere. And once the firm is established and has a number of employees it faces a perhaps more intractable barrier, which is that the firm's primary competitive advantage – smart people – is significantly harder to transfer *en masse* than a factory and its equipment. The importance of retaining smart workers is also

reflected in a greater tendency to establish branch offices or permit distance work in order to accommodate individuals moving to other regions.

Among other location factors, proximity to a local client base was considered particularly important for firms providing more routine services, as well as for firms relating to particular local industry concentrations. In the latter case firms commonly provide specialized support services such as product design, testing, and contract personnel to both established and start-up firms within the sector, revealing that they represent integral components of competitive industry clusters. Additionally, access to specialized labor pools was frequently noted as an important factor. For example, the principal of an environmental engineering firm providing specialized industrial cleanup and remediation services on a national basis noted that Minnesota is not ideal for his firm from a market standpoint due to the general lack of heavy industry. But the availability of scientists and engineers with experience in environmentally progressive firms like 3M would preclude moving the firm closer toward its markets, which are mostly outside the region.

In sum, the evidence from the interviews points toward a complex set of locational dynamics for high-tech producer service firms that implicate both demand- and supply-side factors. Perhaps the most unequivocal statement that can be made in this regard is that the location of these consulting firms is likely influenced by the prior location of potential founders of these firms. In other words, places that attract sufficient agglomerations of high-tech workers may eventually host larger concentrations of consulting service firms. This finding should be qualified by the fact that individuals who left the Twin Cities to start firms were not part of the sample (i.e., a selection bias problem). At the same time,

however, none of the individuals or companies interviewed had moved from other locations to start their business in the Twin Cities.

Public Policy and Economic Development Programs

The impact of public policy on the firms interviewed was mixed. On one hand, the demand for specialized consulting services has been fueled in part by regulatory factors. Two notable but highly different examples of this are environmental regulation (e.g. permitting, testing, remediation), which pertains to a wide variety of sectors, and product validation and liability testing for sectors like medical device manufacturing. Several of the firms interviewed focused in whole or in part on helping firms navigate regulatory frameworks. A small number of firms served defense contractors and subcontractors, although none focused primarily on this market.

Yet by and large the firms interviewed tended to fall under the radar screen of existing state and local economic development programs and initiatives. None of the firms interviewed had received public financial assistance to assist with startup or expansions, and none considered availability of public assistance to be an important factor in deciding where to locate. State agencies promoting technology-based economic development and technology transfer were familiar to some, but collaboration with and active assistance from these agencies was not frequent. More common were collaborations with universities, which were typically focused on the application of specialized technologies to meet the needs of particular clients. Although programs exist to promote collaboration with faculty of public universities in Minnesota, most respondents indicated that contacts were typically established through informal channels. Although many had worked with local institutions

like the University of Minnesota, several had sought out faculty working in universities throughout the United States to obtain highly specialized expertise not available locally.

A substantial share of the firms interviewed took part in industry and trade associations. Engineering service firms, for example, were typically members of the American Council of Engineering Companies (ACEC). Such organizations facilitate networking among firms and often provide support for favorable public policies toward consulting service firms, such as no sales taxes on services. Membership in high-tech organizations was less common, except for firms relating to specific regional high-tech clusters like medical technology and biotechnology. The general perception was that mainstream high-tech organizations were not amenable to service and consulting firms and did not consider them truly "high tech."

In sum, the interviews conducted with firms in the Twin Cities metro area provide meaningful evidence that supports the hypothesized innovation patterns of high-tech producer service firms. While not all were engaged in entrepreneurial activities many others were and others had substantial innovative potential. Innovative firms tended to exhibit organizational learning processes that allowed them to build upon and utilize existing stocks of knowledge in new contexts. Additionally, many high-tech producer service firms are linked either historically or presently to key industry sectors within the regional economy, are strongly embedded locationally, but not very well served by existing strategies for innovation and high-technology development at the federal, state and local levels.

V. Implications for economic development

The findings from this research strongly suggest that high-tech producer service firms represent a more active source of innovation than has traditionally been considered with economic development literature and practice. Cross-sectional and longitudinal data unequivocally show that producer service sectors represent a large and growing portion of high-technology activity and are becoming increasingly concentrated with science and technology content. Interviews with a cross-section of firms in the Twin Cities reveal that many are either directly or indirectly tied to the region's historical and current knowledge specializations in areas like computers, food processing, and medical technology. And importantly, a significant share of these firms is engaged in entrepreneurial efforts that would distinguish them as innovators in their own right and not just as enablers of innovation. So what does this mean for regional economic development planning efforts?

The most obvious implication is that policymakers interested in high-technology development should pay closer attention to the innovative potential within high-tech producer service firms. In particular, programs for assisting fledgling high-tech firms through incubation, technical assistance, and risk capital access should be targeted toward service firms as well as product firms in manufacturing and technology. Examples of such programs include the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, both administered by the U.S. Small Business Administration. Like traditional high-tech startups, high-tech producer service firms tend to have relatively little collateral to secure financing, making them too great of a risk for most traditional lending institutions like commercial banks. But because many of these firms have already developed core technologies, identified key markets, and have revenue

streams through their consulting business, investments to catalyze the development and commercialization process would likely be lower and more cost-effective than with traditional high-tech startups.

A second route for promoting entrepreneurship among high-tech producer service firms could involve industry and trade associations that relate to these firms. Activities to promote awareness about entrepreneurship, technical assistance for intellectual property issues, and available sources of risk capital could get more firms to think about capitalizing upon the entrepreneurial opportunities that are presented to them. The Minnesota chapter of the American Society of Mechanical Engineers (ASME) offers seminars on such topics. Since many high-tech producer service firms are not members of high-tech organizations like the Minnesota High Tech Association, efforts to reach these firms should work through organizations like ASME and ACEC.

But efforts should also be focused on making sure that the pipeline of future high-tech consultants and entrepreneurs is well-stocked. In addition to public investments in higher education and research, which are widely understood as being fundamental to future growth, efforts should be made to sustain key institutions and organizations that serve to import human capital into the region. Again, universities and other publicly-supported research entities are part of this, but equally (if not more) important are innovative flagship firms. In the Twin Cities firms like 3M, Medtronic and Honeywell have been instrumental in recruiting individuals from across the country and the world. Many have stayed and advanced in those companies, others have moved on to other places, and still others have taken the knowledge they accrued with those flagship firms into new endeavors within the region, including high-tech producer service firms.

Consequently strategies and policies that make regions attractive for firms to locate innovative activities should be encouraged. There are few simple answers for this, as the decision making calculus for such firms is extremely complex. However, improving the capacity of key local research institutions (e.g. University of Minnesota) that flagship firms rely upon should be one area of focus. But importantly, because the availability of skilled workers is an important factor for attracting companies, strategies to improve the quality of life / place for potential workers should also be a high priority. Richard Florida's recent work linking creativity and tolerance to innovative technology environments, and the importance of a "people climate" rather than a "business climate," is instructive in this regard (Florida 2002).

The role of the research university in creating a climate conducive to innovation in high-tech producer services extends beyond the provision of an educated workforce and retaining and attracting flagship firms. Technological knowledge created within the university context can either be spun out by faculty entrepreneurs who start their own consulting or product businesses, or alternatively by transferring it to existing high-tech producer service businesses in need of specialized expertise. Neither approach is inherently better than the other, although the record of entrepreneurship among university faculty is generally believed to be relatively poor, especially among individuals lacking experience in the private sector[5]. Initiatives to match up university researchers to individuals with market knowledge and management expertise would likely improve the odds of successfully capitalizing on knowledge created within research universities.

[5] Markusen and Oden (1996) found that federal laboratory researchers with private sector experience were more likely to incubate and commercialize new ideas successfully.

Finally, the evidence presented in this paper speaks directly to nascent theories and strategies for targeting occupations rather than industries (Markusen 2000). A key characteristic of occupations desirable for targeting, according to Markusen, is the ability to cross-fertilize across sectors within the regional economy, both local-serving and export-oriented. As illustrated with the cases profiled, high-tech consulting firms are frequently involved in applying technological knowledge accrued from one industry to applications and customer needs in another, a process that generates new and often unique knowledge. Occupational targeting strategies would be well-served to focus not just on occupations with high-tendencies toward self-employment, sectoral "spread" (i.e. broad presence across industries), and entrepreneurship (which is extremely hard to measure), but also their presence within innovative consulting or service-oriented firms. In the case of the high-tech producer service firms presented here, computer scientists and engineers were most prominent among the occupations within the firms. But the case of WebMetrics suggests that insights from occupations like human resource managers can also be generative when combined with other types of technological and market knowledge.

VI. Conclusion

Strategies for high-technology development are fundamentally about creating environments that are conducive to innovation and new ideas. Firms providing technology-intensive services such as computer and data processing, engineering and environmental services, research, development and testing, and management consulting have generally been considered important but peripheral to this process, representing (at best) an indirect source of innovation. But a more critical examination of this assumption would find that

many high-tech producer service firms are generative and innovative in their own right. These firms engage in entrepreneurial behavior that grows and transforms their own businesses as well as the regional economies in which they operate. And because these firms exhibit characteristics such strong locational embeddedness and considerable market knowledge, they appear to be attractive candidates for economic development interventions aimed at leveraging their entrepreneurial potential. Hopefully, high-tech development strategies will eventually recognize the capacity of high-tech producer service firms to innovate and contribute to regional development and competitiveness.

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Appendices

Table A1. Companies Interviewed, Key Characteristics

Firm	Employees	Industry Code(s)	Services Offered
A	1	8742, 8711	Engineering services firm that provides mechanical, electrical, software design and drafting to industrial clients.
B	20	7379, 8711	Information technology and environmental services firm utilizing supercomputer technology to develop visualization and modeling software for varied applications.
C	6	8742, 7372	Provider of Internet-based human resource assessment application to varied clients, with focus on "geographically challenged" companies.
D	1	8711	Consultant in "forensic engineering" (i.e. identifying why a product doesn't work) to industrial clients.
E	16*	7363, 7379, 8734	Technical staffing and engineering solutions services to local medical technology industry.
F	14	8711	Environmental consulting, with focus on industrial remediation.
G	16	8748, 7371, 8711	Software validation and testing services to local medical technology industry.
H	80	8711, 8744	Environmental consulting in diverse areas: water resources, solid waste, industrial remediation, contamination investigation.
I	15	8734, 8371	Commercial testing laboratory focusing on environmental and food safety and nutritional testing.
J	100	8711	Engineering design and construction firm with specialization in food and beverage process and facility design.
K	6	8731	Testing services and analysis for filtration and particle technology equipment manufacturers.
L	3	8731	Biotechnology firm with focus on assay development for pharmaceutical industry.
M	4	8742	Regulatory consultant to medical technology industry, especially in area of biomaterials.
N	16**	7363, 8711, 7371	Technical staffing and engineering solutions services to diverse industries, including aviation and electronic controls.
O	12	7371, 7379, 8748	Information technology consulting for diverse public and private clients.
P	34	8711, 8734	Environmental engineering and consulting with focus on air and water testing for industrial clients.

* figure does not include approximately 65 contract engineers working through company.

** figure does not includes approximately 50 contract engineers working through company.

Industry Codes

SIC	Industry Title	SIC	Industry Title
7363	Help Supply Services	8731	Commercial Physical and Biological Research
7371	Computer Programming Services	8734	Testing Laboratories
7372	Prepackaged Software	8742	Management Consulting Services
7379	Computer Related Services, NEC	8744	Facilities Support Management Services
8711	Engineering Services	8748	Business Consulting Services, NEC

Appendix B. Interview Question List

Note: Interviews were conducted with approval of the University of Minnesota Institutional Review Board, Human Subjects Committee, exemption number 0202E18302.

I. Firm Characteristics

What is the history of your business? When was it started? Who founded it? What was his/her/their background?

What services do you presently offer? Are you involved in the creation of new technologies, or the deployment of existing technologies, or both?

How many employees at this location? Other locations? Is this a single-location, headquarters, branch operation, subsidiary?

What is the approximate occupational breakdown of your employees?

Which occupation(s) are most essential to your work?

Who is your customer base? Do you primarily serve one industry or multiple industries? Who and where are your biggest customers? Do you serve primarily larger (250+), smaller (<50), or midsize (50-250) businesses? How much of your business is non-local (outside the Twin Cities)? How much non-Minnesota?

Who are your main competitors? Where are they located?

Who are your main suppliers? Where are they located?

II. Location Factors

Why is your firm located in the Twin Cities?

Could your firm be located elsewhere and still maintain the same customer base?

Have you considered relocating to a different, non-Twin Cities place?

Have you ever used a consultant to assess location options?

What locations, if any, are considered to be the "hotbeds" of innovation in your particular technology?

If you were to choose an ideal location for your business, how important would the following factors be?

- History (hometown of founder/exec, parent company)
- Availability of skilled workers
- Local amenities (environmental, cultural)
- Specialized research institutions and universities
- presence of key suppliers

- presence of key competitors
- presence of key customers
- debt / equity capital access
- overall tax burden
- available development incentives (tax, infrastructure, lending)
- physical, transportation, or communications infrastructure

Are there any other factors not mentioned here that might influence your location decision?

III. Relationship to Economic Development Programs, Policies, and Initiatives

Have you collaborated with any of the following colleges or universities?
(Collaboration is defined here as a relationship intended to lead to the development or procurement of new technologies or business opportunities)

- University of Minnesota?
- Local technical colleges? (MCTC, St Paul Tech, etc)
- State universities other than U of M? (MSU-Mankato, St. Cloud State, etc)
- Local private colleges and universities? (Hamline, Macalester, etc)
- Non-local universities? (please name)

Have you taken part in federal research grant programs, such as NIH or NSF?

Have you taken part in federal technology transfer programs, such as SBIR or STTR?

Is your firm a defense contractor or subcontractor, or otherwise affected by changes in national or homeland defense spending?

Have you worked with the following agencies and organizations? (If so, in what capacity?)

- Minnesota Department of Trade and Economic Development
- Minnesota Technology Inc.
- Minnesota Project Innovation
- Minnesota High Tech Association
- Small Business Administration / Small Business Development Center

Have you ever received public assistance with a business startup, (re)location or expansion? (please specify)

Has your firm taken part in industry-specific consortia or development initiatives (i.e. “cluster” strategies), publicly supported or otherwise? (If yes, please elaborate)

Are there any other government programs or policies not previously mentioned that directly impact the location of your firm (or its competitiveness in this location)?