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GREATER BOSTON'S ECONOMY

AND

THE ENTREPRENEURIAL AGE

by

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Executive Summary

Greater Boston has been resilient amidst the whirl of the Great Recession, and the region's technological prowess has been part of its success, but will technology start-ups continue to be an economic engine in the future? Moreover, even if technological success endures as a mainstay of the Boston economy, will technology start-ups provide employment for ordinary workers without advanced degrees? Are there sensible steps that state and local government can take to further strengthen the region's technology eco-system?

Relatively high wages make it difficult for Massachusetts to compete globally manufacturing ordinary, old products, but over the past 30 years, greater Boston has shown a remarkable ability to survive and even thrive through innovation. The economic health of the region depends upon the continued humming of its innovation engine, and ensuring that innovation helps people throughout the income distribution.

Detroit's recent bankruptcy should remind us of the risks. A century ago Detroit was a hotbed of entrepreneurship—a place where small firms competed and collaborated to produce the new, new thing. The success of a small number of those firms transformed the metropolitan area into a city of big corporations. As entrepreneurship vanished, so did economic vitality. As Figure 1 illustrates, using metropolitan level data, an abundance of small scale establishments predicts economic success. Dominance by a few large firms predicts failure. Boston should worry that despite a growing number of small startups, Suffolk County's average establishment has over 28 employees, which is more than 80 percent above the national average.

In Sections II and III of this report, we review the current state of technology entrepreneurship in greater Boston. Section II reviews core trends. The technology sector remains in remarkable flux. In 1998, computers and related manufacturing represented about half of the technology-intensive employment. Twelve years later, that sector had declined by well over 50 percent and now represents only one-in-seven technology jobs in greater Boston. Moreover, the technology sector tends to locate away from the region's poorer neighborhoods and tends to employ the disproportionately skilled. These facts limit the ability of the current technology cluster to employ less advantaged residents of the region.

Section III examines the micro-geography of small technology firms. As of 2010, the two traditional technology clusters around Kendall Square and Route 128 remain strongholds of this sector. These clusters are remarkably successful, but it is an open question whether their success can be reproduced in less privileged places. Kendall Square is anchored by M.I.T.; Route 128 clusters around well-educated communities.

The policy approach to entrepreneurship must be radically different from the traditional economic development policies of the past. Supporting technology entrepreneurs does not mean offering generous tax incentives to attract a single large employer. It is hard to imagine that any government entity—state or local—will ever have the technological expertise to successfully play venture capitalist, funding nascent companies in such an environment of change and uncertainty. Professional venture capitalists have enough trouble playing venture capitalist. Moreover, the challenge is particularly extreme because technology is such a moving target. Section IV discusses the use of tax and financing incentives to boost technology start-ups, as well as infrastructure- a second traditional tool for boosting economic development.

We compare the ex post progress of a small sample of companies that have received some form of financial aid from the Commonwealth's MassDevelopment between 2004 and 2008, with a similar set of firms that did not receive aid. We find no significant difference in outcomes between the two sets of firms, but our results are quite imprecise. This does not imply that the MassDevelopment aid didn't achieve positive results—the data do not come to any firm conclusion-- but it does strongly suggest that these programs need to be better structured for serious evaluation. In particular, all government entities that finance private firms engage in ex post evaluation and ideally should designate a control sample for the purposes of comparison.

While there may be scope for sensible broadband investment in Boston, the small physical footprint of most technology entrepreneurs somewhat limits the ability to engender entrepreneurship through traditional infrastructure. Indeed, the remarkable success of Indian software start-ups, despite the limited level of infrastructure in many Indian cities, seems to belie a view that infrastructure is crucial for technology. In Section III, we find little robust relationship between broadband availability and technology start-ups at the zip code level. Still, there are potentially gains from well-targeted infrastructure investments, especially those that are paid for by users themselves. Indeed, it is possible to see Boston's Innovation District as a form of infrastructure investment, albeit one that is privately funded and aimed primarily at empowering small scale start-ups.

The Innovation District connects an old approach to business development (infrastructure) with an alternative approach that focuses on increasing the supply of entrepreneurs either by luring them from other areas through quality of life or education or reducing the barriers to entrepreneur. Section IV turns to the Supply Side approach to promoting technological entrepreneurship, especially in less privileged communities. We discuss four potential policy levers: (1) strengthening the educational pipeline of entrepreneurs, (2) cluster creation, (3) reducing regulatory barriers to entrepreneurship and (4) legal reforms that reduce the power of non-compete clauses. Regulatory reform that speeds the approval of new permits and centralizes the public sector's administrative interface offers a possibly lower cost to reducing the costs of new entrepreneurial activity. Section V concludes, by emphasizing the need for consistent policy innovation and evaluation.

I. Introduction

Figure 1 shows the relationship between average establishment size in 1977 and employment growth between 1977 and 2010 across America's MSAs. The first bar shows that the one-fifth of MSAs with the smallest average establishment size experienced nearly 200 percent employment growth over the 23 year period. The last bar shows that the one-fifth of MSAs with the largest average establishment size experienced employment growth of only about 20 percent. Statistical procedures that control for area attributes, such as temperature, initial population level and education, show that these variables do little to reduce the robust connection between employment growth and small establishment size (Glaeser, Kerr and Kerr, 2012).

Small establishments are seen by many researchers as one proxy for entrepreneurship. The share of employment in new establishments provides another potential proxy. Figure 2 shows the similarly strong relationship between employment growth between 1977 and 2010 and the share of employment in small establishments in 1977. Those MSAs with the most employment in new establishments in 1977 (defined as those created since 1976) experience an average of nearly 200 percent growth. Those MSAs with the less employment in such start-ups experienced growth of less than 25 percent. Again, these results are relatively unchanged when we control for a bevy of local characteristics.

Despite Boston's well-deserved reputation as a center of innovation, the city is dominated by large employers, not small start-ups. Boston has only 2.3 establishments with less than ten workers each for every hundred workers in Suffolk County. America averages 4.8 establishments with less than ten workers for every hundred workers. Across the U.S., there are on average only six establishments with more than 1,000 workers for every 100,000 total workers, but in Suffolk County, there are about ten such large establishments for every 100,000 workers. Moreover, while the national trend is towards smaller establishments, average establishment size in Suffolk County is growing.

To a certain extent, Boston's large firms represent a few sectors that are disproportionately dominated by major employers. Health care, universities, finance and insurance collectively account for 41 out of Suffolk County's 54 employers with 1,000 or more employees. It's not so much that these sectors typically have such large firms, but rather that Boston has unusually large players in these industries. Boston is lucky to have these successful, world-class institutions, just as mid-20th century Detroit was lucky to have the Big Three, but for the city to avoid the fate of Detroit, it must ensure that these entities do not crowd out the small-scale start-ups that deliver sustainable growth.

The apparent domination of greater Boston by large enterprises is somewhat misleading, because many of those entities are better seen as loose alliances of potential entrepreneurs. On one level, M.I.T. is an enormous institution, which has many of the bureaucratic constraints seen in large entities, like General Motors and U.S. Steel. Unlike those entities, many of M.I.T.'s academic employees have been more likely to operate like individual entrepreneurs than middle managers. Over a century ago, M.I.T. chemist Arthur D. Little found his eponymous consulting company and a few years later M.I.T. engineer Vannevar Bush founded Raytheon and mentored the young Frederick Terman who would later create the Stanford industrial park.

M.I.T. may be a particularly extreme example of a large institution that is also a bastion of entrepreneurship, but business school professors are prone to start-up consulting firms, and law school professors often have their own practices. Massachusetts General Hospital has its own "innovation fund" and helps its researchers commercialize their products. In a sense, this structure reflects Mark Pauly's and Michael Redisch's (1973) observations that hospitals are doctors' cooperatives, rather than traditional shareholder-dominated firms, and an organization oriented around its most skilled workers may naturally end up supporting their attempts at entrepreneurship.

Section II defines the industries that are our focus, which include software publishing, scientific research and development, computer and related manufacturing, computer related services, medical manufacturing and electronic shopping. Section II uses County Business Patterns data to document key facts about these industries, in Suffolk and Middlesex counties and in the U.S. as a whole. In Suffolk County, this group of industries, which we call the technology sector, has been growing, admittedly off a small base. In Middlesex County, the employment in these areas is slightly less than in 1998.

The decline in Middlesex County tech employment since 1998 reflects the massive decline in computer-related manufacturing employment, which has dropped by 60 percent since that year, and a somewhat smaller decline in software publishing. These declines have been offset by an impressively large increase in scientific research and development, and by a smaller increase in computer related services. These declines have also been offset by rising earnings in the tech sector, which mean that these technology sectors have actually increased as a share of county earnings, to 24 percent, even as the number of bodies in these areas has declined.

These changes in employment and earnings have been accompanied by shifts in the size distribution of firms as well. As computer manufacturing has declined, its firms have gotten smaller on average, although the overall number of small establishments in that industry has declined dramatically. By contrast, software publishing firms have gotten bigger, because the decline in that sector has particularly hit smaller establishments.

Firm sizes have increased in the growing fields of computer-related services and scientific research and development, as once smaller firms have become more successful. Research and development has seen a reasonable increase in the number of smaller establishments, while the number of establishments in computer-related services has remained stable in Middlesex County. Suffolk County has seen more growth in the number of small scale technology establishments in computer-related services, but there has been a dramatic decline in the number of software publishers in the city.

Section II also discusses the skills and demographics of workers and the self-employed in the technology sector and elsewhere in the region using data from the American Community Survey. These workers are disproportionately skilled, disproportionately young and somewhat less likely to be African-Americans or Hispanic, but more likely to be Asians and immigrants.

The strong skills and youth of many workers in this technology sector suggest that importance of retaining and attracting young and skilled workers to the region. Yet it also reminds us that in Boston and elsewhere, the technology sector has not managed to significantly employ the less skilled or reduce social inequities. Ensuring that the benefits from technological innovation flow to the poor, as well as the rich, is one of the great challenges of the 21st century.

One remarkable feature of Boston's entrepreneurial eco-system is the close ties between entrepreneurs and large firms. A second is its geographic concentration. Two majors areas—Kendall Square and the Route 128 Corridor—house a disproportionate share of the regions technology start-ups. This concentration reflects the continuing importance of geographic proximity, even during an era in which technology has made long-distance communication almost effortless. The importance that many tech entrepreneurs seem to place on face-to-face contact may reflect the difficulties of communicating very complicated ideas electronically or the need for trust when starting a new firm. Despite the rapidly changing nature of technology firms within greater Boston, the regions that house those firms have remained relatively stable.

This report documents both the persistent geographic concentration of greater Boston's technology entrepreneurs and the changing nature of technology employment in the region. This paper focuses on the geography and trends in technology entrepreneurship in Boston.

Section III of the report addresses micro-geography of entrepreneurship and technology within the greater Boston region, defined as the 105 zip codes within the 495 corridor. One geographic fact is that the technology sector, even more than employers more generally, tends to locate in the region's wealthier zip codes. In the region's poorest fourth of zip codes, there are 17.7 employers per 1,000 residents and 2.5 percent of them are technology firms. In the region's richest fourth of zip codes, there are 44 employers per 1,000 inhabitants and 7.2 percent those employers are technology-related. It is certainly troubling that the region's poorest zip codes are technology employer deserts, but there is no easy policy response, for technology firms have tended to reap the benefits of clustering near one another in areas that benefit from strong research institutions and good public schools.

When the technology sectors are taken altogether, the most dramatic geographic fact is the centralization of employment around two poles: the Kendall Square-M.I.T. area and the Route 128 corridor. Of the 2674 technology establishments in our sample, 662 or one-fourth of them lie in zip codes that include Route 128 between Woburn and Waltham (these also include

Burlington and two Zip Codes in Lexington) and 703 lie in the 13 zip codes within two miles of Kendall Square. Fully, one-half of greater Boston's technology establishments lie within these two tight geographic clusters.

These two clusters represent two alternative visions of metropolitan space in the 21st century. Route 128 is car-oriented and suburban; Kendall Square is dominated by foot traffic and public transportation and sits in the urban core of the region. Boston's innovation district is an attempt to provide an alternative inner city technology hub.

Both models appear able to co-exist, although they seem to excel in slightly different industries and slightly different enterprises. Kendall Square has seen somewhat more growth in smaller establishments and has little manufacturing, but much research and development. Route 128 has a wider range of industries and specializes in somewhat larger and presumably older enterprises. The two clusters may be evolving into a well-defined feeder system where new firms are more likely to start out in Kendall Square, where expensive space is compensated for by proximity to M.I.T. and other start-ups, and if they are successful they move out to Route 128, before eventually moving to even lower cost space outside the region. Density seems most valuable where creativity is most vital.

The establishment size distribution somewhat differs between the two areas, however. The Route 128 cluster tends to be over-represented in large technology firms, with almost one-third of the establishments with over 20 employees, and under-represented in smaller firms. By contrast, Kendall square is the center with the larger share of smaller establishments. This difference reflects the historic roots of the Rte. 128 corridor, and the advantages of a pedestrian-public transit based system for smaller start-up firms, and the greater tendency of large technology firms to cluster.

Moreover, and despite the decline in computer-related manufacturing that was once so important in the Route 128 area, these areas have seen faster growth in the number of establishments than the region as a whole. Overall, there is little evidence that geographic concentration is declining across greater Boston's areas, and establishment growth was stronger in the Rte. 128 corridor and near Kendall Square than elsewhere, at least across technology sectors as a whole.

Despite the growth in those areas, there are newer technology areas that are less tightly tied to these traditional clusters of Massachusetts technology, and this gives some hope to the idea of supporting a new technology cluster in some less privileged area. For example, e-commerce has no particular connection with either Kendall Square or the Route 128 area, perhaps because the skills required in that area are quite different. In these newer technology sectors, the education and youth of the nearby area seems be more important factors predicting growth.

These new industries have, however, clustered around the traditional centers for venture capital within the region. We look at the newest technology firms in greater Boston: firms that host data and firms that deal in online commerce. Boston had no establishments in either category in

1998, but it did have a sizable community of venture capitalists before that time. In both cases, holding constant the overall number of technology establishments in those zip codes in 1998, we find that the presence of venture capitalists as of 1998, predicts the subsequent growth of these industries. We find a strong geographic link between these financiers and new start-ups, which might reflect the importance of financing but could just as easily reflect the extra skills embodied in venture capitalists.

Four conclusions emerge from these facts, none of which should be surprising to observers of the Massachusetts technology scene. First, proximity to other firms appears to be extremely important. The great English economist Alfred Marshall wrote almost a century ago that in dense clusters "the mysteries of the trade become no mystery but are, as it were, in the air" and that appears to be true today, as information-intensive enterprises flock to be near one another. Second, universities, especially M.I.T., have been anchors of innovation, but it is possible to have a technology cluster far from a university. Third, the skill base of the local workforce also matters, especially for the newer technology sectors. Fourth, there is a strong geographic link between the location of venture capitalists and the formation of new industries.

In Sections III and IV, we turn to the policy approaches that relate to entrepreneurship. There are three plausible public policy approaches to entrepreneurship. The more modest view is simply that technology entrepreneurship is an important sector worthy, like any major part of the economy, of decent public governance. According to this view, the sector deserves the infrastructure that it is willing to pay for, regulations that are reasonable, and taxes that are not punitive. Even such a modest view justifies some attention to public policies towards technology entrepreneurship.

But there is a second policy viewpoint that is significantly more radical. According to this more activist stance, entrepreneurs in general, and technology entrepreneurs in particular, yield positive spillovers for the economy as a whole. These spillovers come from the creation of jobs, which reduce the social costs of unemployed workers, and the payment of taxes by employees, landlords and shareholders. In the case of technology firms, there is also the possibility of society-wide benefits from the generation of new ideas and products. For example, technology products that are provided essentially for free, like Facebook, seem guaranteed to generate benefits for users who do not pay for them.

The third approach is to view Greater Boston's technological prowess as a tool for solving other problems, most notably the deprivation that exists in too many of our communities. According to this view, the point of innovation policy is not just to encourage innovators but to ensure that the benefits of innovation are spread more widely. This approach points towards policies that build pathways towards technological employment in educational institutions that cater to the less privileged. It also suggests encouraging technology start-ups to locate in less-privileged areas.

We believe that one can care about technology policy without positively affirming a role for subsidies. Even if technology entrepreneurs generate spillovers, we are also sufficiently wary of the abuse of business subsidies that we would be loath to recommend expensive interventions aimed at aiding any particular sector of the economy.

In the first policy section of this paper, we turn to the traditional tools of supporting businesses: tax subsidies, public lending programs and infrastructure. Given the relatively modest level of profits among most start-up companies, it is crucial to distinguish between taxes on corporate profits and other taxes, which still impact the costs of doing business. A start-up that is currently earning no profits has little to fear from the statewide business tax, but it will still pay the costs of sales taxes or property taxes. Taxing business profits, rather than increasing the cost of business inputs is less likely to drive down entrepreneurship rates.

A second traditional policy approach is to provide financing for apparently promising start-ups. Certainly, would-be entrepreneurs repeatedly complain about the short-sightedness of local venture financiers, alleging something like a market failure. Yet it is neither obvious that these claims reflect more than sour grapes nor that the public sector is in any position to correctly direct the flow of new financing. Economists have regularly heaped skepticism on public financing proposals, citing the shortage of venture capital skills within the public sector and the potential for abuse.

One now classic study of Japanese support for start-ups found that the Ministry of International Trade and Industry (MITI) picked losers rather than winners (Beason and Weinstein, 1995). The Commonwealth has several funds which support start-ups within Massachusetts, and we attempted to follow the Beason and Weinstein approach by comparing the subsequent careers of these supported start-ups with comparable careers of initially similar industries. We have created a data set of firms that received financing from the State's Economic Development fund. Using data purchased from Walls & Associates, who created the National Employment Time Series (referred to as NETS in the text from now on) database based on Dun & Bradstreet data, we compare these firms with similar firms that did not receive such financing. We use a propensity score tool to test whether the public financing appears to have improved their odds of success or survival.

We find that there is little or no correlation between state financing and either employment growth or survival level between these two samples. Despite our best efforts, there is no randomization in this analysis so we cannot be sure that the treatment and control samples are identical.

We cannot conclude from these results that the state's programs are failures, but it would be helpful if the state itself engaged in more rigorous evaluation of these programs, ideally with some randomization of support. The larger policy lesson of this report is that small, nimble technology start-ups play an outsized role in driving technology employment and metropolitan growth. Direct financial support for these enterprises seems less crucial than other activities, such as land use planning and regulations that are more traditional parts of the public purview. As the molders of the Innovation District realize, space that supports entrepreneurship seems to be an important ingredient in the creativity that is the ultimate source of greater Boston's economic energy.

A third traditional approach is to support business development with infrastructure spending. During the 19th century, cities like Buffalo and Chicago grew because of their transportation linkages with east and west. Since technology companies use inputs and produce outputs that are easy to ship, they have relatively little need for classical physical infrastructure. The relevant infrastructure question concerns technologically-specific infrastructure such as fiber or broadband.

We do have measures of broadband accessibility from 2010 and later, and while it is impossible to fully address issues of causality, it does seem quite likely that idiosyncratic forces helped determine the location of broadband within the region. Moreover, we find some significant correlations between broadband availability and the location of technology start-ups. This does not make the case for subsidizing broadband, but it does suggesting revisiting the private provision of fiber options in Boston itself.

In Section IV, we turn instead to somewhat more novel policies that focus on increasing the supply of entrepreneurs including policies surrounding education, cluster-making regulatory reform and legal reform regarding non-compete clauses. The success of the Kendall Square district is only one of the many examples where universities can serve as the focal point for technology areas, providing human capital in the form of both faculty and students. Moretti (2004) finds the presence of a land grant college, such as M.I.T., in a metropolitan area is a good predictor of success during recent decades. Hausman (2013) finds that private sector employment expanded dramatically near colleges after the Bayh-Dole Act of 1980 allowed the commercialization of federally funded research. The correlation between area level education and technology establishments reported here provides further support for the link between skills and start-ups.

Our association with a major research university somewhat precludes us from providing disinterested analysis of policies relating to universities. Moreover, given the direct support given by the Federal government and the support that state and local governments provide in the form of property tax abatements, it is unclear whether universities themselves should receive even more subsidy. However, for local governments, it remains important to consider those local policies, especially land use regulations that may make it develop for private entrepreneurs to grow near university campuses.

A second approach to increasing the supplying of entrepreneurs is to develop clusters such as Boston's Innovation District. Lerner (2009) relates the many failed attempts to produce Silicon

Valley in cities throughout the world, so we must be cautious about throwing significant tax dollars at such plans. Yet there are many reasons to be optimistic about Boston's Innovation District, an innovative attempt to create a third technology cluster in Suffolk County. The district recognizes the power of density to spur technology innovation, and it takes advantage of the pedestrian streetscape that exists at the heart of Boston. It certainly appears to have been a success so far.

Moreover, the real estate is intrinsically attractive, with great views, good public transit access, and easy walks into historic Boston. The area does lack access to a traditional technology-oriented university, and it doesn't sit in the middle of a dense cluster of highly educated workers, but that second lack is being remedied through the construction of residential dwellings right in the Innovation District.

This cluster strategy remains a gamble, but it seems one that is well in line with the traditional sources of innovative success. Creating a center of small technology firms in the heart of Boston is not guaranteed to succeed, but it seems like as sensible a move as a government can make to further the growth of innovative entrepreneurship in the region.

The open question about clustering is whether a cluster can be developed in an area without prime waterfront real estate or proximity to a major research university. We briefly discuss the possibility of supporting an innovation district in Dudley Square, or some other less advantaged neighborhood. Success is surely not guaranteed in such an effort, but if the cost was sufficiently low, this could be an experiment worth trying. A particularly appealing lever would be to offer fast track regulatory approval for firms that locate in such an area.

More generally, reforming regulation is another plausible approach to encouraging entrepreneurship. Rules that bar start-ups are an implicit taxes the limits the supply of entrepreneurship into the region. Typically, technology start-ups complain far less about regulation than entrepreneurs in other industries, such as food service providers. Nonetheless, there are reasons to believe that greater Boston might benefit from centralizing and streamlining its regulatory process, in line with the approach pioneered in Devens more than 15 years ago. A second complementary approach is to re-evaluate old regulations to see whether their benefits really outweigh their costs.

A final approach is to eliminate the enforceability of non-compete clauses in Massachusetts, perhaps while also adopting the Uniform Trade Secrets Act. The overall impact on entrepreneurship of non-compete clauses is technically ambiguous. The act does product firms from losing key employees to competing firms, which may make them more willing to hire and trust workers with sensitive information. However, non-compete clauses also directly prevent the movement of employees into new firms. Moreover, as long as other states, including California, decline to enforce non-compete clauses, then it is unlikely that Massachusetts' enforcing of these losses provides much protection, since workers can always move to a competing firm in another state. Eliminating non-compete clauses, while allowing more protection of trade secrets through the Uniform Trade Secrets Act, offers at least the promise of allowing more start-ups without excessively damaging existing firms' ability to trust their workers.

In the concluding section, we admit that entrepreneurship policy is a work in progress. We believe that the weight of evidence pushes away from traditional policies towards more novel policies that emphasize the supply of entrepreneurship. But we also believe that we are just beginning to understand what policies will really have a meaningful impact on the supply of entrepreneurs. As such, we urge an approach of constant policy innovation and evaluation. Governments, like entrepreneurs themselves, should consistently try new approaches, including the Innovation District. We also urge experimenting with a second innovation district in a less privileged area, as long as the cost can be limited. But the gains from these innovations depend critically on proper evaluation, so that other jurisdictions can learn what works.

II. The State of Technology Firms and Entrepreneurship in Greater Boston

In this paper, we focus on a narrow, but important, slice of greater Boston's entrepreneurs—high technology—which we define as a set of related industries including computer-related manufacturing and services, research and development, software publishing and medical equipment manufacturing. We focus on Middlesex and Suffolk Counties. In Middlesex County, technology employment is a behemoth, accounting for almost one-fourth of all wage earnings. Technology is a much smaller share of Suffolk County's employment, but technology employment in Suffolk is increasing, while it is actually falling slightly in Middlesex.

The sectors are rich but volatile. Earnings are enormously high -- $126,000 per year in Middlesex County—but change is dramatic. The number of computer manufacturing jobs in Middlesex declined by 60 percent over the past 15 years. The decline has almost been offset by growth in other areas, but a regional dependence on technology entrepreneurship is a bit like hitching your wagon to a whirlwind. The upside is phenomenal, but there is a real chance for disaster.

We begin with an overview of the technology sectors in Suffolk and Middlesex County in 1998 and 2011. We rely on County Business Patterns, which is an annual survey of business establishments throughout the United States. The survey contains counts of employees, earnings and establishments, although occasionally data on earnings and employment is suppressed if the number of establishments is small for confidentiality reasons. We supplement this data with information from the NETS database, which also catalogues the number and size of establishments by industry. The County Business Patterns data enables us to look at the size of the establishment, but not whether the establishment is new or old. The NETS data enables us to look at new entrants separately.

One potential issue is that the data is available at the establishment rather than the firm level. As such, it is possible that a new establishment may actually be part of a larger firm. In the case of fast-food restaurants, for example, this would be a major issue, but in the case of technology firms, this seems less likely to be a major issue.

Table 1 presents the broad facts about employment change in technology sectors in Middlesex and Suffolk County and in the United States as a whole for comparison purposes. Relatively arbitrarily, we have chosen 1998 and 2011 as our two comparison years. The year 2011 is the last year where data is available. The year 1998 is a relatively convenient earlier point, capturing the situation at almost the peak of the late 1990s technology boom.

The data is divided up by the North American Industry Classification System (NAICS), which attempts to categorize establishments by their primary function. Table 1 focuses on 8 key industries: computer and electronic equipment manufacturing (NAICS code 334), computer-related services (5415), software publishers (5112), medical equipment manufacturing (3254), research and development in the hard sciences (which includes both the life science and engineering—NAICS code 54171), electronic commerce (45411), data processing, hosting and related services (NAICS code 518210), and internet publishing, broadcasting, and web search portals (NAICS code 519130). This cannot be a completely inclusive list of people involved in technology in greater Boston, as there are management consultants who specialize in technology and plenty of academics, lawyers and others who are directly involved in technology. We will also use employment in venture capital (NAICS code 523910), but we will be more interested in that as a determinant of technological growth rather than a cause.

We have again relatively arbitrarily split big vs. small firms by using a twenty employee cutoff. The alternatives within the County Business Patterns would be to use 10 or 50 employees as a cutoff, but to us establishments with 40 workers seem relatively large and we still think of establishments with 15 employees as reasonably small. Yet we recognize that reasonable people may disagree with this choice, just as they can disagree with our choice of industries.

The top row yields results for all eight industries put together. Perhaps the most salient fact is how much large technology employment is in Middlesex County than in Suffolk County. There are approximately 120,000 technology workers in Middlesex County and roughly one-tenth as many in Suffolk County. About 14 percent of Middlesex County workers are in these technology sectors, while the comparable figure for Suffolk County is two percent. As such, Middlesex is far more technology-intensive than the U.S. as a whole (where the average is 3.7 percent), while Suffolk is less technology intensive. Finance, insurance and health care are far more important sectors in the city of Boston.

But the trends are different in the two counties. Technology employment in Suffolk County rose by over 75 percent between 1998 and 2011, which is faster than the national average. Technology employment in Middlesex County grew by only 9 percent over that period, reflecting primarily the decline in computer and related manufacturing. Middlesex has expensive land and expensive labor, and it should not be surprising that manufacturing has departed, just as manufacturing has been leaving metropolitan America for the past fifty years. Suffolk began with so little manufacturing that this trend had little impact.

Technology workers are extremely well compensated in the Boston region. Earnings per employee were $126,000 in Middlesex County and slightly over $100,000 in Suffolk County. Moreover, the inflation-adjusted earnings trend is quite positive. We have reported earnings per employee in both years in 2012 dollars, so the growth in earnings is over 30 percent in Middlesex County and 22 percent in Suffolk County. Earnings growth in Suffolk County technology approximately matches the general increase in earnings in that area, but technology earnings growth in Middlesex County exceeds the county norm. Relative to the regional or national average, technology workers are quite privileged, and they are generally getting even more privileged as time goes by.

These high earnings mean that the technology sector has an outsized share as a fraction of total Middlesex County earnings. Almost one-fourth of all the earnings reported in County Business Patterns in that county come from technology-related establishments. That large share reminds us just how important these industries are for the local economy. The comparable figure for Suffolk County is 2.7 percent, which certainly leaves plenty of room for growth.

We then turn to the individual industry groups. Computer and related manufacturing was a large part of Middlesex County's recent past. Over 50,000 workers were in that sector as late as 1998, when more than 15,000 workers made semi-conductors alone. Just 13 years later, the sector is a shadow of its former self, with less than 20,000 workers. Semi-conductor employment has dropped by over 50 percent. In percentage terms, the decline in computer and electronics manufacturing in Suffolk was even more extreme. There are 88 percent fewer jobs in these sectors in Suffolk County than there were in 1998, but that loss is far less important, because the initial base was so much smaller (only 2500 workers).

During the post-World War II period, America's cities evolved from being centers of manufacturing into centers of service provision, and business services came to play an outsized role as urban export industries. A core difference between manufacturing and services is that the end product in manufacturing is inanimate and shippable. Declining transportation costs have made it increasingly easy to produce goods anywhere and cheaply move them across the globe, which has meant that manufacturing has typically either moved to areas with lower cost labor or evolved in high cost areas into a far more capital intensive industry. The evolution in computer manufacturing occurred at a somewhat later date, because computers, like most products, were originally manufactured near to where they were invented. But just as Apple moved its production from California to cheaper locations across the Pacific, computer manufacturing has also left Massachusetts. In 1998, 6 percent of the earnings in Middlesex County was in computer-related manufacturing, but by 2011, that share was below four percent.

Computer-related services has somewhat taken the place of computer-related manufacturing in greater Boston. In Middlesex Counties, computer-related service employment increased by over 6,000 between 1998 and 2011, a twenty-six percent increase. In Suffolk County, the percent increase is over 75 percent, representing over 2,000 new jobs. In Suffolk County, the rise in computer-related services is almost identical to the decline in computer-related manufacturing, making the city about as computer-intensive as it was during the tech boom. In Middlesex County, the computer services rise is still much smaller than the manufacturing decline.

For those who believe in the power of smaller-scale entrepreneurial business, the shift from manufacturing to services has an added benefit. The manufacturing companies were typically fairly large, especially in Middlesex County. The service companies are small. In 1998, more than one-half of the computer-related manufacturing establishments in Middlesex County had more than 20 employees. In 2011, more than 85 percent of the computer-related service establishments in Middlesex had less than 20 employees. Those firms are training a new crop of entrepreneurs, who may excel as computer service providers or may move into some related field if things don't work out.

Our third computer-related sector is software publishing, which has growth in Suffolk County and tumbled in Middlesex County. Nationwide there has been a healthy 20 percent increase in software publishing, and Suffolk has experienced an over 30 percent growth in this sector to over 1800 workers. Middlesex County has actually experienced in decline in software publishing from over 20,000 jobs to 18,282 jobs, meaning that overall the two counties and the state have seen their software publishing employment decline, even though national software publishing employment has risen substantially.

The decline in software publishing in Massachusetts is something of a puzzle. This is a skill intensive industry that thrives on interaction. Our technology clusters should be particularly good in this area, and indeed, the workers in this industry earn high wages that have continued to rise over time. One possible cause of the decline is that whatever productivity advantages Massachusetts possesses may not offset the high cost of such skilled labor. We have also seen a particular decline in the number of smaller software publishers, and our software establishments are larger than the national norm. In a sense, there has been a failure of entrepreneurship in this area that should be worrying to the Commonwealth.

The largest increase that offsets the decline in computer-related manufacturing is the rise in scientific research and development establishments, which includes both engineering and life science research. In Middlesex County, employment in this area has risen by almost 200 percent, or 27,000 new jobs, since 1998. In Suffolk County, the increase is almost 80 percent, or almost 1200 new jobs.

The shift between computer and related manufacturing and research and development has been dramatic over a short thirteen year period. The speed of change reminds us the highly fluid nature of the technology sector. Government policies that attempt to support particular subsets of the technology world, therefore, face a particularly difficult change of hitting a very mobile target.

We now turn to three considerably smaller sectors: medical device manufacturing, pharmaceutical and medicine manufacturing, and electronic shopping, which includes internet commerce. Pharmaceutical manufacturing has been growing slightly in Middlesex County, but is completely absent from Suffolk County. Medical device manufacturing has been declining, just like the manufacturing of computer-related items.

E-Shopping wasn't present in 1998, and it is still a small share of overall employment, with 1,248 workers in Suffolk County and 906 workers in Middlesex County. It is the only industry in our group that is larger in Suffolk than in Middlesex County. It is also interesting that the Middlesex County cluster is actually more dominated by small firms than the Suffolk County cluster, but both clusters are marked by large numbers of small establishments. As in most industries, however, large establishments are more dominant in Suffolk County than in the nation as a whole, even in internet shopping.

Who Works in Technology Firms?

We turn now to the nature of technology firm employment. There are two primary reasons why we are interested in who works for these firms. First, many papers have documented that a supply of relevant workers is a major draw for prospective employers. Indeed, one can plausibly argue that Greater Boston has been so successful in attracting technology firms precisely because the region has so many skilled workers. Second, if we are concerned with the broad economic health of the region, then we should be concerned about whether firms are employing workers of all sorts, including people of all races, ages and educational backgrounds. It is true that even if technology firms are employing only the skilled, then they will still create jobs for the less skilled who provide services to these workers. Yet the social case for supporting technology entrepreneurship becomes even stronger if these firms can help reduce the inequities that loom so large in modern America.

Table 2 shows data on employment in our technological sectors for the state as a whole (panel 2a) and for Suffolk County (panel 2b). We are using data from the American Community Survey from 2007-2011, and as such these represent five year averages. We have also examined annual data, but there are few obvious trends. These data are based on place-of-residence, rather than place-of-work, which is why we decided to use the entire state as one of our areas of interest.

The first row of both panels shows the characteristics of employees who are not in one of the technology sectors and the second row combines all of the technology sectors together into a single group. The first column shows earnings, and documents that in the state, technology workers earn 76 percent more than non-technology workers, while in Suffolk County technology workers earn 55 percent more than non-technology workers. Software publishing is the highest earning technology sector in both geographies, with annual earnings over $100,000, and computer and related manufacturing is a close second. The high wages in the manufacturing group illustrates the loss that the state's economy suffered from the decline of this once-mighty sector. Workers in "electronic auctions" earn the least. The high wages in technology overall suggest one reason why it would be desirable for a larger share of the population to able to participate in this set of industries.

The second column shows the share of workers in each industry with high school diplomas. Massachusetts is a well-educated state, and even in non-technology areas, 92 percent of workers have a high school degree. In Suffolk County, only a slightly smaller share of non-technology workers (89 percent) have a high school diploma. In technology, at both levels of geography, high school degrees are ubiquitous. Ninety-eight percent of technology workers have high school degrees in both the state and Suffolk County. Medical equipment manufacturing is the only technology sector in which there are a significant number of high school dropouts— seven percent across the state and nine percent in Suffolk County. Given these facts, there seems to be virtually no chance that technology companies are likely to employ significant numbers of high school dropouts.

The need for a college degree in technology job is slightly less extreme. Across the state, 74 percent of technology employees have a college degree. In Suffolk County, 79 percent of employees have a college degree. The manufacturing industries, including both computers and medical equipment, typically employee a great share of non-college educated employees. More than one-half of medical equipment manufacturing employees lack a college degree. By contrast, about 85 percent of workers in software publishing are college educated. Again, this highlights the social losses associated with declining manufacturing.

We now turn to race. The technology industry disproportionately employs Asians and under-employs African-Americans. While about five percent of the state's non-technology workers are Asian, about thirteen percent of technology workers are Asian. While 18 percent of Suffolk County's non-technology employees are African-American, only seven percent of the county's technology employees are African-America. The one technology industry that employs African-Americans at a particularly high rate is medical equipment manufacturing.

We must stress that this pattern in no way implies any discrimination on the part of technology employers either towards Asians or against African-Americans. We have not been able to control adequately for appropriate skills, and it seems quite likely that much if not all of this pattern reflects skill differences across demographic sub-groups. Yet even if that explains the gap, the gap retains policy relevance.

The last three columns split workers on the basis of age. We have defined three age categories: 20-24 year olds, 25-39 year olds and 40-59 year olds. Somewhat surprisingly, given the reputation of technology workers as young hipsters, we find 20-24 year olds to be under-represented in the technology sectors. Across the state, about 9 percent of employees outside of technology are 20-24 year olds, but only about 5 percent of technology workers are that age. There are more young workers in Suffolk County, but they are still under-represented in technology.

The 25-39 years represent the core of technology workers. Fifty-eight percent of technology workers in Suffolk County are in this age category. Almost forty percent of technology workers state-wide are in this age bracket, and that also represents larger representation than in non-technology firms. Older workers are typically under-represented in technology firms.

These results don't suggest any immediate policy imperative—except, perhaps, the benefits of closing the state's achievement gaps. Technology firms have tended to pay high wages, and employ skilled workers. They have tended to hire more workers who are aged between 25 and 39. Yet these results still demonstrate the enormous challenge of ensuring that technology firms help left a larger segment of greater Boston's population. Unless workers have the skills that these firms need, they are unlikely to be able to participate in the information economy.

Changes in Entrepreneurship and New Establishments

We now shift from the overall trends in employment to the shifts in the number of establishments. Is greater Boston seeing an entrepreneurial expansion, with a growing number of little firms, or instead, is the number of establishments declining, even in the industries that are growing? If we interpret the correlation between average firm size and subsequent employment growth as reflecting a causal effect, where abundant small firms generate subsequent growth, then greater Boston should care deeply about whether these dynamic technology sectors are experiencing growth in the number of establishments.

Figure 3A shows the time paths of total establishments across all industries for Suffolk County, Middlesex County and the U.S. as a whole. As in all of the figures that follow, we have normalized 2004 (the midway point of the graph) to equal one for all three series so that they are comparable. As such, the graph can be interpreted as showing the percentage change in the number of establishments for a given geography relative to 2004.

Figure 3A shows that the number of establishments in the U.S. as a whole rise by 10 percent between 1998 and 2007, and then declined by about four percent when the recession hit. By contrast, Suffolk County saw its establishment number rise during the early period, but it then fell after 2003. Middlesex County has been quite stable showing only a modest decline after 2007. The two local series are actually far more stable than the national series. However, given that Suffolk County, has long had very large average establishments, the decline in the number of establishments over this time period suggests that there has not been any dramatic move towards smaller firms over this period overall.

Figure 3B shows the change in Computer and Related Manufacturing Establishments. All three geographies have seen some contraction in the number of these manufacturing establishments, but the decline has most severe in Middlesex County, which is not surprising since employment in this industry was also contracting severely over this time period in Middlesex County. In fact, the number of workers declined more rapidly than the number of establishments in Middlesex. Suffolk had been declining as severely as Middlesex County in the number of establishments in this industry, but this was reversed in 2010. Of course, before we get too excited about this turnaround, we should remember that this represents only six new establishments, all of which had fewer than five employees.

Figure 3C shows the trends for computer-related services. As we saw earlier, this is a growing, not declining area in greater Boston, but despite this growth, the number of establishments, especially in Middlesex County has declined since 2000, which the real fall occurring between 2000 and 2005. The number of establishments has stabilized since then, but overall, this suggests that the industry, while thriving, is getting less entrepreneurial, not more. The much smaller sector in Suffolk County shows stronger cyclical variation, booming upward between 1998 and 2001 (when Middlesex County also saw an increase in the number of establishments) and then falling through 2006 and then rising again during the recession. One possibility is that technology workers who left more established jobs during the downturn switched into starting their own small consulting services. That is one path towards entrepreneurship.

Figure 3D turns to software publishing. As in the case of computer-related manufacturing, there has been a steady decline in the number of establishments in Middlesex County that has outpaced the national decline. All told, Middlesex County has forty percent fewer establishments in software publishing then it did in 1998. This decline illustrates the remarkable cooling of entrepreneurship in this area that we have already discussed. The number of software publishers in Suffolk County has been far more stable, although since employment in software publishing has risen over this time period in Suffolk, average establishment size is also rising.

Figure 3E shows changes in the number of establishments in research and development. Here Middlesex County entrepreneurship seems strong, with over a fifty percent increase in the number of establishments during this time period. Suffolk has also seen an increase in the number of establishments, but the growth has been less than the national average.

Figure 3F looks at medical manufacturing establishments. The U.S. trend is quite stable. Middlesex county has shown more cyclicality than the U.S. as a whole, but little visible trend. In Suffolk, where the numbers are much smaller and more volatile, there was a boom that peaked in 2003 and a subsequent decline.

Figure 3G looks at electronic commerce establishments, which have boomed since 2003 when they first started appearing. The growth in the number of establishments has been phenomenal, especially in Suffolk County, but it is worth stressing that the number of establishments and employees is still small. Figure 3H looks at the similarly nascent industry of data hosting/processing and related services. There was stability and growth through 2007, but then the number of establishments declined dramatically.

We now turn to the NETS data that enables us to look at the formation of new establishments. Most industries have substantial churning, so an abundance of new establishments is typically compensating for an offsetting decline in the closing of old establishments. Nonetheless, the rate of entry provides another means of looking at the state of technology entrepreneurship in greater Boston.

In this case, we present data from 1991 to 2010. Each data point will represent the number of new establishments divided by the stock of establishments during the prior year. We unfortunately do not have comparable data for the county as a whole so these graphs will only allow comparisons over time for Middlesex and Suffolk County.

Figure 4A shows the rate of new establishment births in computer and related manufacturing. Despite the general decline of this industry in Middlesex, the rate of new establishment births has declined only mildly, from about ten percent at its peak during the 1990s, to around seven percent during the slower years after 2003. The time series for Middlesex and Suffolk Counties mirror each other quite closely. The contraction in computer-related manufacturing seems to be related more to firm contractions and closure than to a decline in the number of new firm births.

Figure 4B shows start-ups in computer-related services. Despite the general growth in this industry, there has been a precipitous decline in new firm start-ups since the 1990s. During those years, the start-up rate could top 20 percent. In recent years, the Figure has been closer to five percent. While employment in this sector remains robust, the drop-off in the start-up rate is worrisome for anyone who hopes that growth in the area will bolster the economy of greater Boston.

Figure 4C shows results for software publishers. A downward trend is again quite visible for both counties. The start-up rate was over 20 percent, both in the early 1990s and in the years of the internet boom. In recent years, the start-up rate has been closer to five percent, although there has been substantial pick-up since the recession. More time will be needed to assess whether this rise in start-ups represents a new burst of entrepreneurship in this industry, or whether it has become far more stagnant than it was during the past.

Figure 4D shows the start-up rate for research and development establishments. Here the norm is a birth rate of about 10 percent, although there are peak years when the rate has topped 20 percent. In this case, there is no visible trend in either Middlesex or Suffolk Counties. This seems to be an industry that is holding onto its entrepreneurial edge.

Figure 4E looks at medicine and pharmaceutical manufacturing enterprises. Apart from a burst in 1993 and a trough in 2003, this industry shows start-up rates that are remarkably stable, running again at around ten percent per year. Figure 4F shows data host births which were extremely high during the 1990s and have been much slower since the internet boom's collapse.

Overall, the trends show stability and even growth in research and development, but a general decline in new establishment births in all of the computer related fields. Computer-related services remains stable in employment, but the decline in the number of new establishments suggests that greater Boston will not be able to depend on continuing growth in this area. Hopefully, research and development will be able to make up some of the slack, but we suspect that Boston's future depends on some other new, new thing.

III. The Geography of Technology Entrepreneurship within Greater Boston

We now turn from area-level trends to the geography of entrepreneurship within greater Boston. We have two sources of sub-county data by industry: the Census' County Business Patterns and NETS establishment level data. The CBP data is quite inclusive, as it is based on employer identification numbers taken from tax records. The data only goes down to the zip code level. Moreover, one downside of the data is that for confidentiality reasons, detailed information, especially at the industry level, is frequently withheld. As such, we are able to note the number of establishments in any industry within any zip code in Boston in the different size categories provided by the Census, but we are not able to identify the actual number of employees in each of these zip codes or their earnings.

The NETS data is based on Dun and Bradstreet's register of businesses. It contains street addresses of establishments, with estimates of firm size and sales. As such, it allows us to look at entrepreneurial employment with more granularity, but probably less accuracy. It also includes sole proprietorships, which we will generally exclude.

Figure 5A shows the geography of all of our tech companies using County Business Patterns. The map illustrates the two technology clusters in greater Boston. The outer cluster runs along Route 128, from Waltham to Woburn, and includes five zip codes. The inner cluster is East Cambridge, centered around M.I.T., and includes three zip codes. The average number of technology establishments in both of these clusters was 105 in 2010, and in both clusters about

30 percent of the establishments have more than employees, while 70 percent of the establishments are smaller than that amount.

Figure 6A shows the same figure, drawn at the smaller geography of Census tracts, using the NETS data. These graphs again show the tight concentration of technology firms along Route 128. This map also illustrates a significant amount of activity in Boston itself. Figure 6B shows the geography of sole proprietorships for all the technology firms altogether. While we will generally exclude these enterprises, to make the NETS data more comparable to County Business Patterns, this graph does show the sole proprietorships do tend to cluster in the typically clusters and that there is a particularly rich array of them in downtown Boston. This group provides something of a base for the Innovation District in Boston.

Figures 5B and 5C shows the clustering of large and small technology establishments. Figure 5B includes only firms with more than 20 employees. These larger firms are disproportionately in the Route 128 Corridor, although there is also some preference in Kendall Square. Figure 5C includes only the smaller establishments. Here the spatial concentration is far less extreme, which much more spread throughout the region. Two forces may contribute to the suburbanization of larger firms. They may have larger in-house research teams, which reduces slightly, the gains from proximity to M.I.T. Perhaps even more importantly, they typically demand large office structures which will tend to push them towards an area where space is somewhat cheaper.

Rich and Poor Zip Codes

To further assess, the accessibility to technology employers of rich and poor, we divided our zip codes into three groups based on per capita income. The first group includes the poorest fourth of zip codes within the region. The second group includes the fifty percent of zip codes that are in the middle of the income distribution. The third group includes the wealthiest one-fourth of all zip codes. Table 3 shows the distribution of all employers and technology employers across these three groups.

The first column shows the average median household income across the three groups, which rises from about $40,000 in the poorest group to $128,000 in the richest quarter of zip codes. The second column shows the average number of employers per 1,000 people in each zip code. In the poorest quarter of zip codes, there are 18 employers per 1,000 residents. In the richest zip codes, there are 44 employers per 1,000 inhabitants. This gap is striking, for wealthy people are willing to pay more for the benefits of short commutes and firms often choose to locate near more skilled employees. Yet even if this gap in employment accessibility reflects understandable economic forces, it still means that poorer residents of the region suffer from less employment accessibility.

The third column shows the number of smaller establishments per 1,000 inhabitants, and the fourth column shows the number of larger establishments per 1,000 inhabitants. The percentage gap in the number of employers between rich and poor zip codes is roughly similar—around 145 percent. Yet since there are so many more small employers than large employers, this means that the bulk of the total employer difference is explained by the absence of smaller establishments in low income areas.

The fifth column shows the share of all establishments that are in technology by zip code group. Only 2.5 percent of employers in low income zip codes are in technology. In the wealthiest zip codes, 7.2 percent of employers are technologically oriented. When combined with the overall gap in employer density, this means that the number of technology employers per capita is seven times larger in wealthy zip codes than in poorer zip codes.

The fifth column shows the share of small establishments that are in technology by zip code income level. This share rises from 2.4 percent in the poorest areas to 6.7 percent in the richest areas. The seventh column shows that the share of large establishments that are in technology rises from 3.2 percent in the poorest zip codes to 9.7 percent in the wealthiest zip codes. Notably, the middle income districts have the highest share of large technology establishments perhaps reflect a desire of these firms to avoid the costliest real estate. In all cases, the number of technology establishments per inhabitant rises monotonically with income.

This table illustrates the challenges of creating technology clusters in lower income areas. On their own, technology firms appear drawn to higher income areas, perhaps because their thirst for highly skilled employees or other amenities that exist in these locales. Inducing even a few technology start-ups to locate in a lower income area will require effort.

Kendall Square and Route 128

But above all, the technology sector seems drawn to two great clusters—one along Route 128 and the other in Kendall Square. The general similarity between the Route 128 and Kendall Square clusters masks a somewhat different pattern in the dynamics of establishment change, as Table 4 illustrates. In 1998, the Kendall Square Cluster had fewer firms than Route 128, and relatively more big establishments. Over time, therefore, there has been somewhat faster growth in the number of big establishments in Route 128 (24% growth over 12 years as opposed to 10 percent growth) and distinctly faster growth in the number of small establishments in Kendall Square (36 percent growth as opposed to 8 percent growth).

Figure 5D shows the growth in the number of these technology establishments between 1998 and 2010. The growth in the number of establishments shows somewhat more dispersal, with substantial numbers of new, typically smaller, establishments in places that have not traditionally been at the center of technology entrepreneurship in greater Boston, such as Malden and Newton. Nonetheless, these hubs have attracted many of the new establishments in the region.

The patterns of concentration differ somewhat by industry. We have also performed statistical tests to see whether these firms are disproportionately in the two clusters, holding other zip codes the total number of establishments in the zip code and the share of the population with a college degree constant. As we lacked demographic data for some zip codes, we used the average share of population with a college degree across all of our zip codes for those areas, and included an indicator value that takes on a value of one if the college variable is missing as an added control. We have estimated results separately for big and small establishments. The core results from these tests are shown in Table 5.

Internet shopping is the only industrial group that is not disproportionately located in either cluster. Online publishing and software is not disproportionately in the Route 128 corridor and big firms in that industry are not disproportionately located in Kendall Square (there are only 24 such large firms across all of our zip codes). Large computer-related manufacturing establishments are not disproportionately in Kendall Square. With those minor exceptions, every one of our industries are disproportionately in both of these clusters. Computers are certainly a significant part of the concentration, but this clustering even appears in sectors that are marginally related to computing (like medical manufacturing).

As an illustration, Figure 5E shows the clustering of computer and related manufacturing from County Business patterns. Figure 6E shows a comparable Figure using the NETS data.[1] Some computer and related manufacturing in almost all of the zip codes, but it is disproportionately prevalent in the Route 128 Zip codes. On average those zip codes have at least six more establishments in that industry than their education and total establishments counts would suggest.

Figures 5F and 6F show the pattern for computer related services, which is far more balanced between Kendall Square and Route 128. In this industry, firms are far more likely to be small. While about 30 percent of establishments in computer-related manufacturing have more than 20 employees, only about 14 percent of establishments in computer-related services are that large. The small size explains part of the tendency of these firms to be somewhat more urbanized, but even within size category, Kendall Square attracts more service providers relative to manufacturers. There is a broad tendency of manufacturing firms to suburbanize (Glaeser and Kahn, 2003), so it is unsurprising to see that here as well.

Figures 5G and 6G show the pattern for research and development. In this area, Kendall Square is supreme. Those zip codes have almost 40 more establishments in this industry than their education and total establishment counts would predict. It is striking that research and development is the most dynamic sector of technology, as we discussed previously, and also the most prone to be near Kendall Square.

Finally, Figures 5H and 6H show maps for online publishing and software. These are not statistically more likely to be in Route 128, once we control for skills and total establishments, but there is still a cluster of firms there nonetheless. The lack of a statistical relationship partially

[1] Figure 6C and 6D do not exist to facilitate comparisons of the two figures.

reflects the small number of firms in this industry in greater Boston, and it partially reflects the impact of controlling for skills and total number of establishments. If we don't control for these variables, then there is a disproportionate tendency to locate in both clusters.

Education is an important predictor of technology location, and it is, of course, the ultimate source of Boston's strength in technology. To illustrate this, Table 6 shows the correlation between education in a zip code and the presence of different technology establishments. This table excludes the two clusters discussed above, and the zip codes for which we do not have good demographic data. As such, there are only 67 zip codes in each regression. We also control for the total number of establishments across all industries. Each coefficient can be interpreted as the impact of a 100 percent change in the share of college graduates on the number

Across all technology areas, a ten percent increase in the share of the population with a college degree is associated with 3.3 more establishments. The bulk of this effect occurs in small establishments, as a ten percent increase in college share increases the number of small establishments by 2.75. The effect on the number of large establishments is much smaller and statistically indistinguishable from zero. One reason why small firms are more correlated with local education is that they may be less prone to move to lower cost locales to reduce space costs.

The skills relationship is particularly strong with computer services and research and development, and particularly weak with computer and related manufacturing. These findings remind us that Boston's human capital advantage is least likely to matter when making things, and most likely in more creative, interactive pursuits.

Venture Capital Location and Entrepreneurship

Our final examination of geography attempts to measure the impact of local venture capitalists on the location on new technology start-ups. Boston is the third largest center for venture capital nationwide (Chen et al 2010). In 2010, 7.4 percent of the nation's venture capital offices were in greater Boston, although that share has been declining over time. Moreover, the location of venture capitalists is highly concentrated within the region, as shown in Figures 7A and 7B. Figure 7A shows the location of these establishments in 1998; Figure 7B shows the locations in 2010. There is relatively little change between the two periods, although there is slightly southern drift among the western zip codes and a slightly northern drift among the eastern zip codes.

In both maps, the Route 128 area and Waltham are particularly well represented, but so is Boston itself. Indeed, venture capital, like many financial service industries, seems more drawn to the city center than our high technology firms themselves. This urbanization creates an added advantage for firms locating in Boston's Innovation District.

In Figures 8A and 8B, we look at the spatial connection between venture capital firms and technology establishments. Figure 8A shows the correlation between venture capital presence in 1990-1998 and the number of technology establishments today across all sectors. There is certainly a significant positive correlation, but interpretation is confounded by the problem of reverse causality. It is possible either that venture capitalists follow technology firms or that the presence of venture capitalists spurs the creation of technology firms nearby.

To somewhat address this issue, Figure 8B looks at the relationship between venture capital firms and establishments in two industries – data hosting and online commerce—that did not even exist, at least according to County Business Patterns, in Boston in 1998. While it is certainly possible that nascent firms in both industries were actually present in that year, it seems unlikely that venture capitalist location was driven by their location.

Figure 8B, however, shows an even stronger correlation between venture capital establishments prior to 1998 and the location of these industries in 2010. These new industries seem to have locates quite near to the suppliers of start-up finance. The zip codes with the highest number of venture capital establishments (more than 10) have over five times as many establishments in these new sectors than the zip codes with few or no venture capital establishments. Of course, we can't rule out the possibility that omitted factors are driving the correlation, although we have engaged in multiple regression analysis that attempts to control for typical area level variables, such as education, and have found that the correlation between venture capital and start-ups withstands these controls.

Even if the correlation between venture capital location and new industry formation is causal, we cannot be sure why the correlation exists. It may be that venture capitalists are critical because they provide financing. Alternatively, they may be providing other forms of guidance. Perhaps most famously, John Doerr of Kleiner, Perkins and Mike Mortitz of Sequia Capital were critical in pushing Google to hire an experienced corporate leader, Eric Schmidt. If venture capitalists successfully nurture new start-ups with guidance as well as funding, then it is more difficult to imagine that their role will be played by a public alternative.

We now end this overview of facts about technology start-ups in greater Boston and turn to the policy discussion sections of this report. We begin with a discussion of the tradition forms of public intervention, involving taxes, start-up financing and infrastructure. We then turn to somewhat more novel policies that aim to increase the supply of entrepreneurs.

IV. Traditional Approaches to Development: Taxes, Subsidies and Infrastructure

The public sector has three major tools that it has historically used for economic development: taxes and tax subsidies, financing and investing in infrastructure. These tools are traditional because they are general tools, not particularly suited to technology start-ups. Tax policy concerns every firm, not just those new firms are firms engaged in technology production. Financing is more important at the early stage of the firm life cycle, and as such it is at least entrepreneurially oriented, but it is no more relevant for the technology sector than for a restaurant business. Finally, infrastructure investment has an ancient history among American governments dating back to turnpike and canal construction during the early years of our Republic.

Taxes and Tax Subsidies for Entrepreneurs

Perhaps the simplest way that a government can impact any business is by altering the tax code, either towards a broad swath of businesses or towards an individual firm. A specific cash subsidy can also be seen as merely a change in the sign of the tax payment. The literature on entrepreneurship and taxation, particularly within the U.S., is somewhat limited for two main reasons. One perpetual problem is the debate over the appropriate measure of entrepreneurship. For example, self-employment, which is used as a measure by many studies, is seen as capturing too many small, relatively irrelevant entities. A second reason is that state taxes are not random experiments, but rather a reflection of other local conditions. Moreover, it surely matters whether the taxes are being used to provide services that are valued by entrepreneurs or whether they are spent on other items (perhaps social services).

Djankov et al. (2008) examine taxes and entrepreneurship across countries and find a strong negative relationship between business taxes and the level of entrepreneurship. While this work surely has some relevance, one can readily argue that higher tax states do far more that is good with their money than many high tax countries throughout the world. Gentry and Hubbard (2000) examine the impact of tax rates on self-employment across states and time periods within the United States, and also find a negative impact of higher tax rates. Papke (1991) similarly finds a mild negative effect of state taxes on start-up activity. Bruce and Mohsin (2006) provide time series evidence for the U.S. and find a mild negative relationship. As such, there is at least some evidence that higher tax rates can deter some forms of new business activity.

Subsidies are the opposite of taxes and it is surely true that granting subsidies to companies can lure them to locate in a particular state or county. The larger question is whether the benefits from those subsidies cover the costs. Greenstone, Hornbeck and Moretti (2008) show that counties that win bids for million dollar plants see productivity increases in related firms, but winning counties are typically far less wealthy and less dense than greater Boston. One can readily argue that these benefits are far larger than those that would be experienced in our far more developed economy.

There are at least three types of Massachusetts taxes that might conceivably impact entrepreneurship within the state: Moreover, any tax burden must be weighed against the offsetting benefits that taxes provide.

The relevant taxes to consider are business income taxes (such as the eight percent excise tax), personal income taxes, and taxes that impact either business inputs or sales. For many start-ups, profitability takes years and this will tend to mute the impact of Massachusetts' business excise tax. Assuredly the firm is hoping for profitability down the line, but as long as it is able to shift activity elsewhere once it starts turning a profit, then Massachusetts business taxes will end up being relatively unimportant. Moreover, the example of California's thriving technology community, reminds us that start-ups can readily exist in an even higher tax environment. As such, while the evidence on taxes and entrepreneurship suggests that it may hurt entrepreneurship within the state to raise the business tax rate further, it is far from clear that cutting business taxes is a particularly well targeted tool to increase entrepreneurial activity.

Massachusetts also has significant personal income taxes, and perhaps more importantly significant capital gains taxes, which can be as high as 12 percent for short term capital gains. Even if firms do not earn profits, they still will pay their workers and those workers will pay taxes. Massachusetts tax payments do not obviously distort the decision about whether to be an entrepreneur given that they are not particularly progressive and impact salaried workers and entrepreneurs alike. Again, while it seems likely that higher income taxes might have a deterrent impact on entrepreneurship, lowering income taxes would seem to be a very expensive way of potentially increasing entrepreneurship.

Taxes can also specifically target entrepreneurs by increase the price paid for inputs or outputs. Most notably, the state legislature had passed a 6.25 percent technology sales tax in the summer of 2013 to help fund transportation. Standard economic reasoning suggests this tax would have both increased costs to the technology firms that buy technology related services and decreased the revenues that these firms would have received. These payments would have occurred whether or not the firm in question was itself profitable. The subsequent repeal of the tax seems quite justified given the potential downsides of increasing this particular tax burned on the technology sector.

It is, of course, possible to imagine all sorts of technology related tax tricks to make entrepreneurship more appealing, but such approaches risk enormous abuse. Imagine, for example, a general tax credit for individuals investing in Massachusetts technology start-ups. Even defining these start-ups would be difficult, and providing these tax credits would be costly. A far safer strategy seems to be avoiding any particularly targeting of the technology sector, and working to keep taxes as low as decent service level permits.

Finance Subsidies

One way in which the public sector has recently taken to supporting entrepreneurship is through a variety of direct and indirect subsidies, including equity investments, loans, lines of credit, loan guarantees, and other products to promising start-ups. For example, the Commonwealth has both an Emerging Technology Fund and the Massachusetts Growth Capital Corporation, both of which are intended to support entrepreneurship in various forms. The Growth Capital Corporation targets firms that are "unable to obtain traditional financing." The Emerging Technology Fund is specifically oriented towards the technology sector. At the local level, the Boston Local Development Corporation also provides loans of up to $150,000 for "businesses in, or relocating to, the City of Boston."

Economists have long voiced a certain amount of skepticism towards such programs. One line of criticism emphasizes the difficulty of accurately assessing the growth prospects of volatile start-ups. According to this view, the venture capital process is difficult even for experienced professionals. It is just extremely hard to ascertain which new technology is really likely to blossom. It may also be difficult for the public sector to attract skilled venture capital professionals who have the ability to earn much higher compensation in the private sector. A secondary view is that the public provision of financing aid may be poisoned by political incentives that run counter to economic sense. This criticism was particularly evident after the problems at the publicly financed firms of Evergreen Solar and Solyndra.

The supporters of public funding, by contrast, suggest that there may be market failures in the private financing part. Most obviously private financiers are unlikely to take into account the full range of public benefits associated with the growth of a new company, including both increased employed and technological innovation. Moreover, it is conceivable that private financiers are too risk averse to invest in many really risky, transformative technologies.

Beason and Weinstein (1995) provide a key citation in the economic discussion of industrial aid. During the 1980s, Japan's remarkable growth led to speculation that the active support given to many firms by the Ministry of International Trade and Investment (MITI) was responsible for boosting growth. By examining the subsequent growth of firms that did and did not receive such aid, they found that MITI was typically backing losers not winners. This seemed to suggest that the agency was not playing a key role in the country development.

It is worth stressing that this study does not prove that MITI had no effect. It is possible that these firms would have grown even less without the aid. Moreover, even if MITI aid did have an effect, it is not obvious that this aid is delivering benefits that cover the costs.

We believe that these questions can only be resolved by serious analysis of the impact of public financing aid. Ideally, such analysis would be performed by using loan randomization across a qualified sample. In this process, aid-eligible firms would first be selected on the basis of standard criteria, but then among these eligible firms some would be randomly selected to receive financing aid while others would not. While such randomization may seem unfair, we already randomize access to public housing units, among a much more vulnerable population. Randomization would have the great virtue of allowing us to follow the careers of firms that did and did not receive financing aid, but that are otherwise identical, and thereby estimate the true treatment effect of this financing.

Since the financial aid was not randomly allocated, we must create our own imperfect facsimile of a treatment and control group. We do this by starting with the firms that received some form of financial aid from the Commonwealth's MassDevelopment between 2004 and 2008. MassDevelopment, created in 1998 by the Massachusetts State Legislature, offers a wide range of financing and real estate development aid, including bond financing and loans for equipment, real estate, and more. It is also an umbrella for a number of specialty programs, such as the Emerging Technology Fund Loan, TechDollars (which give loans to non-profits so they can buy electronic equipment such as computers), and the Brownfields Redevelopment Fund, which provides loans for the revitalization of abandoned industrial and commercial properties in EDAs (economically distressed areas). Though many of the recipients of this financial aid are non-profits, schools, and public entities, MassDevelopment offers aid to for-profits such as banks, hospitals, manufacturers, and technology and other businesses. Financial aid is offered for both new and existing projects, and for new and existing entities.

Our dataset culls financing aid information from MassDevelopment annual reports, and covers loans and loan guarantees (e.g., Emerging Technology Fund loans, equipment loans, business loans, green loans), bonds (e.g. tax-exempt industrial development bonds, environmental bonds), lines of credit, tax credits, and other related financing instruments. We look all financial aid given to all types of entities, not just aid given to start-ups, to expand our sample size. Using NETS data we can look at the employment and sales growth history of the financially aided firms until 2011. We have a total of 99 firms that received financing assistance. In the case of loans, the average size was around 3 million dollars.

We then create a control sample using the Propensity Score matching method developed by Harvard's Donald Rubin and others. The basic goal of propensity score matching is to create a sample that is quite similar to the sample that received public aid, at least along observable attributes. The basic procedure is to use all of the available attributes prior to receiving state aid for firms across the sample. We then estimate the connection between receiving aid and observable attributes. The predicted probability of receiving state aid is then called a propensity score. We then match each recipient of state aid with its nearest neighbor, i.e. the firm that had the closest propensity score that did not receive state aid. Because some of the firms didn't have a close match that would allow a useful comparison, our sample drops to 30 firms. We then examine the subsequent different between the two firms in employment and sales growth.

Table 7 then shows our results. We focus on the change in the logarithm of sales and the logarithm of employment. Using the logarithm minimizes the impact of extreme outliers and enables interpretation as the impact of the aid program on growth. The first three rows show the estimated impact of the program on employment growth in the first, second and third years after receiving the loans. The second two rows extend the employment growth to the fourth and fifth years after receiving the loans, but our sample drops considerably. The next five rows show the estimated impact of the program on sales growth during the same time periods. We perform the same calculations, using levels instead of logs, and put them in the next 10 rows of the table.

During the first year, the program seems to be associated with both job and sales growth of .02 log point, or approximately two percent. By the third year, the program seems to be associated with job and sales declines of approximately four percent. In no case do we estimate the impact of the program to be statistically significant. Moreover, we cannot rule out the possibility that the program had economically meaningful positive effects, just as we cannot rule out the possibility that it had no effect.

These results do not help us reach a conclusion on the impact of these lending programs. We just do not have enough precision to know whether the programs are increasing employment, let along to conclude that the programs benefits outweigh its costs. But we believe that these results help make the case for further analysis hopefully involving randomization.

If our results had indicated a strong positive effect, then it perhaps would be reasonable to carry on with the loan program without further analysis. But given that our results are inconclusive, we believe that they make the case for further study an imperative. We should not be engaging in such an active loan program unless the program also engages in a meaningful evaluation of its own impact.

Infrastructure

For centuries, public investment in infrastructure—primarily transportation infrastructure—has been seen as a tool of encouraging economic development. In the 19th century, America's local and national government invested in canals and then railroads, and in many cases, these investments had a transformative effect. Great cities, like Buffalo, grew up on nodes of this publicly supported transportation network.

The public interest in infrastructure has not disappeared. The American Recovery and Reinvestment Act of 2009 had a major infrastructure component, which was justified both as a tool to put Americans directly to work and also as a means of encouraging long-term economic development. At the local level, highway and harbor improvements, rail connections, and broadband connectivity have all been seen as tools for encouraging economic growth.

But the hallmark of most technology entrepreneurs is that they are not buying or selling large physical objects that need heavy hauling. In many cases, the inputs are just human beings and highly portable electronics, and the outputs are ideas or software. Even those technology companies that do produce physical objects often produce objects that have an extremely high value per ton, making transportation costs a trivial share of their overall expenses.

The relatively limited dependence of technology on most forms of infrastructure is well illustrates by the rise of software and other technology companies in India. Indian roads are difficult at best, and shipping manufactured goods is difficult. But software can be sent through the ether regardless of the state of the nearby highways. As long as a technology company has its own generator, and some form of decent internet connection, it can operate successfully even when the overall level of infrastructure is quite weak.

In Massachusetts, there are two natural ways in which infrastructure investments are likely to matter to technology firms. The infrastructure that enables trips to work from home matters for almost every employer. One of greater Boston's two main technology hubs is named after a highway—Route 128—and that highway serves mainly to bring human capital to work. The public transportation that is available around Kendall Square is also a major asset for that neighborhood's firms.

But while basic people-moving transportation may be important to technology firms, like every other firm and worker, it doesn't make sense to give the needs of technology start-ups pride of place when determining investments in highways or the MBTA. Major transportation infrastructure is always expensive and must be made with the entire Commonwealth in mind. However, it is distinctly more plausible to imagine that broadband technology plays a special role in enabling entrepreneurship and that ensuring broadband availability might be part of a technology entrepreneurship strategy.

Yet it remains an open question whether marginal improvements in the quality of broadband will make a major difference to technology entrepreneurs in greater Boston today. The empirical question is not so much whether technology firms need broadband, relative to dial-up modems, but rather whether additional advances in speed make much of a difference. Early advances in electronic connectivity made a huge difference, but it is possible that we've reached a point of diminishing returns where additional bursts of velocity have little impact.

To analyze this question, we turned to the Massachusetts Broadband Institute's data on broadband availability throughout the state. They provide data at the very local level on availability of fiber optic (fiber), digital subscriber line (DSL), cable modem and various forms of wireless broadband. We have aggregated this data to the Zip code level and analyzed whether the available of broadband makes a major difference to the presence of technology entrepreneurs.

One major problem with this form of analysis is that the presence of broadband technology is not random. Providers may put broadband in areas that have either been hubs of technology in the past or that are likely to be so in the future. After all, companies like to cater to customers. We can only hope that the availability of some services is sufficiently random so that our results have some chance of validity, but it seems likely that the non-random location of much broadband will tend to bias our results upward. Moreover, we can control, in part, for the non-random nature of broadband location by controlling for the number of technology firms in 1998.

Our primary control variable is the share of land in the area that has access to various broadband technologies. We have used four measures: total wired broadband, total wireless broadband, DSL and fiber. The first two measures have fairly widespread availability across Zip Codes in our sample. The average Zip code has 85 percent wireless broadband accessibility and 84 percent wired broadband accessibility. The ubiquitous nature of the technology certainly reduces the probability that it will appear to have an impact on the location of technology firms. DSL is rarer and fiber optic rarer still, with only seven percent of land in the average zip code having access to fiber.

We present results only on Fiber Optic in Table 8, but results for the other technologies are generally weaker. Moreover, we show results only for the total number of firms, but results are broadly similar if we separate out results in big and small firms. We have also confirmed that different means of defining access to broadband, such as having more than five or fifteen percent of land with access to fiber make little difference to the results.

The first column in the table shows the impact of fiber optic access on the number of establishments in the area. The results show the estimated impact of a 100 percent change in the amount of land that has fiber accessibility (i.e. from no fiber access to complete fiber access), but readers should keep in mind that no zip code in our sample had fiber access as of 2010 on more than 37 percent of its land area. The regressed estimates that total fiber access would increase the total number of technology establishments in a zip code by 100, which is significant both economically and statistically.

The bulk of this effect is coming through the estimated connection between fiber and computer services. We estimate that as the share of land where fiber optic is available increases by 100 percent, the number of these firms increases by 62. There are also statistically significant increases in software establishments (11), data hosting establishments (10), computer manufacturing establishments (9) and online publishing/software and online shopping (4 each). Research and development and medical manufacturing show an increase of 18 establishments and 1 establishment, but both of these results are less significant. These results seem to suggest that fiber access can be a powerful tool for increasing technology start-ups.

However, the remaining columns show that these results are quite sensitive to the inclusion of other areas controls. For example, in the second column we control for the share of adults in the zip code with a college degree in 2000, which is also a powerful predictor of the location of technology start-ups. For those zip codes where this data is not available, we follow a standard procedure of assigning those zip codes the average level of education across all zip codes in the sample and also including an indicator variable that takes on a value of one if data was missing.

The column shows that the connection between fiber and total technology establishments drops by over half and becomes less statistically significant. The estimated connection with computer service establishments also drops by more than fifty percent and also becomes less statistically significant. The only coefficients that remains robust to this control is the impact of fiber on computer manufacturing establishments and data hosting. In the third column, we show that this effect is also robust to controlling for distance from Route 128.

In the fourth column, we take a slightly different approach and control instead only for the number of establishments in 1998. Since fiber was not available in 1998, these coefficients can be seen as asking whether technology establishments increased more in those areas that got fiber after that date. None of the coefficients are large, and only computer manufacturing has a significant positive coefficient of 2. We have run similar regressions for all other measures of broadband access and different methods of measuring this access and found quite similar results. Occasionally there is a statistically significant effect when we control for nothing else, but there is no relationship that is robust to a set of serious controls. One explanation for the limited impact of broadband is that broadband has become so widely accessible in the region.

We do not interpret these results as meaning that broadband access or fiber optic access is irrelevant. Certainly the raw correlations are impressive and may really be capturing some effect of these forms of infrastructure. But it seems unlikely that this infrastructure is incredibly important given the fragility of our results.

To us, these results suggest a policy approach that supports, but does not subsidize, broadband investments. The best test for whether these investments will deliver value is whether users are willing to pay for them. This means that the public should ensure that there are no major barriers to further investments in electronic connectivity, but that the norm should continue to be that users should ultimately pay for the costs of future investments.

V. Expanding the Supply of Entrepreneurs: Education, Clusters, Regulation and Law

We now turn to supply-side policies for entrepreneurs, which include state policies towards education, cluster policies, like the innovation district, regulations and laws concerning the enforceability of non-compete clauses. The general theme of all those policies is that they are aimed at increasing the number of Massachusetts residents who become entrepreneurs.

Education

The link between education and technology entrepreneurship seems straightforward. Our universities have long been centers of scientific development. Many prominent entrepreneurs got started as students or faculties in leading centers of scientific learning, such as Larry Page and Sergey Brin of Stanford. They connection between research universities and local economic success was made by Moretti (2004) who found that the presence of a land grant college in one's metropolitan area prior to 1940 was associated with significantly higher earnings since 1980. Glaeser and Saiz (2004) similarly found that areas with land grant colleges have experienced faster population growth.

Massachusetts' land grant college is M.I.T. and it has certainly played an outsized role in fostering new start-ups. M.I.T's role in furthering local business activity dates back over a century to the pioneering consulting of Arthur D. Little and Vannevar Bush's Raytheon start-up. Hausman (2011) shows that after the Bayh-Dole act enabled the commercialization of federal funded research, there was a flood of related private sector activity in related industries near major research universities. The economic spillovers from educational institutions are real.

It is not clear what the importance of universities implies for state or local policy. At the state level, it is at least conceivable to suggest supporting science campuses in poorer Massachusetts cities in the hope that they will spur more economic revival. Of course, such efforts beg the question of whether it is really more sensible to disperse entrepreneurship given the benefits that entrepreneurs appear to get from clustering. But it is even harder to imagine additional state expenditures to support M.I.T., which would surely be dwarfed by Federal support, tuition and philanthropic revenues.

Our connection with the education sector makes it awkward for us to argue for aggressively subsidizing our own industry, but even without that constraint, we doubt that we would argue that state and local investments are obviously sensible. It seems more reasonable to ask whether state and local policies are doing all that they can to leverage the strong academic resources that are already in place.

Two areas whether state policies connect with our educational strength relate to student retention and local land use planning. Massachusetts is a large exporter of education, meaning that we educate many people from outside the state, region and country, and it is not surprising that our graduate retention rates are relatively low (Sasser, 2008). Still, given that improving the quality of life is a clearly defined function of state and local governments it seems reasonable to ask whether our governments are doing all they can to retain recent college graduates.

Indeed, one way of analyzing many of our local policies is that they are far better suited to the needs of long-term insiders instead of potential recent college graduates. For example, our land use policies (Glaeser, Schuetz and Ward, 2006) make it extremely difficult to build new housing in greater Boston. Restrictions on new construction suit existing home owners, by minimizing the inconveniences of new construction and keeping housing prices. However, those high prices are also a deterrent preventing recent college graduates from staying in the area.

A related land use question concerns the land that is itself proximate to educational institutions. If we think that the neighborhoods around universities are particularly natural spots for new start-ups, and that new start-ups generate advantages for the state as a whole, then we should be particularly wary about restricting density levels near universities, especially near science campuses. It would be possible, for example, for the state legislature to override local zoning regulations, as they do with Chapter 40B and the Dover Amendment, to ensure that it is sufficiently easy to build space for start-ups in areas near existing science campuses.

In many cases, including Kendall Square, localities seem to understand the advantages of allowing new growth, as such the need for state action may be limited at this time. Still, it is worthwhile focusing on non-educational state policies that nonetheless connect with the entrepreneurship that can grow up around universities.

One particularly pressing educated-related question is whether more can be done to create pathways towards technology employment in the educational institutions that serve the less privileged. M.I.T. is a great success in training engineers and entrepreneurs, but this is one of the world's most elite institutions. If the benefits of technological innovation are going to be spread more widely, then there is surely an imperative towards bringing technology-relevant education to a wider swath of the population in greater Boston.

We have prior experience in democratizing scientific education. In the 1980s, the Nation at Risk report helped create fervor for reform. Throughout the U.S., states increased the minimum requirements of science and math education needed for graduation from high school. These changes impacted different schools and populations in different ways and this created something of a natural experiment.

Goodman (2012) uses the interstate variation in minimum math and science requirement to estimate the impact of that added training on post-graduation employment and earnings. He finds that African-Americans, but not whites, significantly benefitted from these changes. That research provides at least some support for the idea that increasing the technical training in Boston-area high schools, especially for more disadvantaged populations can have significant effects on adult earnings.

This paper is not the place to speculate on the best paths for improving technology-related skills in high schools or community colleges. Moreover, it is not clear that we fully understand how to use technology itself in order to better teach competence in technology. Yet it does seem clear that change is necessary and that the technology sector itself should be engaged in the process. For technology entrepreneurs know, better than school administrators, the skills that they are seeking. They may also have ideas for technological innovations that can aid in inculcating those skills.

Clusters

A second strategy meant to attract particularly entrepreneurial people to an area is to create an entrepreneurial cluster. Stanford Industrial Park was an early example of such a clustering approach, but in this case, the driving force was university leadership (especially Frederick Terman) not the public sector. The idea of the industrial park was to attract employers who would see he advantages in being near Stanford's rich horde of engineering talent and near one another. The Kendall Square area has deep similarities to the Stanford model, in that it proceeded largely through private rather than public place-making.

North Carolina's research triangle is another example of a prominent entrepreneurial cluster in the United States, but one in which state and local government played a more central role. The Research Triangle Park was founded in 1959, and it exists as a distinct political entity as opposed to being merely a neighborhood within Cambridge. It has its own master plan and is technically an unincorporated area. The Triangle refers also to the three universities (two of which are public) that surround the Triangle Park.

The strategies of cluster-building have been tried throughout the world with distinctly mixed results. The biggest success stories, such as those in Bangalore or China, reflect a combination of abundant, typically initially underpaid, human capital and large advantages accruing from proximity in the targeted area. One advantage of cluster-making in the developed world is that it is easier to provide infrastructure to a small area. So even if it would be desirable to have good roads and reliable electricity everywhere, that appears impossible and instead firms are steered towards a particular locale in which these services can be made available. A second advantage is that the cluster may receive special regulatory or tax advantages. The Special Economic Zones of China, initially adopted by Deng Xiaoping, were vastly more accessible to foreign investors than other areas in the mainland. The presence of these privileges made areas like Shenzhen natural targets for foreign investment.

When cluster really work, though, their advantages snowball as proximity to initial residents then lure added firms. So today, proximity to Stanford is still an advantage of locating in Silicon Valley, but a much larger advantage is proximity to all of the other firms that are located nearby. Moreover, a critical mass of firms then attracts workers and that labor force provides a lure to yet more firms. One implication of the importance of worker location is that place-makers need to think about living as well as working space.

The two clusters that we discussed above evolved with little state or local leadership, and the Route 128 area straddles several local jurisdictions. By contrast, Boston's Innovation District is largely a publicly produced affair. The district represents a congruence of available, under-utilized land and a perceived need for more entrepreneurship within Boston itself. The land had been part of the harbor and it was generally seen as unattractive before the harbor itself was cleaned up. It sits nestled between the downtown and the convention district and is in ready walking distance of both.

The vision for the district involves small firms and living spaces. MassChallenge was an early, important anchor tenant, although it has subsequently moved. The district's web page trumpets that in three years, the district has housed over new firms and created 4,000 new jobs. While it is not possible to be sure that those firms and jobs wouldn't be located elsewhere within greater

Boston, if the innovation district didn't exist, it does seem likely that the district has significantly increased the city's own role as a hub of technology entrepreneurship.

At the very least, the district serves an important branding function and allows city leadership to support business formation in the area in a politically appealing fashion. The district helps Boston itself signal its commitment to technology start-ups and it is a major part of most public pronouncements about the city's openness to new technology. Moreover, it is far more palatable to the broad public to support innovation than to give such attention to larger, less appealing firms. The designation of the district also makes it easier to justify place-making attention to that area.

In the long run, the district will need to be evaluated and re-evaluated. We are part of one team that is evaluating the impact of residential location in the district. We hope that there are many such evaluations. But it seems almost sure that the area will be a success, in part because it just occupies such appealing land in the center of a successful city.

Indeed, the very appeal of that land presents an ongoing problem for the district. As Jane Jacobs argued a half century ago, new activities need cheap space and it is hard for the innovation district to remain cheap. One approach is to focus on providing very small amounts of shared space, but this will only be attractive for some firms. While the area seems quite likely to thrive, keeping it affording for less wealthy start-ups will be quite difficult.

The more difficult question is whether a cluster strategy could work in a less advantaged neighborhood. The social benefits if such a cluster could succeed in a poorer neighborhood might be considerable. Yet it is not obvious that such a cluster would succeed, and if it does succeed, it might lead only to improvement in the neighborhood without bringing benefits to the poorer residents nearby. As such, if a technology cluster is to really succeed it must achieve more than gentrification. It must genuinely engage and employ the current residents of the neighborhood.

The first important task in designing a lower income technology cluster is site selection. Four attributes would seem to be desirable. Most importantly, there must be ready access to location from other parts of the region. This argues for choosing an area with good public transit access that ideally could even be reached on foot from other thriving parts of the Greater Boston. It is far easier to imagine technology entrepreneurs moving to an area that is poor but close, especially if rents are much lower, than to imagine those entrepreneurs relocating in a place that is remote and isolated.

A second desirable attribute is that the location is already slated for change. If a neighborhood's building stock is essentially fixed, this will make the process of redevelopment more difficult. If an area already has a bevy of new projects underway, then it is easier to imagine that this location will be mutable in a way that facilitates new technology entrepreneurship.

A third desirable attribute is density of local educational institutions. Schools are the natural place for young people to learn the skills that technology entrepreneurs demand. Proximity to schools makes it more feasible to imagine that those entrepreneurs will be engaged with a process of school reform that improves the quality of instruction, particularly toward technological topics.

A fourth attribute is that the area has potential clients for the technology entrepreneurs themselves. A technology cluster can benefit from a client anchor, which will create an obvious reason for locating in that community. For example, if the Boston Public School system was in the market for ongoing innovations in computer-related instruction, then the Dudley Square area, near to the new School System headquarters, could potentially become a hub for technology entrepreneurs interested in supplying school-related software.

After site selection, the next important task is to create a physical and social infrastructure that supports a technology cluster. For example, incubator space would seem like a necessary first step. Ideally, this space would not be provided by the public sector, but the public sector could take steps to make sure that no zoning barriers stood in the way of such a building. The public sector can also visibly support the effort, which will help convince private investors that a cluster will eventually emerge. Public support from the Mayor's office was a significant part of the Innovation District's success.

The public sector can also help with other aspects of the environment. Clean, safe streets would seem necessary. Supporting activities, such as coffee shops and other retail establishments, should not receive public subsidy but would benefit from rapid permitting. Indeed, the public sector might consider making a special effort to speed all permitting in the proposed new technology district.

A third task is for the public sector to focus on connections with the broader community. A major reason to support a technology cluster in a neighborhood is the hope that the benefits of that cluster will spill over to the neighborhood's other residents. Yet those spillovers are too important to be left to chance. It would seem helpful to have dedicated personnel specialized in connecting technology entrepreneurs with the neighborhood and its schools, whose performance can be judged by the number of people who end up working for these firms and finding subsequent success even without public assistance.

A final task is that the project should be cheap and regularly evaluated. As we have stressed, clusters often fail. This is an experiment not a sure thing. It is far more important to learn what works at a reasonable cost than to spend whatever it takes. This argues for low cost experimentation that improves our knowledge of how to implement technology clusters in lower income areas.

Regulation

It is almost impossible to sensibly argue that regulations are irrelevant to legal entrepreneurship. In principle, a sufficiently draconian regulatory regime can surely prevent law abiding firms entering into an industry, although the historic example of prohibition reminds us that illegal entrepreneurship may still flourish during an epoch of extreme regulatory limits. The practical question is whether the current level of regulation in greater Boston is sufficiently stringent as to have a material impact on entrepreneurship.

The major studies on regulation and entrepreneurship tend to use cross national, rather than U.S. data. For example, Desai, Gompers and Lerner (2003) look across countries and find that those nations with tougher regulations typically have less entrepreneurship. Klapper, Laevan and Rajan (2006) examine cross-industry and cross-country variation and come to a similar country. Areas that heavily regulate industries that would naturally have high entry rates typically experience significantly less entrepreneurship. Within U.S. data also tends to find less entrepreneurship in states with less business friendly environments.

Massachusetts is certainly well-known for having stringent regulations in many areas. Glaeser, Schuetz and Ward (2006) for example chronicle the dizzying array of local regulations that restrict new construction. Anyone hoping to start a restaurant with a liquor license in Boston must jump through considerable regulatory hoops. Indeed, many of the most ardent complaints about regulations in Boston come from the highly regulated food service industry, and liquor licenses are still, somewhat bizarrely controlled at the state level.

But typical technology firms face a much milder regulatory burden. A small technology firm that doesn't privately contract for waste removal or put up an external sign will have to register their business, and ensure that the current Certificate of Occupancy allows their business to operate in their location, but these are relatively mild requirements. The one exception is that if they have any non-metal furniture or rugs or drapes or wall coverings, those will need to be approved by the fire department. Despite this, we suspect that there are any number of wooden chairs and area rugs that have been installed without prior discussions with the fire department chemist. As long as the company rents, the other more onerous building related regulations will be handled by the landlord.

The regulations that face the biotechnology industry are somewhat more stringent. For example, the Massachusetts' Community Guide to Biotechnology lists more than 20 areas where regulations exist and more than 15 areas where permits or licenses are required. Biotechnology can be dangerous, so these regulations may indeed be appropriate, but it remains true that a biotechnology venture will have to deal with a remarkable array of different permitting entities.

Even if regulatory reform is not critical for computer software companies, reform does seem relevant for entrepreneurship in greater Boston more generally. There are two natural paths forward. The first is to undertake a wide-ranging cost-benefit analysis of existing regulations. The Federal government has required cost-benefit analysis for any new executive branch regulations since the 1980s and has recently undertaken an attempt to review existing regulations. The same requirement should exist at the state and local level.

The most natural step would be for the state government to require such a review both for state-level regulations and for any ordinances passed at the local level. Since cost-benefit analysis requires expertise, it would be sensible for the state to fund a central office that can specialize in reviewing new and past rules. Regulations tend to accrete as jurisdictions age, and as such, it seems likely that there are many rules that no longer justify their costs, even if they were sensible at the time that they were established.

A second complementary approach is to centralize the regulatory review process so that would-be entrepreneurs only need to get approval from a single office. That office would then deal with the existing examining bodies in order to get approval. It would also keep metrics on time to approval and approval rates, which would enable its service quality to be judged.

Devens pioneered this approach in Massachusetts with its Enterprise Commission. The Commission was created after Fort Devens closed in 1996. It was an attempt to fill the vacuum created by the departing military. The program has worked well and is worthy of emulation. In its purest form, it involves no reduction in regulatory standards, but just a centralized permitting authority with a mission of speeding the time to regulatory approval.

Law and Non-Compete Clauses

A final area for potential reform relates to the enforcement of non-compete clauses. Some of our competitor states, most notably California, do not enforce those laws, which makes it easier for a departing employee to start a new firm. The overall economic impact of non-compete clauses is ambiguous. These clauses have a negative impact on employees departing and starting their own firms. They have a positive impact on firms that will be more willing to hire and share important secrets with employees that they know will not depart. There is a distinct possibility that these clauses are over-used, however, since potential employees who refuse to sign such clauses will be sending a negative signal indicating their lack of loyalty to the firm.

Moreover, in a Federal system, the positive benefits of non-compete clauses seem likely to be outweighed by their negative aspects. If Massachusetts enforces such clauses while California does not, then our legal system is not really protecting existing firms. Their workers can easily move to a competitor in another state. Our laws are only ensuring that these exiting employees are not starting a business here.

It is also quite possible that there is a public interest in ensuring the cross-business information flows that non-compete clauses restrict. The history of Silicon Valley was built on employees who exit one firm and then take their knowledge elsewhere. Famously, the “traitorous eight” were eight brilliant scientists who left Shockley Semiconductor to work for Fairchild Semiconductor and then left to form their own businesses that include Intel and Kleiner, Perkins. The economy of that region would have been much reduced if they had been forced to continue working for Shockley. Fallick et al. (2006) document more broadly the relatively high degree of mobility in Silicon Valley, although it is hard to attribute the cause of that mobility to the California legal environment alone.

Marx, Strumsky and Fleming (2009) examine the Michigan experiment in enforcement of non-compete clauses and find that enforcing these clauses reduces employee mobility. In 1905, Michigan, like California, banned the enforcement of non-compete clauses, but this rule was reversed (apparently inadvertently) in 1985. The rate of inventor mobility decreased after that point in Michigan relative to other states.

One natural approach, with the Patrick administration seems to have now approached, is to simultaneously end the enforcement of non-compete clauses and to adopt the Uniform Trade Secrets Act. The Act would make it easier to prosecute individuals who really do steal the secrets of their erstwhile employers. This would be a relatively easy legal change that would make ease the supply of potential entrepreneurs.

VI. Conclusion

Technology start-ups have become a critical part of greater Boston's economy. Whether or not they deserve subsidies, they surely deserve attention and sensible policies. The state cannot easily cut taxes, without cutting service levels, which makes it all the more important to compete effectively in other areas. It also seems important to avoid taxes, like the technology service sales tax, that particulate target this important area of the Boston economy.

We are not confident that the public financing approach to technology start-ups has been successful. Our attempt to examine the impact of public loans on employment growth yielded few significant results. We urge the state to properly evaluate their loan programs, and ideally to even adopt a policy of randomized trials among a hand-picked set of good alternatives. We also believe that it is sensible to revisit the issues that have limited the availability of broadband in much of the city.

Moreover, we believe that there is a case for adopting a more supply-oriented approach to entrepreneurship that focuses on education, regulation and non-compete clauses. Our educational entities may or may not be appropriate recipients of added state aid, but it does seem sensible to adopt policies that make it easier to leverage their success. One natural policy tool for be to relax local land use regulations that impact private construction near science campuses.

We also believe that it is appropriate to apply cost-benefit analysis to existing state and local regulations that impact entrepreneurship and to expand the Devens model of one-stop permitting.

An added proposal is to follow California's lead and cease enforcing non-compete clauses. These rules do not protect existing firms from employees who exit, since those employees can always work in states that don't enforce these laws. But by enforcing non-compete clauses, we do ensure that those employees who exit will not start firms in that industry in Massachusetts. To strengthen the protection of existing firms, we might also consider adopting the Uniform Trade Secrets Act.

Our most high-risk proposal is to consider an innovation district in a lower income neighborhood. Much of the data we have marshaled suggests that such an experiment has a reasonably high probability of failure. Technology firms prefer to employ highly educated workers and to locate in higher income zip codes. Yet technological innovation must serve both rich and poor, and an district in a poorer community provides a possible way to achieve that dream. Since such a district would be an experiment, it should be low cost and appropriately evaluated.

Too little time has passed to properly evaluate the Boston Innovation District, but certainly the early results are more than promising. The area has become a hub of entrepreneurship filled with exciting new start-ups. Its biggest challenge is keeping real estate costs low enough to continue attracting impecunious start-ups. The approach certainly is sensible, and offers some hope for transforming Boston from a city of big firms into a more sustainable city of start-ups.

References

Beason, Richard and David Weinstein. 1995. “The MITI Myth: Central Planning Fails in Japan,” *The American Enterprise,* 6(4), 84-86.

Chen, Henry, Paul Gompers, Anna Kovner, and Josh Lerner. 2010. "Buy local? The geography of venture capital." *Journal of Urban Economics* 67(1): 90-102.

Bruce, Donald and Mohammed Mohsin. 2006. “Tax Policy and Entrepreneurship: New Time Series Evidence,” *Small Business Economics*, 26(5), 409-425.

Desai, Mihir; Gompers, Paul; Lerner, Josh. 2003. “Institutions, Capital Constraints and Entrepreneurial Firm Dynamics: Evidence from Europe,” NBER Working Paper **#**10165.

Djankov, Simeon, Tim Ganser, Caralee McLiesh, Rita Ramalho, and Andrei Shleifer. 2008. "The effect of corporate taxes on investment and entrepreneurship." In *American Law & Economics Association Annual Meetings*.

Fallick, Bruce, Charles A. Fleischman and James B. Rebitzer. 2006. “Job-Hopping in Silicon Valley: Some Evidence Concerning the Microfoundations of a High-Technology Cluster,” *Review of Economics and Statistics,* 88(3), 472-481.

Gentry, William M and Glenn R. Hubbard. 2000. “Tax Policy and Entrepreneurial Entry,” *American Economic Review***,** 90(2), 283-287.

Glaeser, Edward L. and Albert Saiz. 2004. "The Rise of the Skilled City,” *Brookings-Wharton Papers on Urban Affairs*, 47-94.

Glaeser, Edward L., and Matthew E. Kahn. 2003. “Sprawl and Urban Growth,” in: J. V. Henderson & J. F. Thisse (ed.), *The Handbook of Regional and Urban Economics*, 1(4), 2481-2527.

Glaeser, Edward L., Sari Pekkala Kerr and William R. Kerr. 2012. “Entrepreneurship and Urban Growth: An Empirical Assessment with Historical Mines,” NBER Working Paper 18333.

Glaeser, Edward L., Jenny Schuetz, and Bryce Ward (2006) “Regulation and the Rise of Housing Prices in Greater Boston,” Rappaport Institute - Pioneer Institute Working Paper.

Goodman, Joshua, 2012. "The Labor of Division: Returns to Compulsory Math Coursework,” Working Paper Series rwp12-032, Harvard University, John F. Kennedy School of Government.

Greenstone, Michael, Richard Hornbeck and Enrico Moretti. 2008. “Identifying Agglomeration Spillovers: Evidence from Million Dollar Plants,” NBER Working Paper #13833.

Hausman, Naomi. 2013. “University Innovation, Local Economic Growth, and Entrepreneurship,” Working Paper.

Klapper, Leora, Luc Laeven, and Raghuram Rajan. 2006. “Entry Regulation as a Barrier to Entrepreneurship**,”** *Journal of Financial Economics* 82(3), 591-629.

Lerner, Josh. 2009. *Boulevard of Broken Dreams: Why Public Efforts to Boost Entrepreneurship and Venture Capital Have Failed and What to Do About It.* Princeton University Press.

Marx, Matt, Deborah Strumsky, and Lee Fleming. 2009. “Mobility, Skills, and the Michigan Non-Compete Experiment,” *Management Science* 55, 875-889.

Moretti, Enrico. 2004. "Human capital externalities in cities." *Handbook of regional and urban economics* 4: 2243-2291.

Papke, Leslie E. 1991. “Interstate business tax differentials and new firm location: Evidence from panel data,” *Journal of Public Economics* 45(1), 47-68.

Pauly, Mark, and Michael Redisch. 1973. "The not-for-profit hospital as a physicians' cooperative," *The American Economic Review* 63(1), 87-99.

Sasser, Alicia. 2008. “The Future of the Skilled Labor Force in New England: The Supply of Recent College Graduates.” New England Public Policy Center Research Report #08-1.

Table 1
Technology Industries in Greater Boston and the United States

Employees	*Middlesex*		*Suffolk*		*United States*	
	1998	**2011**	**1998**	**2011**	**1998**	**2011**
Total Tech	111,874	122,245	8,247	14,446	3,329,537	4,240,737
Computer & Related Mfg	51,905	19,506	2,527	309	1,680,833	877,469
Computer Related Services	22,687	28,646	2,848	5,021	873,270	1,444,864
Medical Mfg	2,880	3,113			217,111	227,894
R & D in Hard Sciences	13,817	40,562	1,475	2,654	275,141	651,026
Electronic Commerce		906		1,248		140,441
Data Processing, Hosting, & Related Services		9,280		1,222		401,079
Internet Pub & Broadcasting & Web Search Portals		1,944		2,141		135,554
Software Publishing	20,585	18,288	1,397	1,851	283,182	362,410
Venture Capital	123	421	483	0	25,721	31,265

Establishments	*Middlesex*		*Suffolk*		*Massachusetts*	
	1998	**2011**	**1998**	**2011**	**1998**	**2011**
Total Tech	2,786	3,068	469	689	126,132	199,829
Computer & Related Mfg	458	298	22	22	17,625	13,151
Computer Related Services	1,542	1,611	301	363	85,356	125,837
Medical Mfg	30	38	3	5	1,812	2,008
R & D in Hard Sciences	337	538	73	97	9,650	15,068
Electronic Commerce		97		39		17,628
Data Processing, Hosting, & Related Services		174		53		12,294
Internet Pub & Broadcasting & Web Search Portals		82		63		6,398
Software Publishing	419	230	70	47	11,689	7,445
Venture Capital	36	65	49	59	9,650	6,986

Source: County Business Patterns

Table 2
Technology Firm Employment: Massachusetts v. Suffolk County

2a: Massachusetts

	Earnings ($2013)	*Education*		*Race*			*Age*		
		High School Grad	*College Grad*	*Asian*	*Black*	*White*	*20-24*	*25-39*	*40-59*
Non Technology Sectors	$49,734	92%	40%	5%	6%	84%	9%	30%	45%
Technology Sectors	$87,383	98%	74%	13%	3%	82%	5%	39%	47%

2b: Suffolk County

	Earnings ($2013)	*Education*		*Race*			*Age*		
		High School Grad	*College Grad*	*Asian*	*Black*	*White*	*20-24*	*25-39*	*40-59*
Non Technology Sectors	$48,770	89%	44%	7%	18%	64%	13%	42%	34%
Technology Sectors	$75,741	98%	79%	12%	7%	75%	9%	58%	27%

Source: American Community Survey Microdata, 2007-2011

Table 3
Technology Firm Employment by Income Distribution in Zip Codes, 2010

	(1) Average Median Household Income (2011)	(2) Average Number of Establishments per 1,000 People	(3) Average Number of Small Establishments per 1,000 People	(4) Average Number of Large Establishments per 1,000 People	(5) Share of Establishments in Technology	(6) Share of Small Establishments in Technology	(7) Share of Large Establishments in Technology
Poorest 25%	$40,710	18	15	3	2.5%	2.4%	3.2%
Middle 50%	$75,382	31	26	5	7.3%	6.6%	11.0%
Highest 25%	$127,967	44	37	7	7.2%	6.7%	9.7%

Source: County Business Patterns, Zip Code Level

Table 4
Technology Employment along Route 128 (5 Zip Codes) and in Kendall Square (3 Zip Codes)

	Route 128 Corridor	Kendall Square Area
Average Number of Big Establishments 2010	35	33
Average Number of Small Establishments 2010	70	72
Percent Small Establishments	70%	70%
Average Number of Big Establishments 1998	28	30
Average Number of Small Establishments 1998	65	53
Growth in Big Establishments 1998-2010, (Number)	7	2
Growth in Big Establishments 1998-2010, (Percent)	24%	10%
Growth in Small Establishments 1998-2010, (Number)	9	18
Growth in Small Establishments 1998-2010, (Percent)	8%	36%

Source: County Business Patterns, zip code level

Table 5
Industries that Concentrate in the Two Clusters
(holding total establishments and share of adults with college degrees fixed)

Regression Results	**Route 128 Corridor**	**Kendall Square Area**
Sectors that tend to locate near the cluster	Computer-related manufacturing (all)	Computer-related manufacturing (small only)
	Computer-related services (all)	Computer-related services (all)
	Data hosting and processing (all)	Data hosting and processing (all)**
	Medical manufacturing (all)*	Medical manufacturing (all)*
	Research and development in the hard sciences (all)	Online publishing and software (small only)
	Software (all)	Research and development in the hard sciences (all)
		Software (all)
Sectors that don't tend to locate near the cluster	Online publishing and software (all)	Internet Shopping (all)
	Internet Shopping (all)	

Results report statistical significance of indicator variables that take on a value of 1 if the zip code is in either East Cambridge or in the Route 128 cluster, controlling for total number of establishments, share of the population with a college degree, and a variable that indicates missing education data. There are 105 observations. Unless starred, significance is at the one percent level or higher.
*Concentration in Kendall Square for big medical manufacturing establishments is significant only at the 10 percent level.
** Concentration in the Kendall Square area for data hosing is significant only at the five percent

Table 6
The Impact of Share of the Adult Population with College Degrees on the Number of Technology Establishments Across Zip Codes, Excluding Kendall Square and Route 128

Industry	**Impact on All Establishments**	**Impact on Big Establishments**	**Impact on Small Establishments**
All Technology	33 (7.5)	5.3 (3.1)	27.5 (5.2)
Computer or Medical Manufacturing	Insignificant	Insignificant	Insignificant
Computer Serivvces	21.5 (4.2)	23 (1.2)	19.3 (3.5)
Software	3.3 (1)	1.6 (.65)	1.7 (.6)
Research and Development	7.5 (2.7)	1.5 (1.3)	5.9 (1.8)
Online Publishing and Software	2.86 (.73)	.82 (.35)	2 (.6)
Data Hosting and Processing	2.54 (.85)	.88 (.47)	1.7 (.6)
Venture Capital	4.2 (1.3)	Insignificant	4 (1.2)

Note: Standard errors in parentheses

Table 7
Effect of Government Financing on Sales and Job Growth

	Difference in Means of Treated and Untreated Firms	Standard Error	95% Confidence Interval		Number of Treated Firms
Log Job Growth in the First Year	0.02	0.05	-0.09	0.13	30
Log Job Growth in the Second Year	0.00	0.06	-0.12	0.13	30
Log Job Growth in the Third Year	-0.05	0.04	-0.12	0.03	30
Log Job Growth in the Fourth Year	-0.08	0.07	-0.23	0.07	20
Log Job Growth in the Fifth Year	-0.02	0.02	-0.06	0.02	8
Log Sales Growth in the First Year	0.02	0.06	-0.10	0.14	30
Log Sales Growth in the Second Yea	0.00	0.06	-0.13	0.13	30
Log Sales Growth in the Third Year	-0.04	0.04	-0.12	0.03	30
Log Sales Growth in the Fourth Yeai	-0.06	0.07	-0.21	0.08	20
Log Sales Growth in the Fifth Year	-0.02	0.02	-0.06	0.02	8
Job Growth in the First Year	0.00	0.01	-0.01	0.01	30
Job Growth in the Second Year	0.00	0.01	-0.02	0.01	30
Job Growth in the Third Year	0.02	0.02	-0.01	0.05	30
Job Growth in the Fourth Year	0.06	0.02	0.01	0.11	20
Job Growth in the Fifth Year	-0.02	0.06	-0.16	0.11	8
Sales Growth in the First Year	0.09	0.10	-0.12	0.30	30
Sales Growth in the Second Year	-0.02	0.02	-0.06	0.02	30
Sales Growth in the Third Year	-0.02	0.02	-0.06	0.02	30
Sales Growth in the Fourth Year	-0.02	0.04	-0.10	0.06	20
Sales Growth in the Fifth Year	-0.01	0.01	-0.05	0.02	8

Sources: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data and MassDevelopment Annual Reports

Table 8
Availability of Fiber Optics and Technology Firm Growth

Impact of Fiber	**No Control**	**Control for Education**	**Also Control for Distance to 128**	**Just Control for Firms in 1998**
Total Technology	100***	46**	43	7
Computer Manufacturing	9***	8***	8***	2**
Computer Services	62***	30**	28*	9
Data Hosting	10***	7**	6*	No Data for 1998
Medical Manufacturing	1*	1	1	1
Online Publishing and Software	4***	1	1	No Data for 1998
Research and Development	18**	1	1	4
Online Shopping	4***	1	0	No Data for 1998
Software	11***	6	5	0

Notes: Standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).The number indicates the estimated effect of a 100 percent change in the presence of fiber in the Zip Code on the number of establishments in that zip code in that industry in 2010. Numbers that are not starred are not statistically significant even at the 10 percent level. Columns that have one star are statistically significant between the one and ten percent level. Numbers that are double starred are statistically significant at the one percent level or better. The first column shows the estimated coefficient with no controls. The second column controls for the Census 2000 estimate of the share of adults with a college degree. When such estimates were not available, we use the mean level of education across the region and include an indicator function that takes on a value of one if this imputed education value was used. The third column includes a control for miles from Route 128 as well as the two education variables. The fourth column includes only one control: the number of firms in the Zip code in the industry in 1998.
Sources: County Business Patterns and Massachusetts Broadband Institute

Figure 1
Economic Growth and Firm Size

MSA Employment Growth (1977-2010)
by Average Firm Size (1977) Quintiles

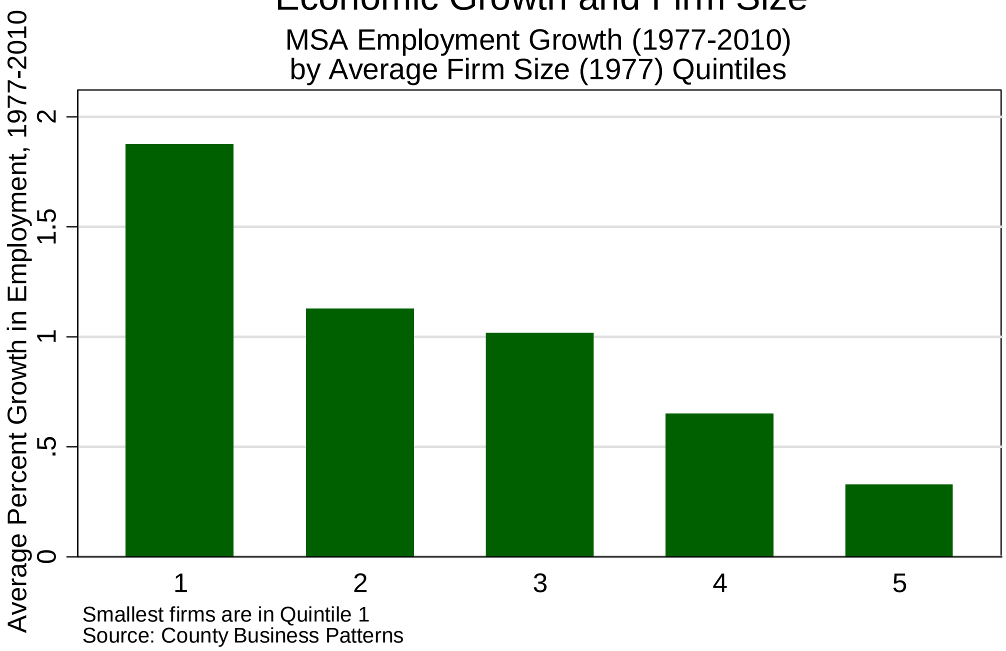


Figure 2
Growth and New Establishments

MSA Employment Growth (1977-2010)
by Quintiles of Share of Employment in New Establishments, 1977

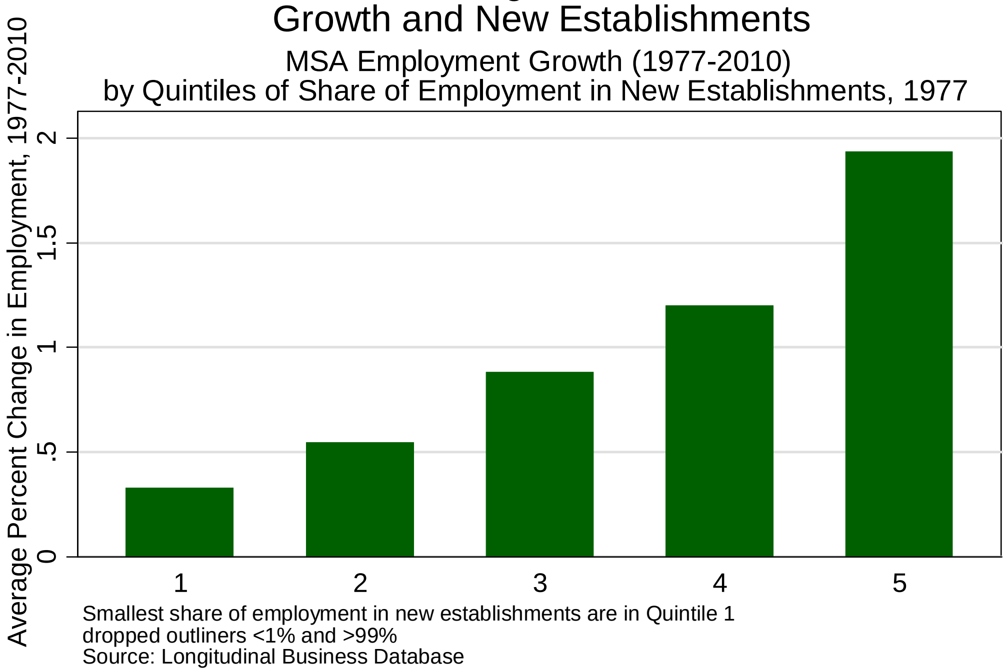
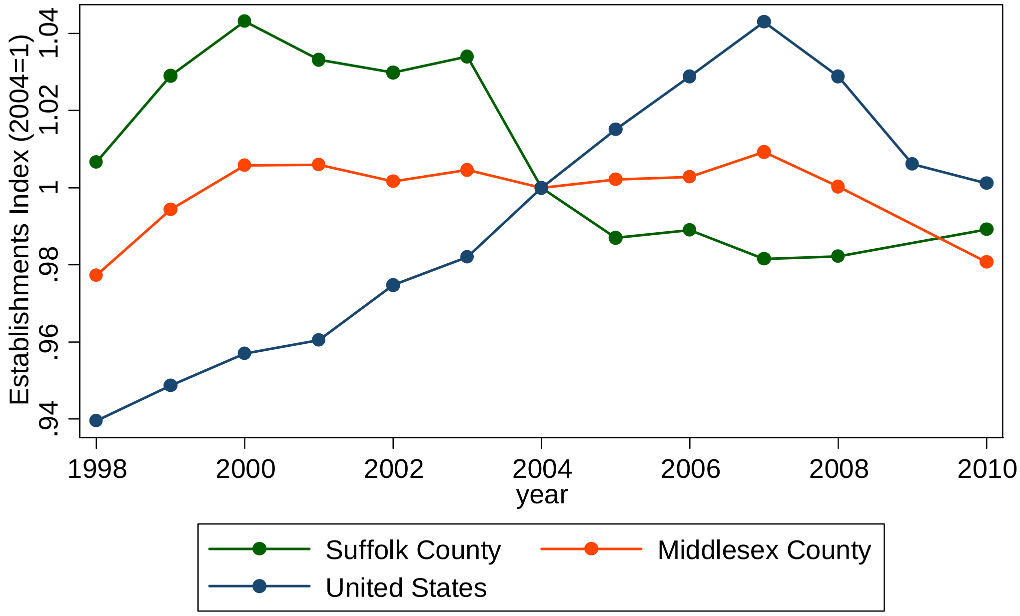
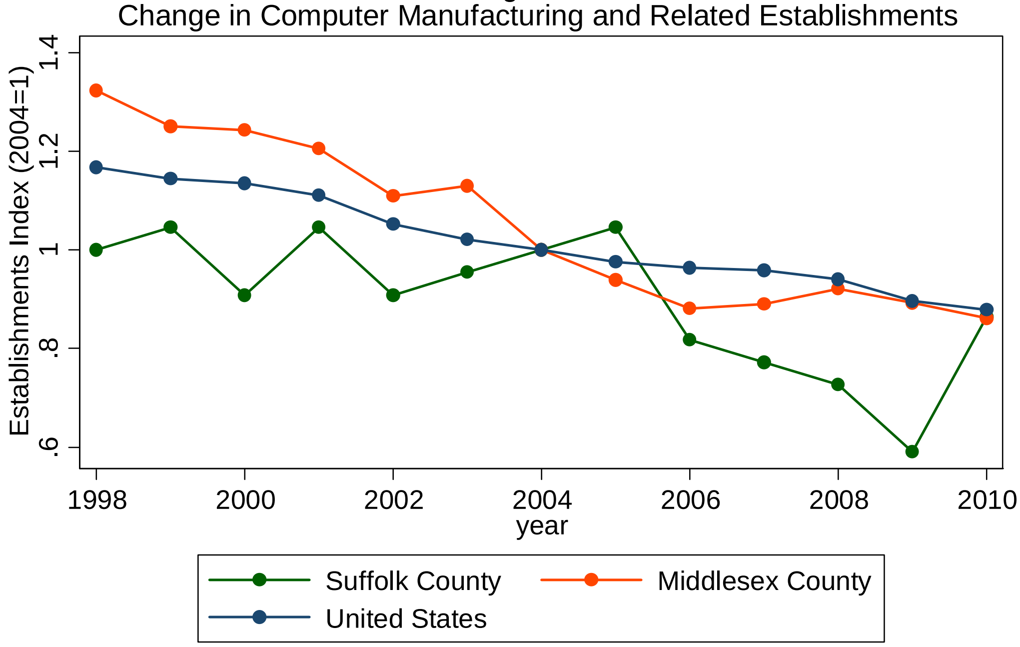


Figure 3A
Change in Total Establishments



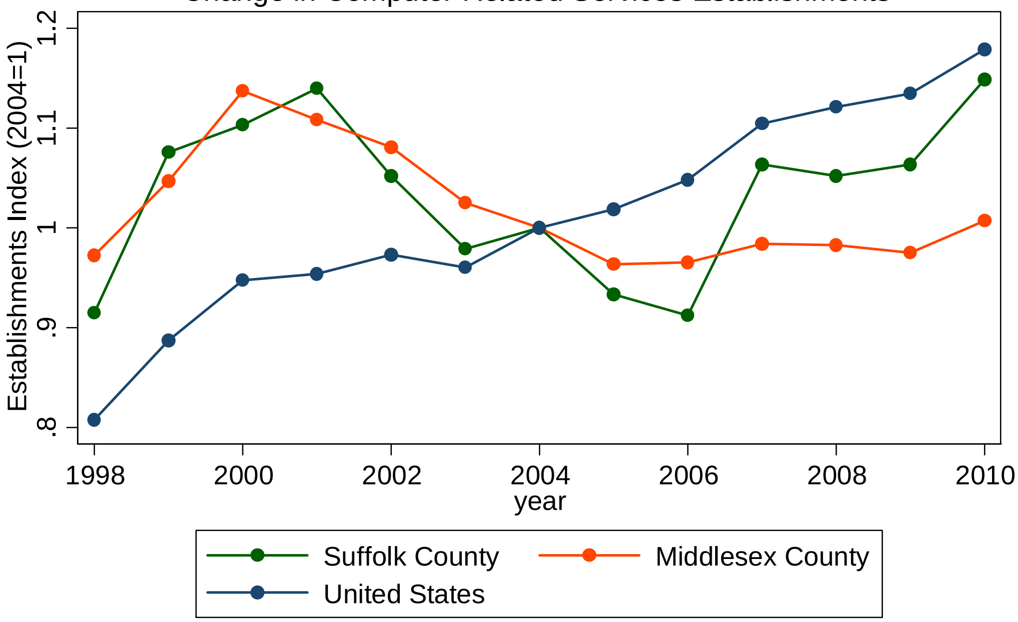
Source: County Business Patterns

Figure 3B
Change in Computer Manufacturing and Related Establishments



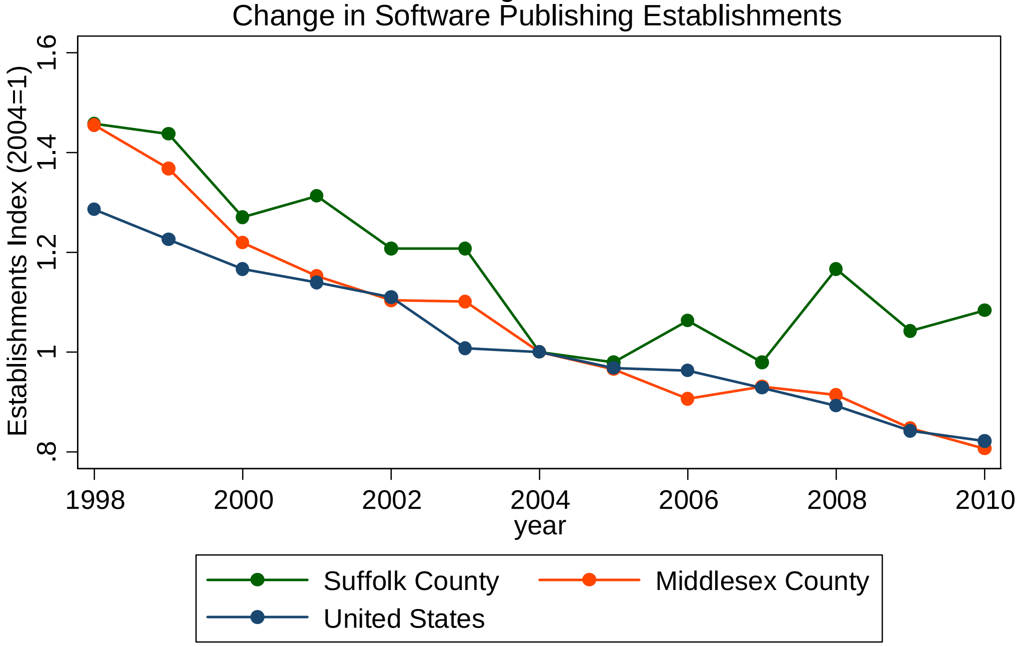
Source: County Business Patterns

Figure 3C
Change in Computer Related Services Establishments



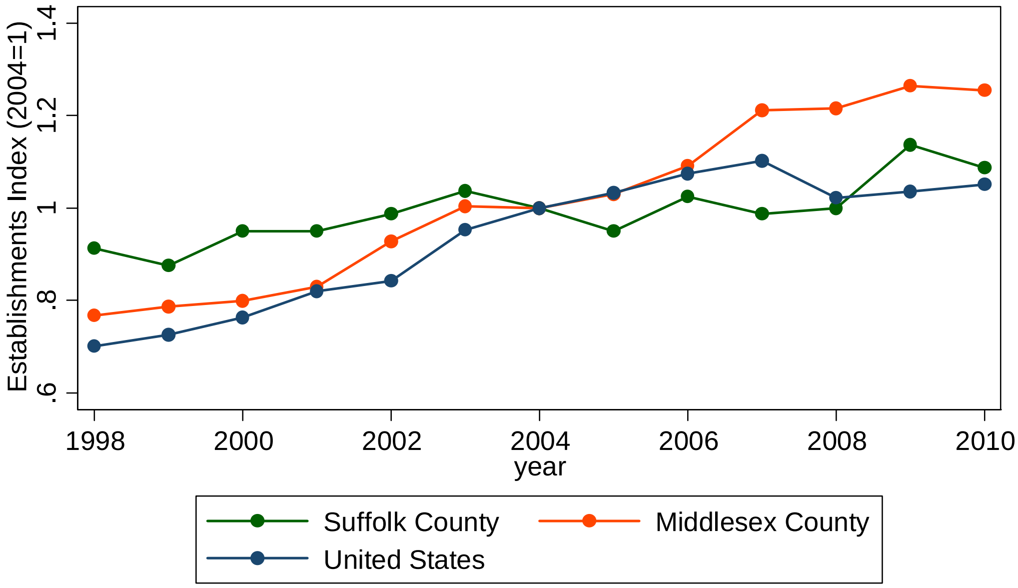
Source: County Business Patterns

Figure 3D
Change in Software Publishing Establishments



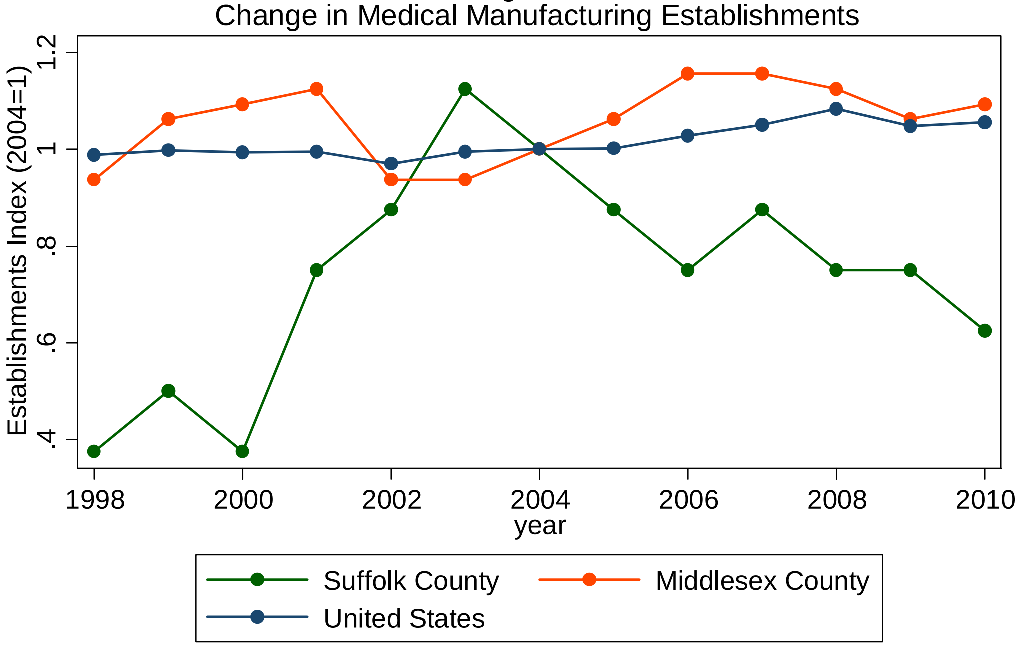
Source: County Business Patterns

Figure 3E
Change in Research and Development
In Hard Sciences Establishments



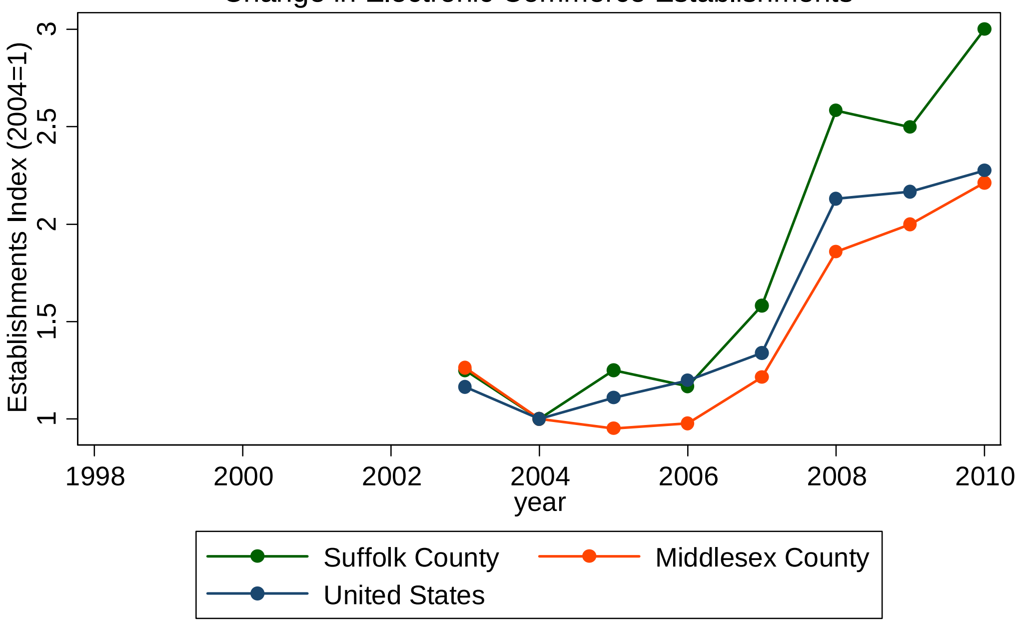
Source: County Business Patterns

Figure 3F
Change in Medical Manufacturing Establishments



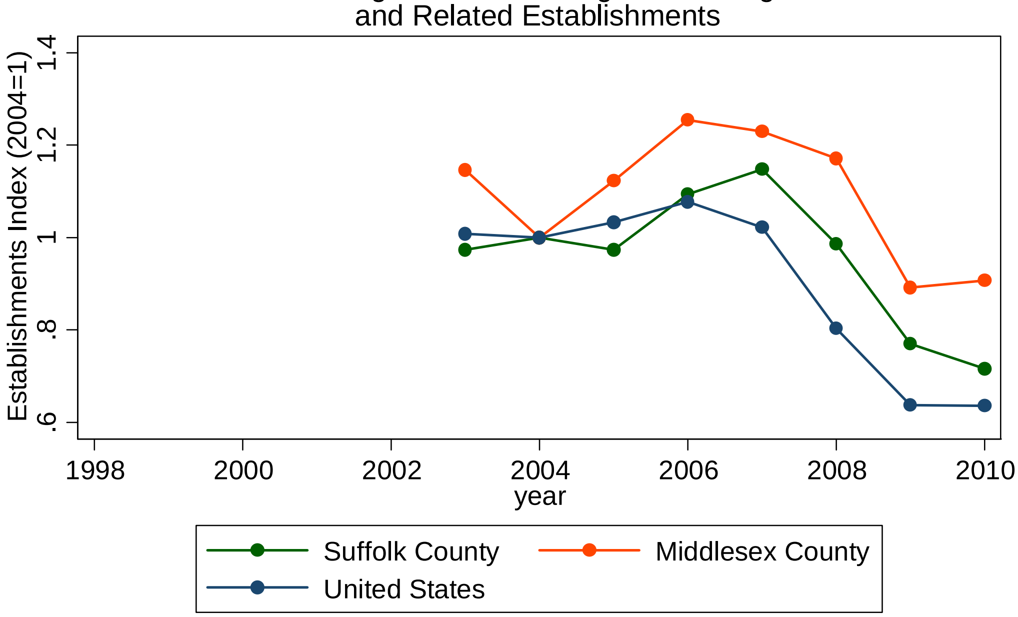
Source: County Business Patterns

Figure 3G
Change in Electronic Commerce Establishments



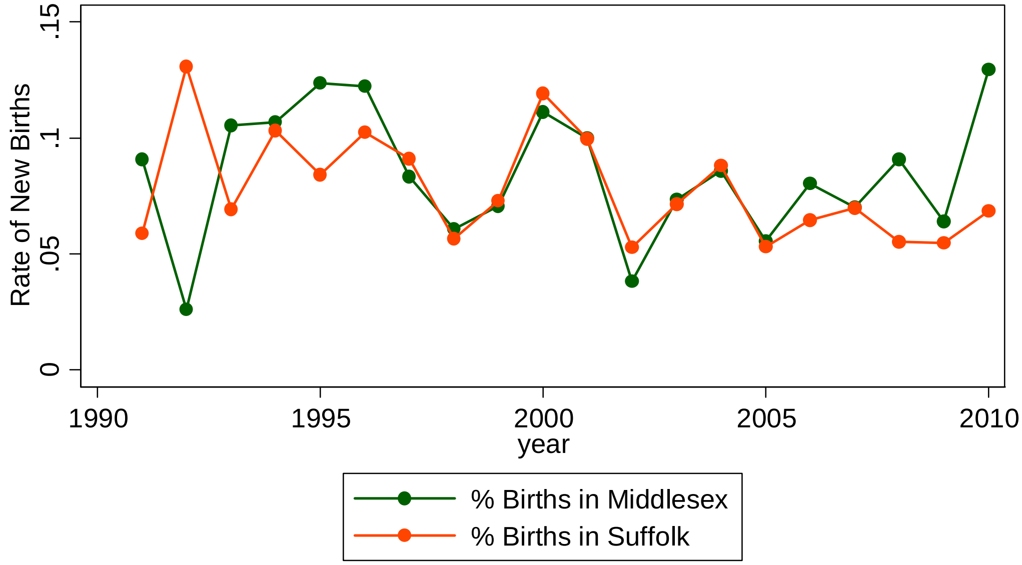
Source: County Business Patterns

Figure 3H
Change in Data Hosting, Processing
and Related Establishments



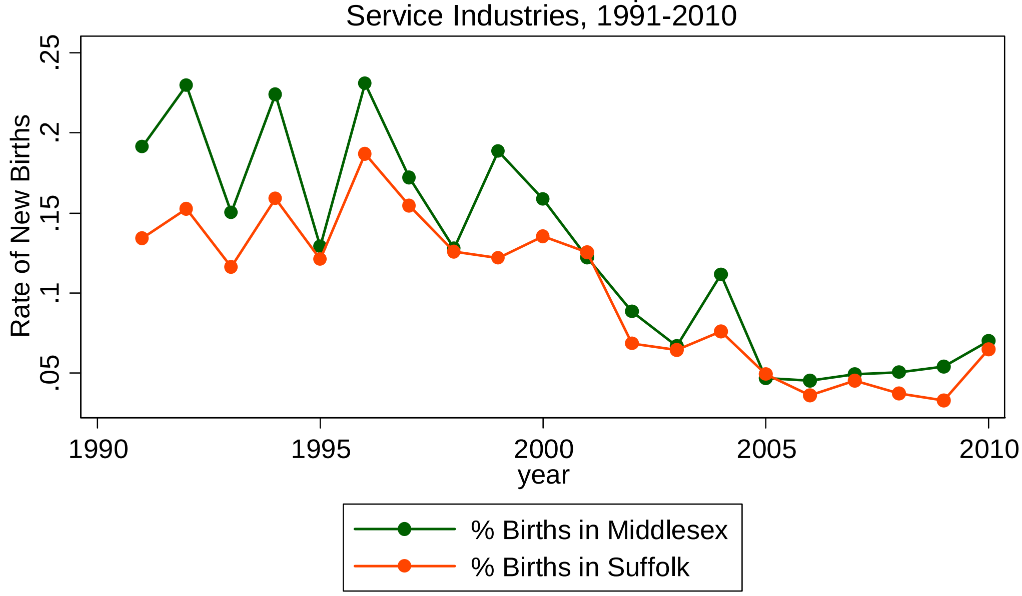
Source: County Business Patterns

Figure 4A
Rate of New Births for Computer Manufacturing
and Related Industries, 1991-2010



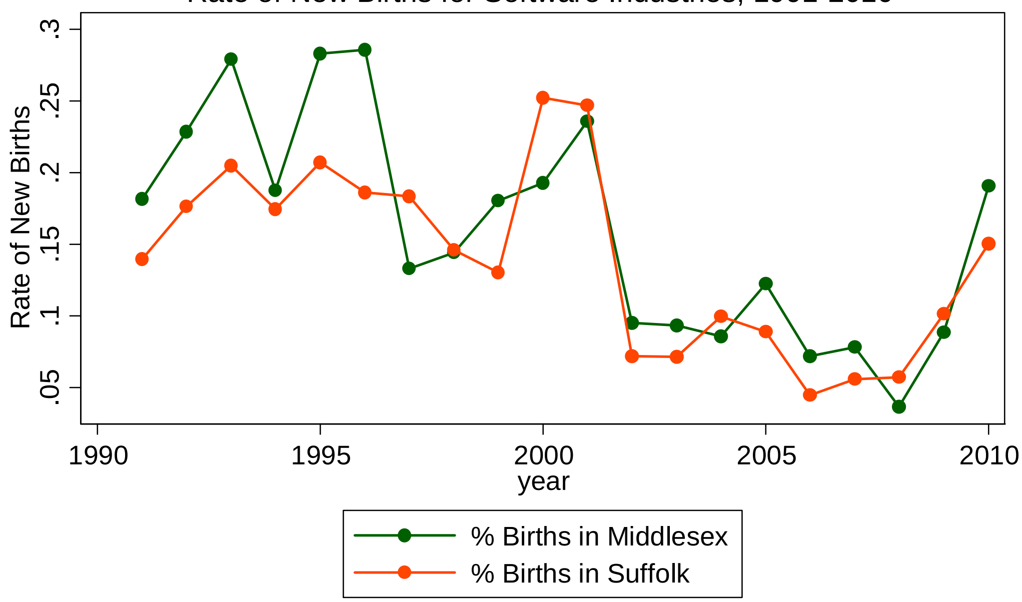
Source: National Employment Time Series (NETS) database
offered by Walls & Associates based on Dun & Bradstreet data

Figure 4B
Rate of New Births for Computer Related
Service Industries, 1991-2010



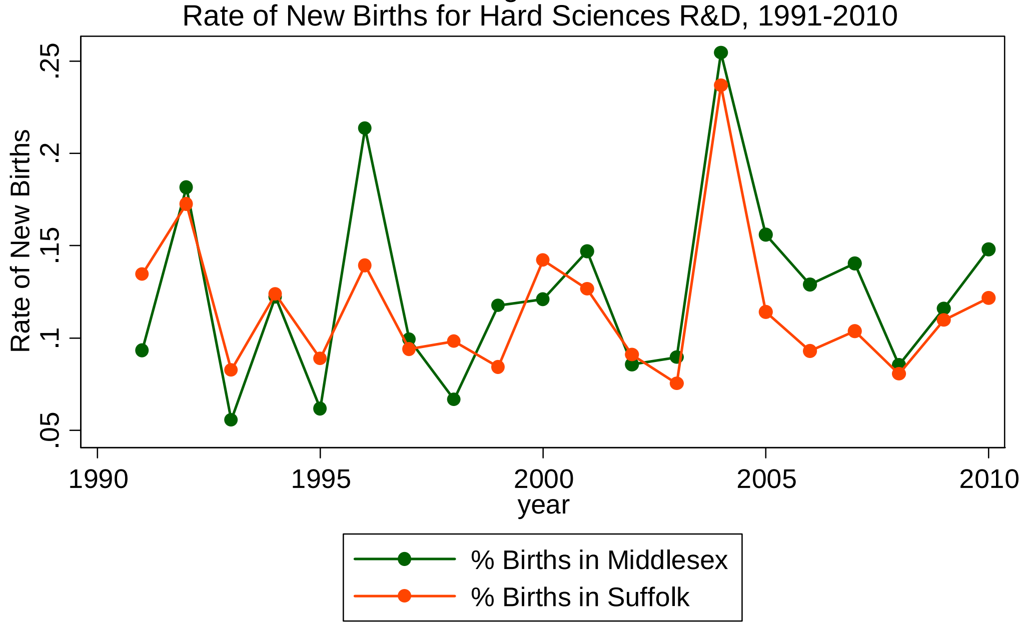
Source: National Employment Time Series (NETS) database
offered by Walls & Associates based on Dun & Bradstreet data

Figure 4C
Rate of New Births for Software Industries, 1991-2010



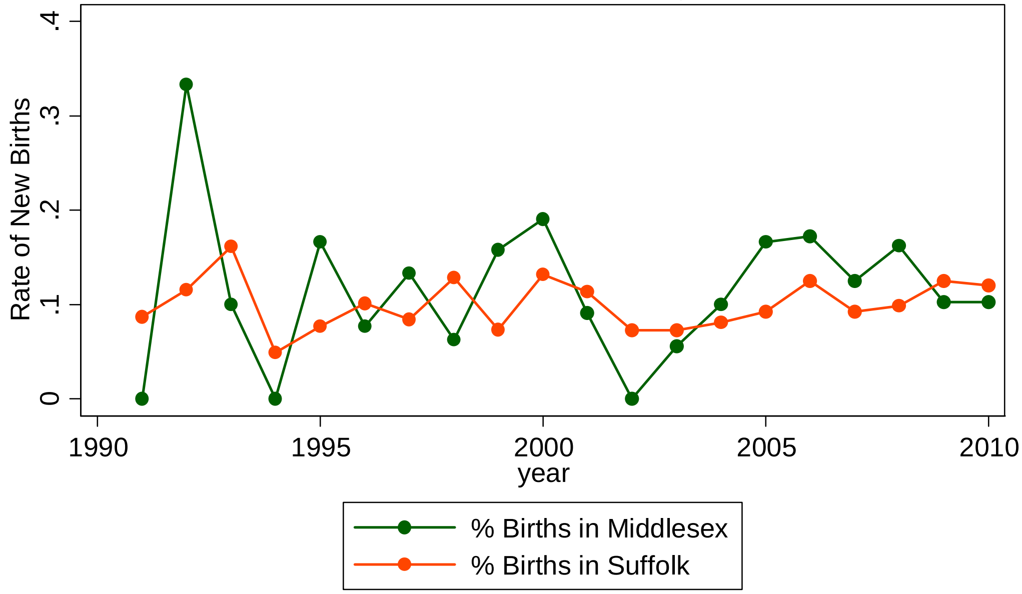
Source: National Employment Time Series (NETS) database
offered by Walls & Associates based on Dun & Bradstreet data

Figure 4D
Rate of New Births for Hard Sciences R&D, 1991-2010



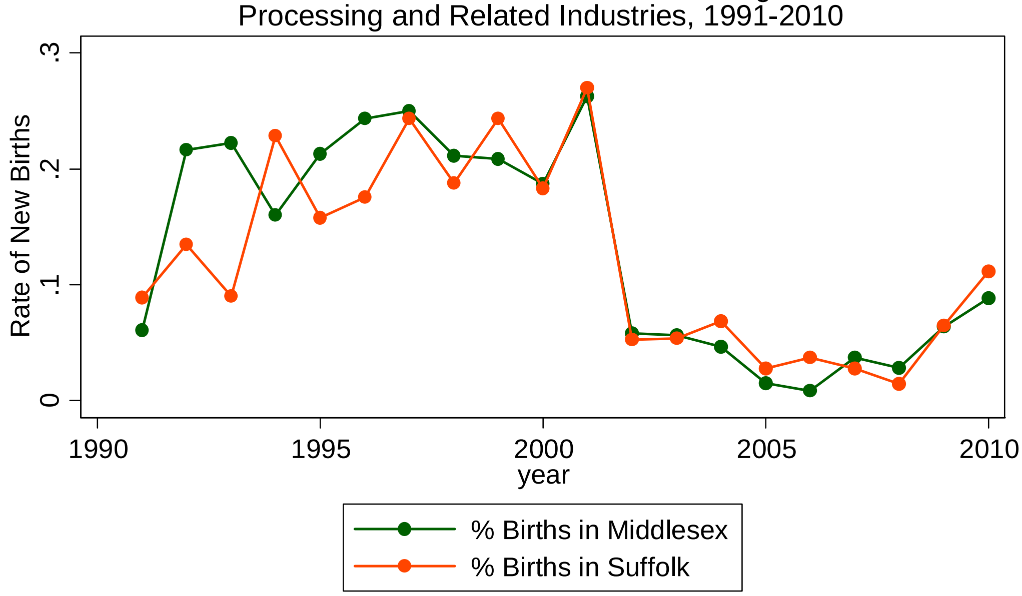
Source: National Employment Time Series (NETS) database
offered by Walls & Associates based on Dun & Bradstreet data

Figure 4E
Rate of New Births for Medical Manufacturing Industries, 1991-2010



Source: National Employment Time Series (NETS) database
offered by Walls & Associates based on Dun & Bradstreet data

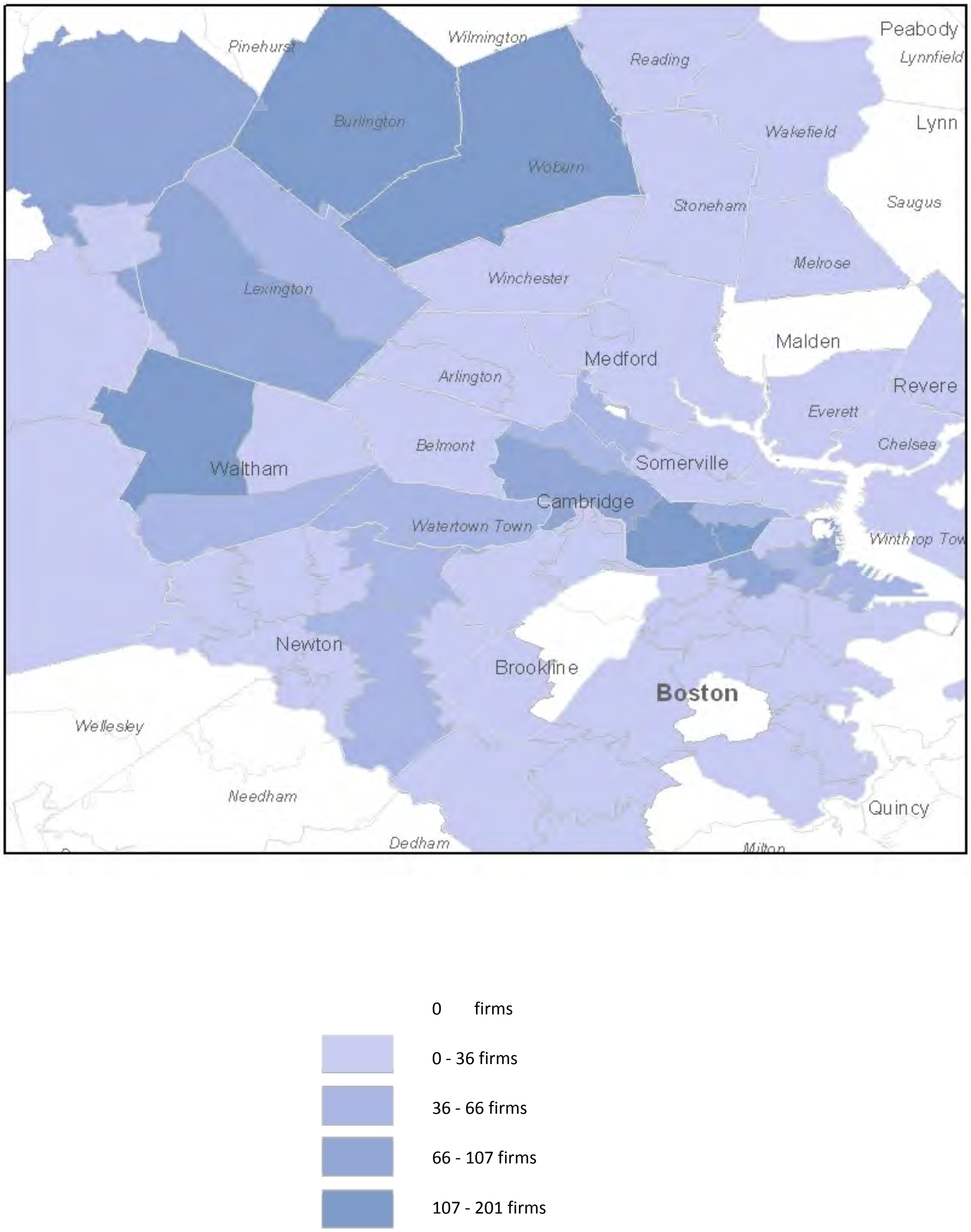
Figure 4F
Rate of New Births for Data Hosting,
Processing and Related Industries, 1991-2010



Source: National Employment Time Series (NETS) database
offered by Walls & Associates based on Dun & Bradstreet data

Figure 5A

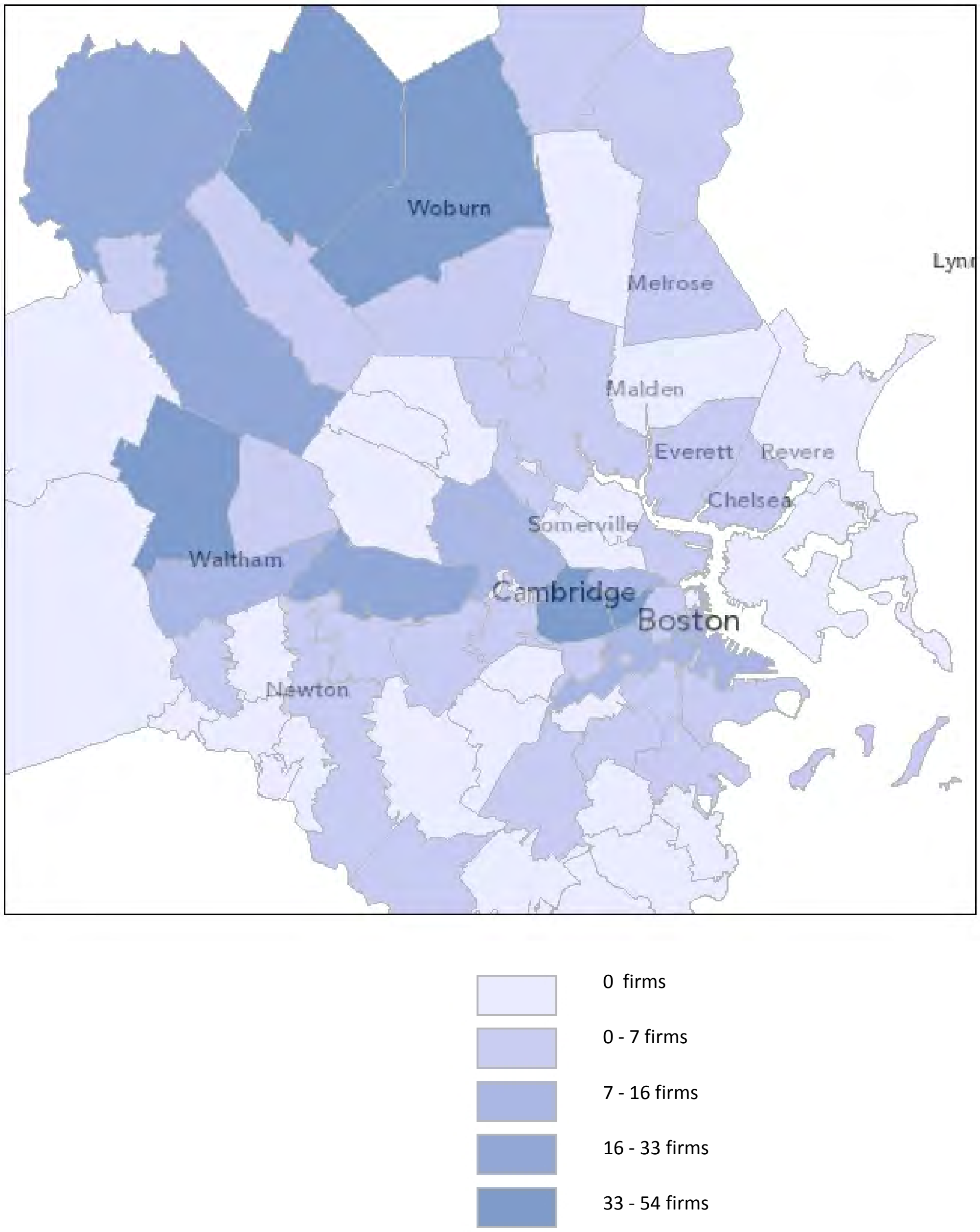
Concentration of Tech Firms in Greater Boston, 2010



Source: County Business Patterns

Figure 5B

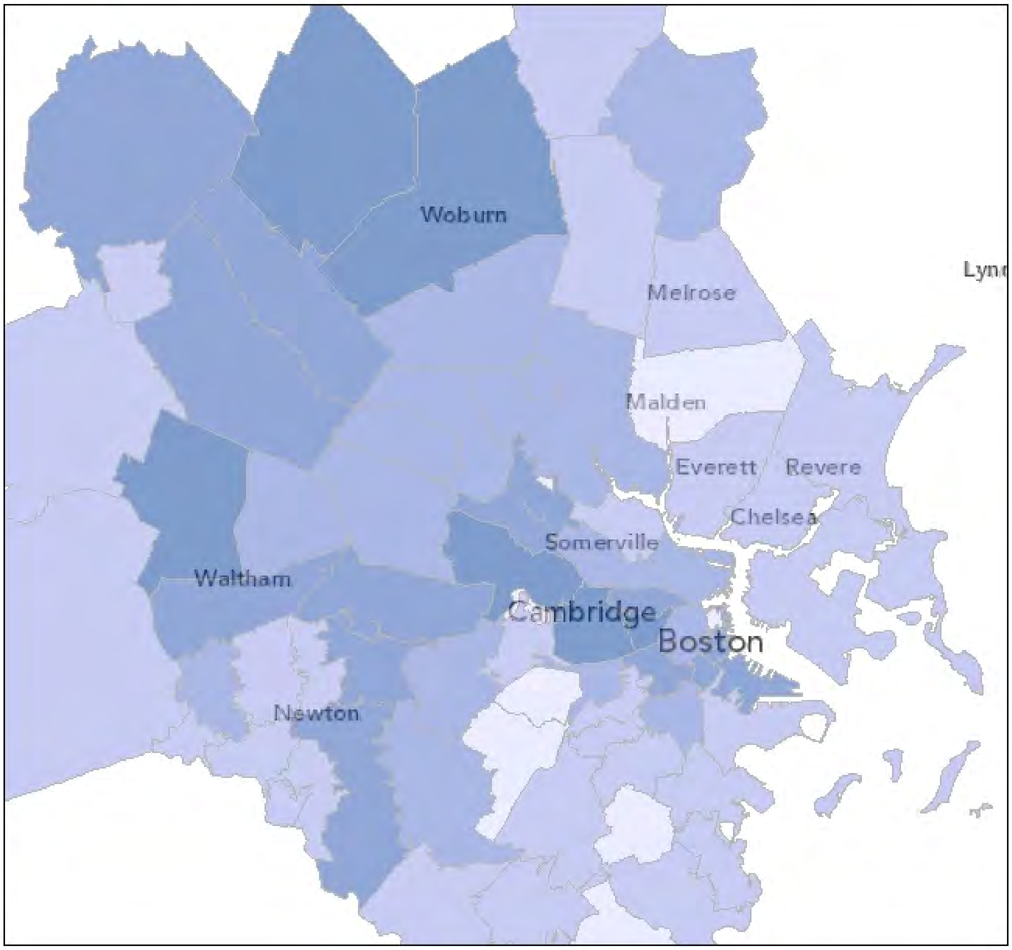
Concentration of Large Tech Firms in Greater Boston, 2010



Source: County Business Patterns

Figure 5C

Concentration of Small Tech Firms in Greater Boston, 2010



0 firms

0 - 15 firms

15 - 24 firms

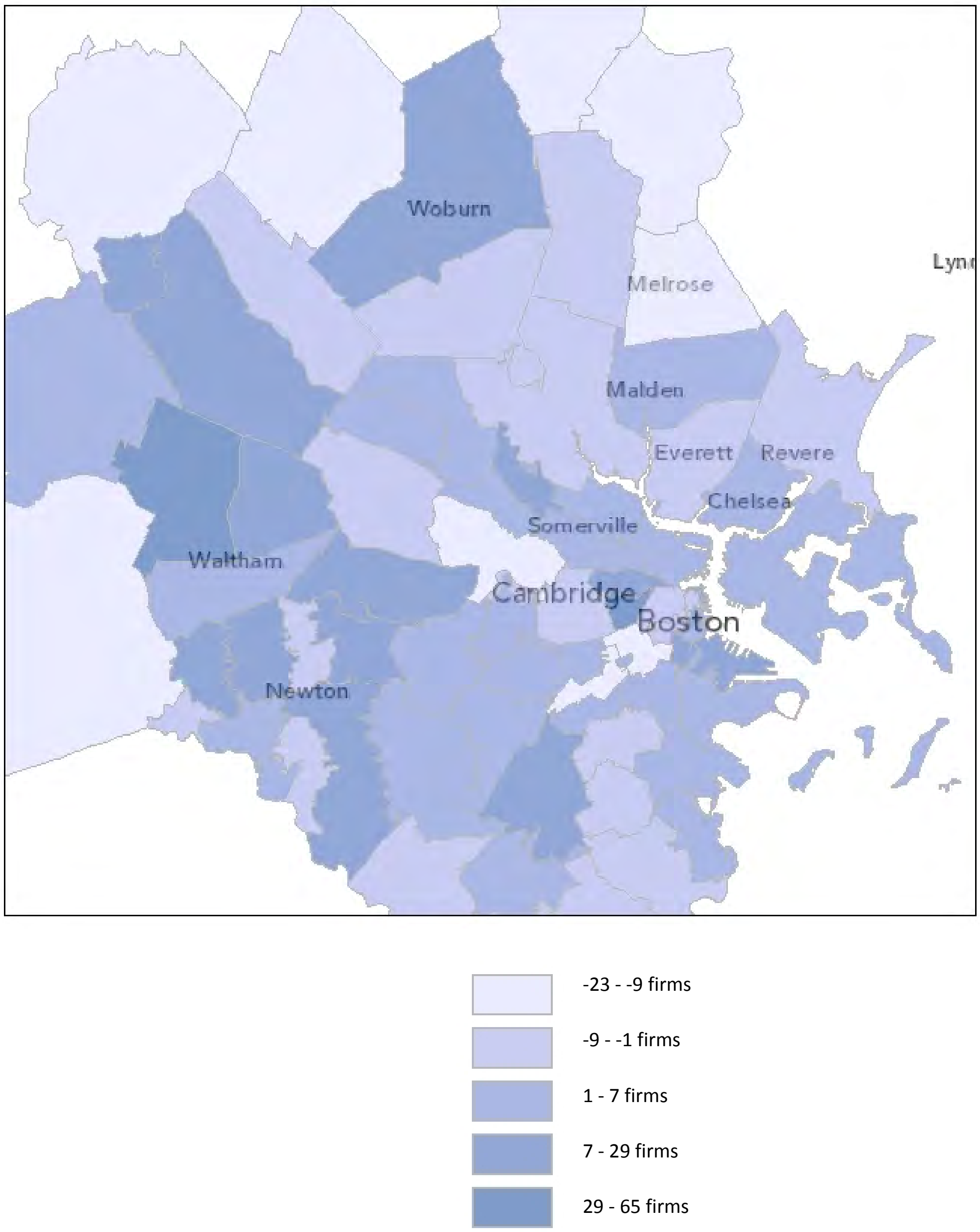
24 - 51 firms

51 - 110 firms

Source: County Business Patterns

Figure 5D

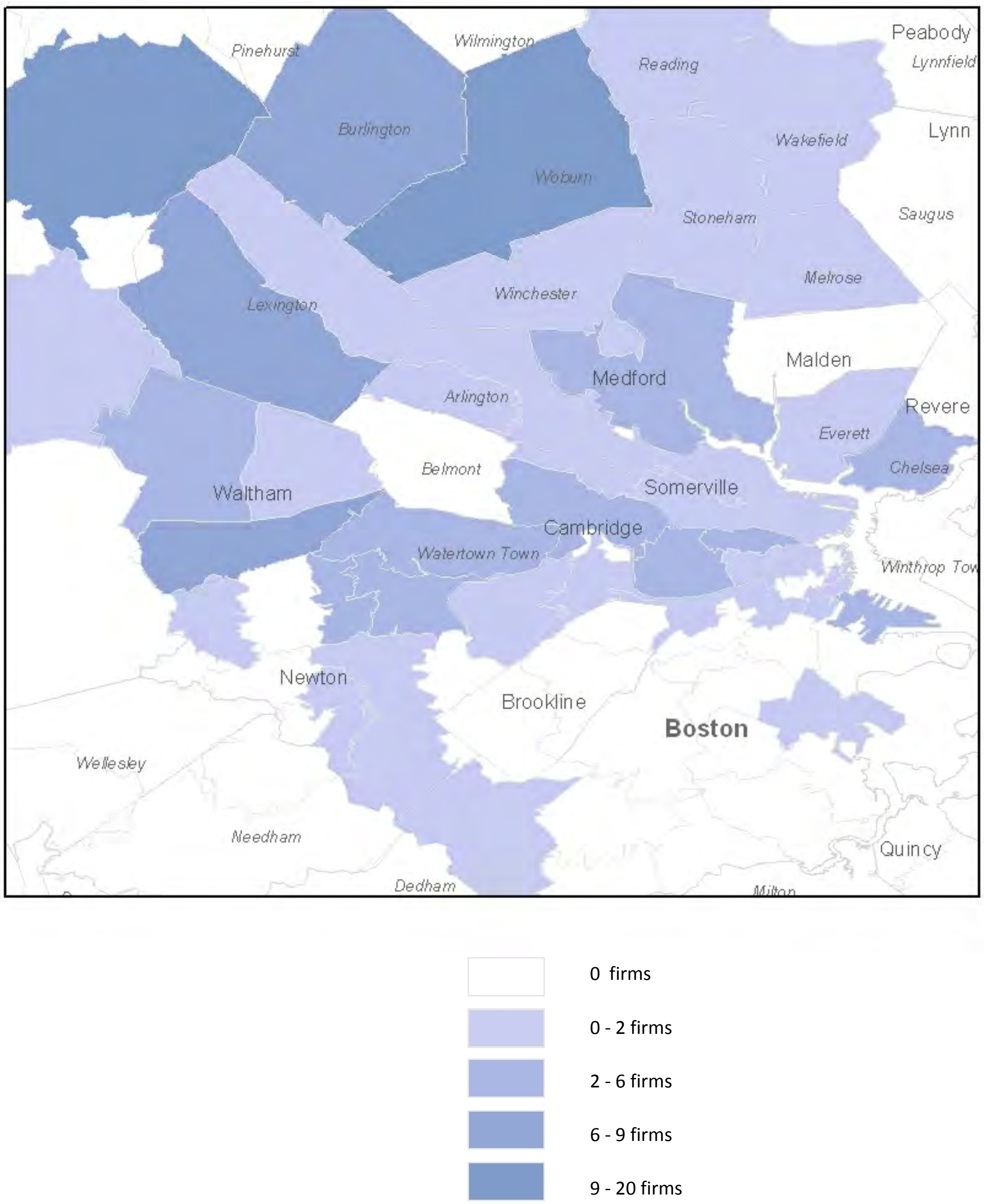
Change in the Count of Tech Firms in Greater Boston, 1998-2010



Source: County Business Patterns

Figure 5E

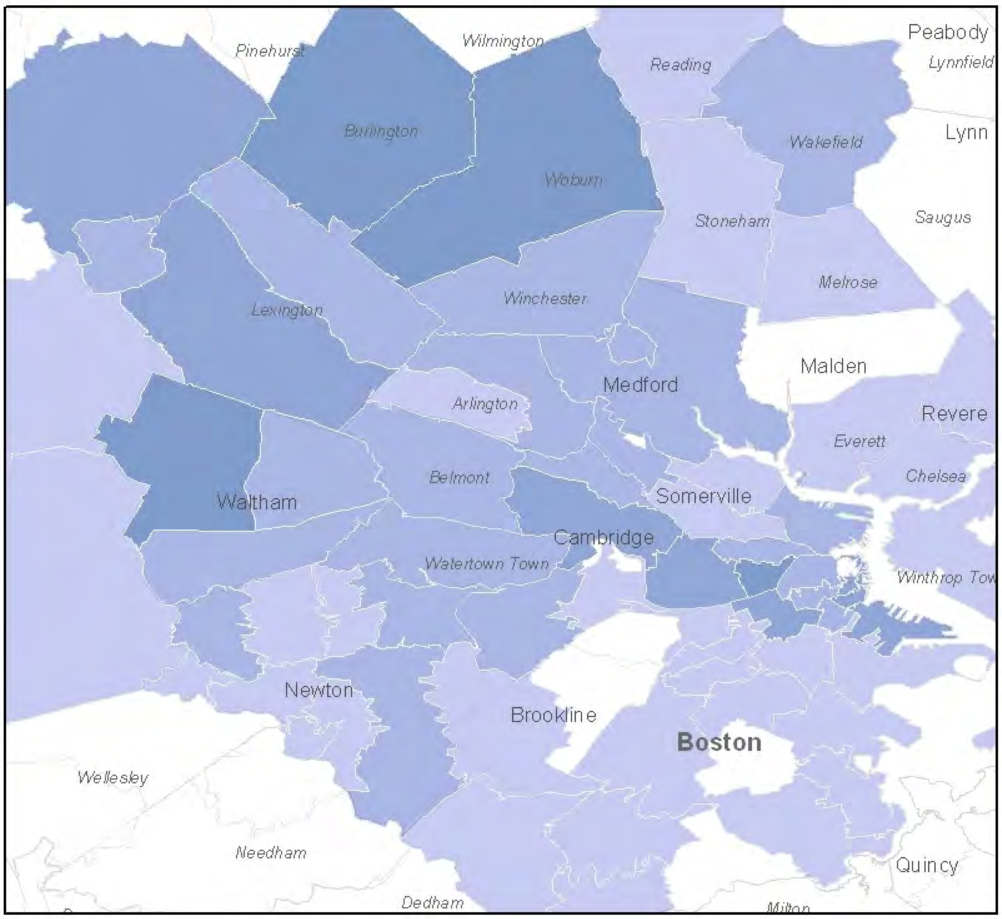
Concentration of Computer Manufacturing and Related Firms in Greater Boston, 2010



Source: County Business Patterns

Figure 5F

Concentration of Computer Related Services Firms in Greater Boston, 2010



0 firms

0 - 15 firms

15 - 24 firms

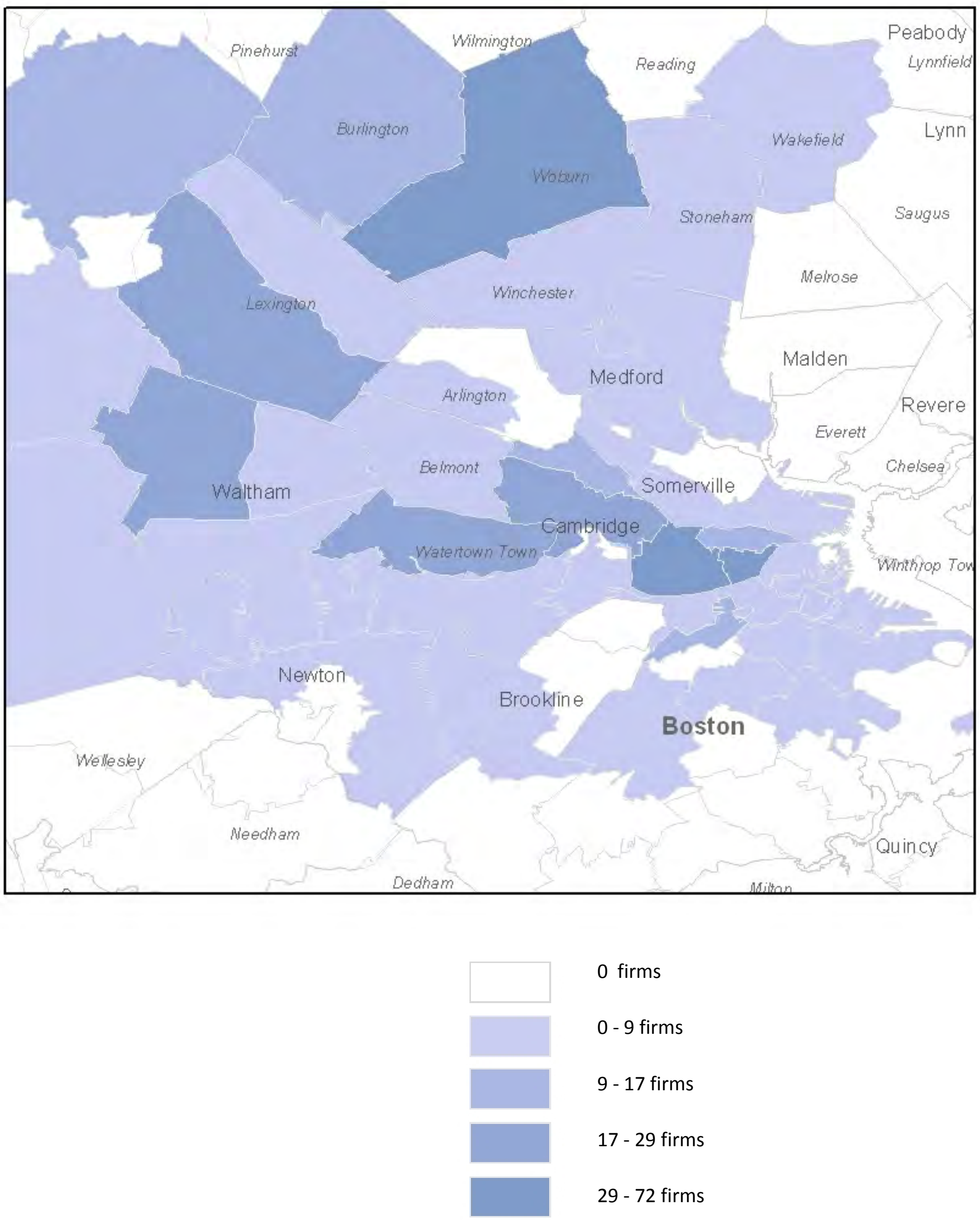
24 - 51 firms

51 - 110 firms

Source: County Business Patterns

Figure 5G

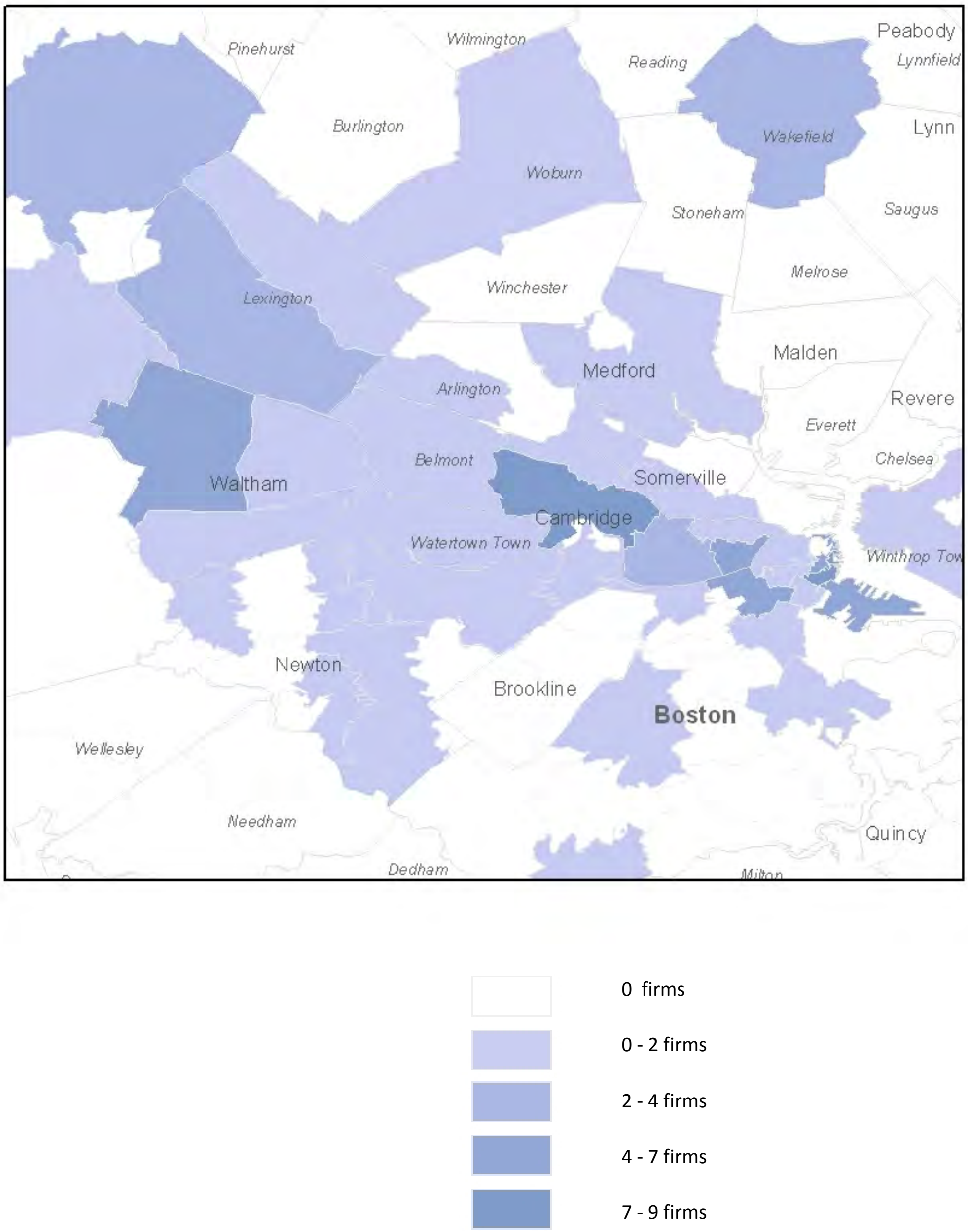
Concentration of Hard Science R & D Firms in Greater Boston, 2010



Source: County Business Patterns

Figure 5H

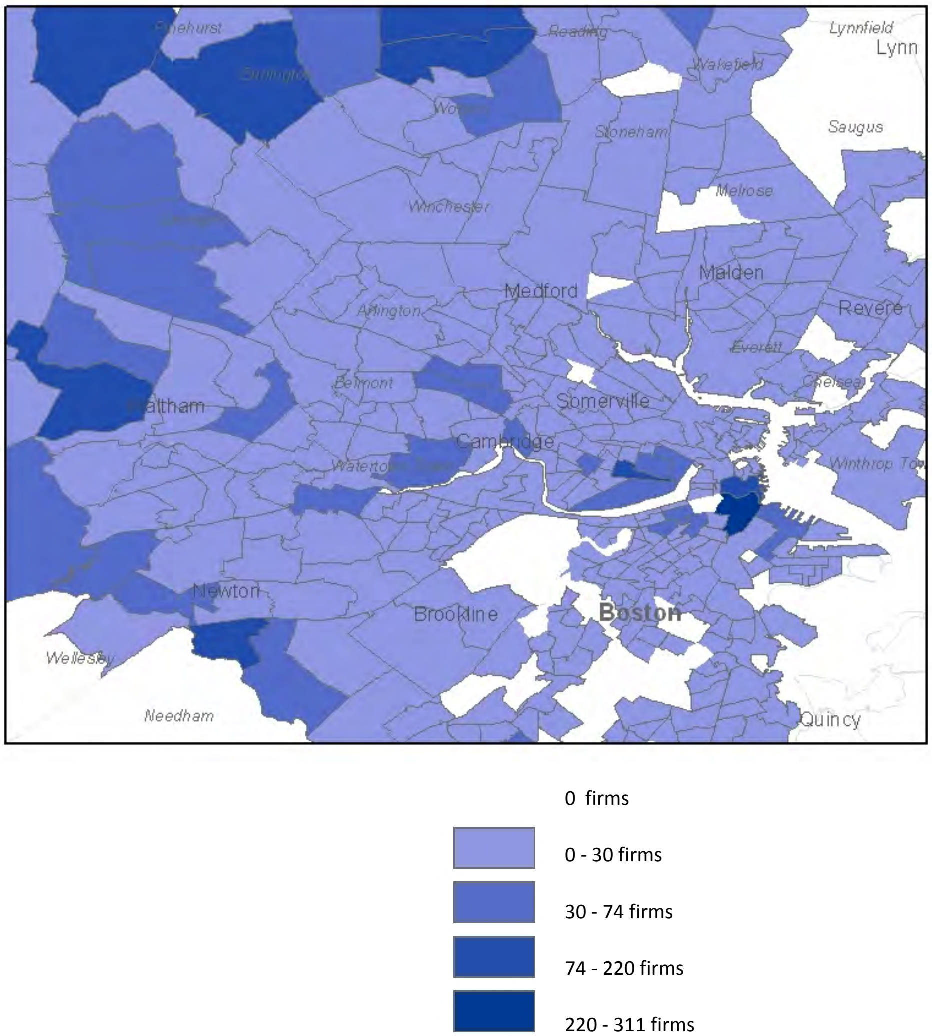
Concentration of Online Publishing and Software Firms in Greater Boston, 2010



Source: County Business Patterns

Figure 6A

Concentration of Tech Firms in Greater Boston, 2010



Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

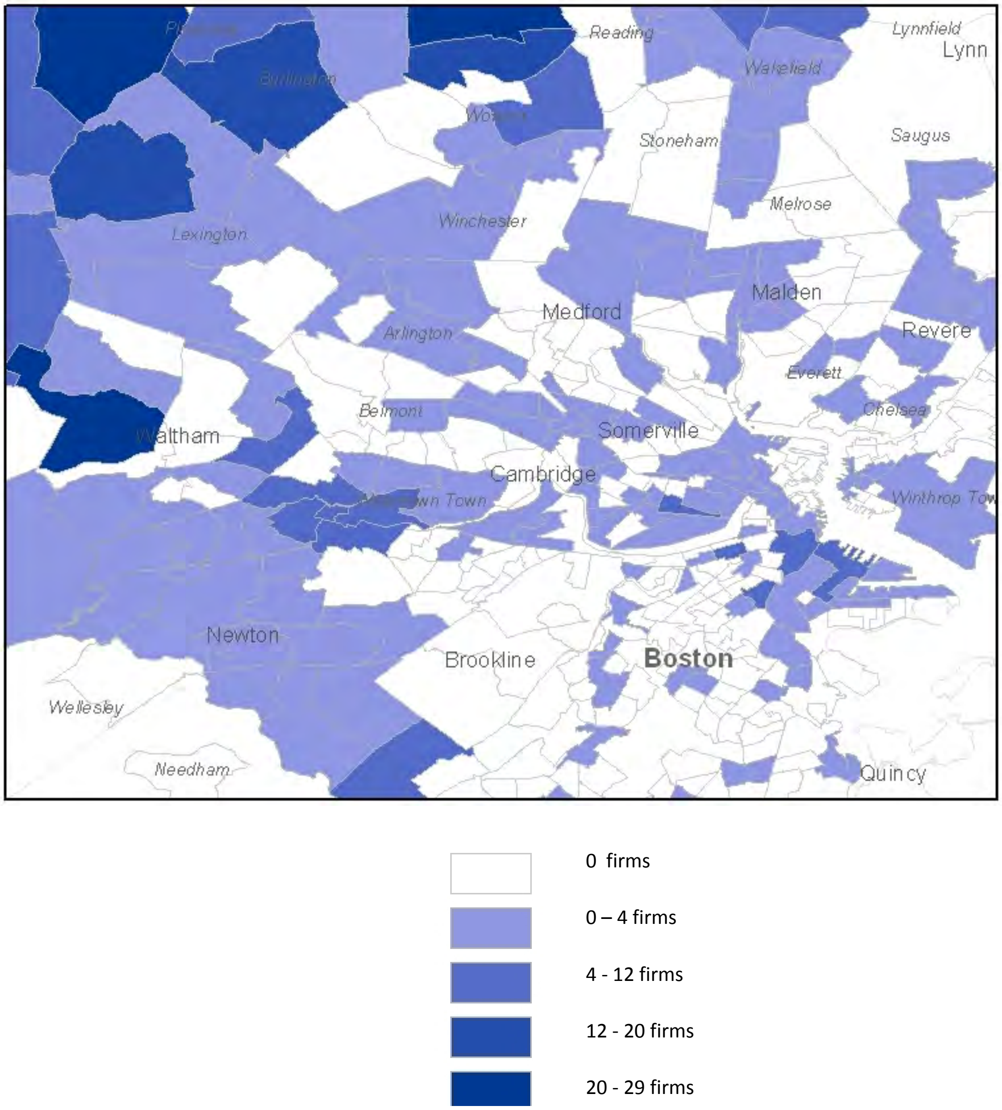
Figure 6B

Concentration of Sole Proprietor Tech Firms in Greater Boston, 2010

Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

Figure 6E

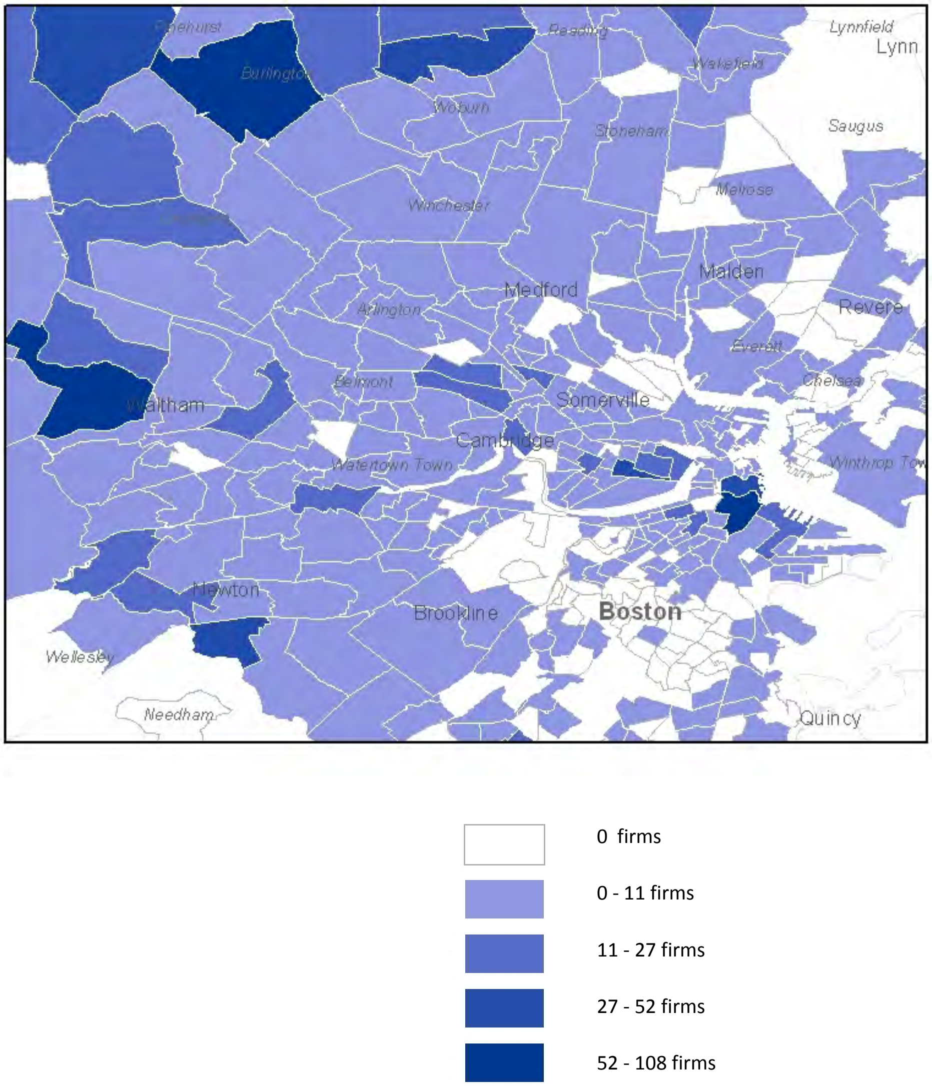
Concentration of Computer and Related Manufacturing Firms in Greater Boston, 2010



Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

Figure 6F

Concentration of Computer Related Services Firms in Greater Boston, 2010



Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

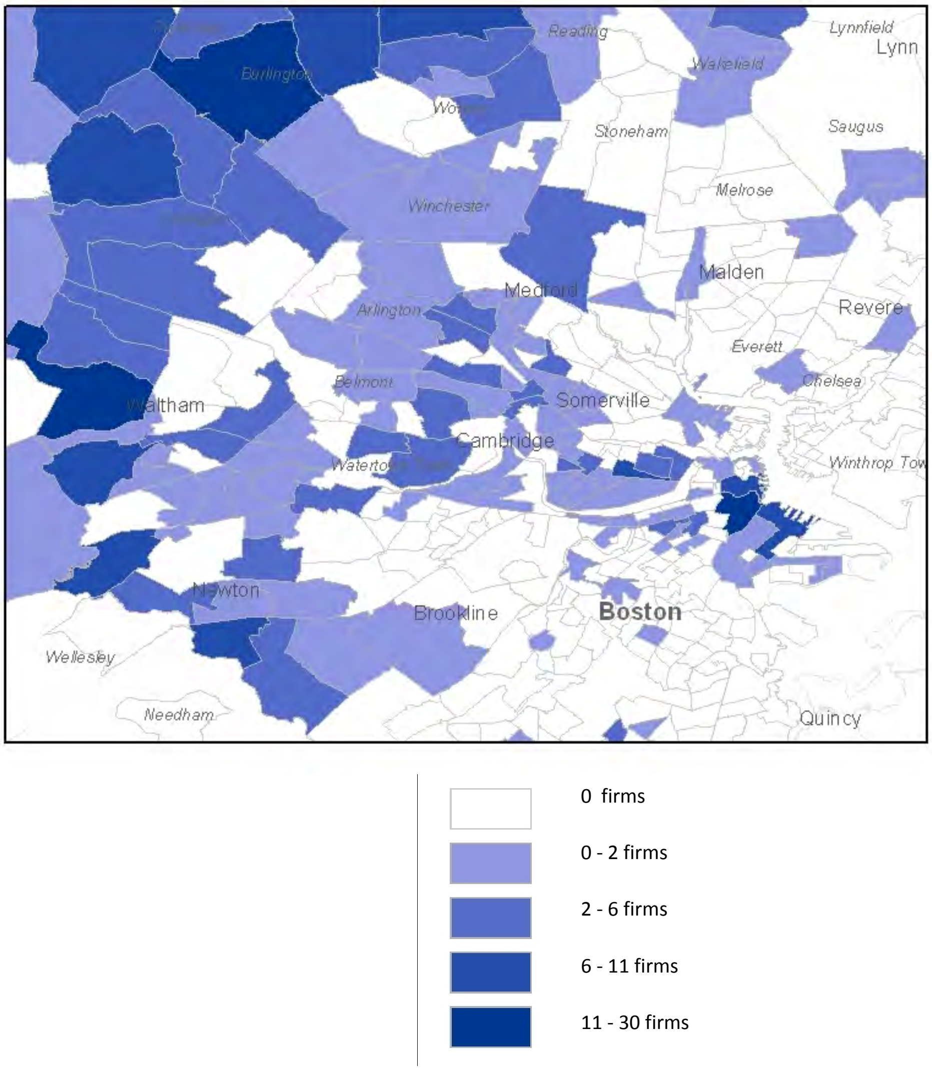
Figure 6G

Concentration of Hard Science R & D Firms in Greater Boston, 2010

Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

Figure 6H

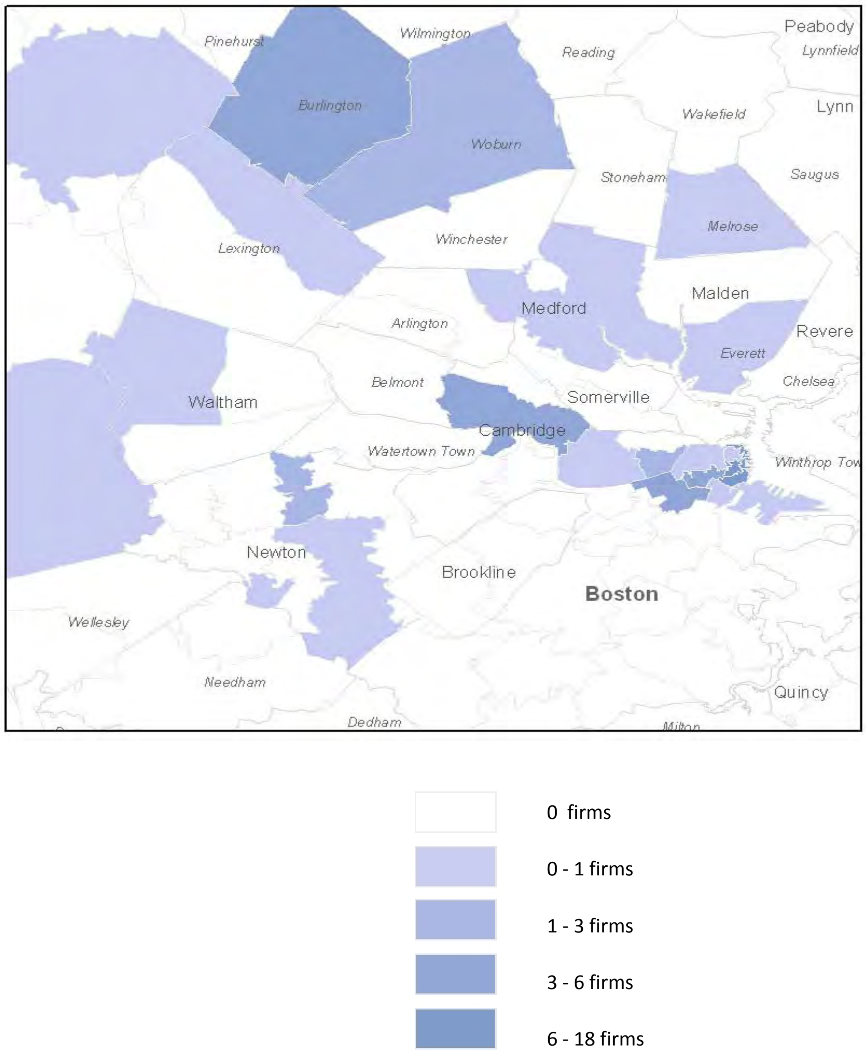
Concentration of Online Publishing and Software Firms in Greater Boston, 2010



Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

Figure 7A

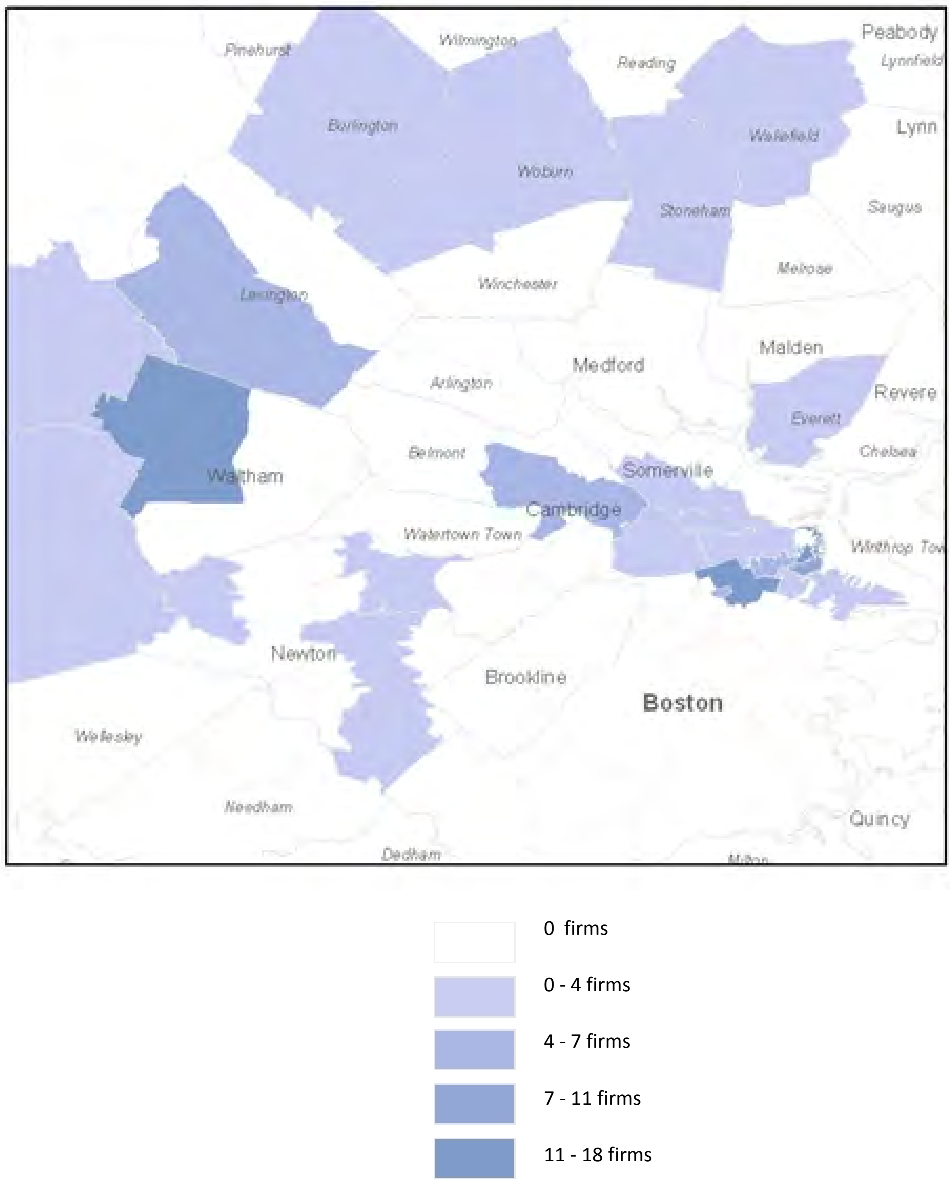
Concentration of Venture Capital Firms in Greater Boston, 1998



Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

Figure 7B

Concentration of Venture Capital Firms in Greater Boston, 2010



Source: National Employment Time Series (NETS) database offered by Walls & Associates based on Dun & Bradstreet data

Figure 8A

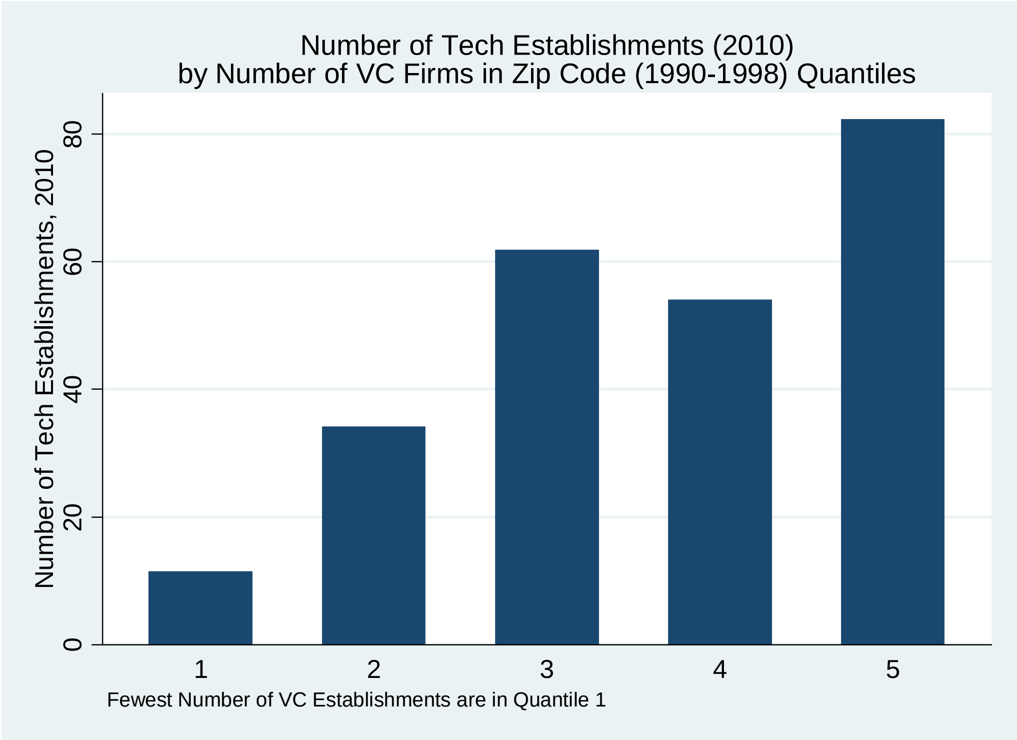


Figure 8B