Survival and growth of Silicon Valley high-tech businesses born in 2000

High-tech businesses born in 2000 in the Silicon Valley had below-average survival and employment growth rates from 2000 to 2009, except for the year 2000, during which surviving firms of the cohort experienced significant growth that carried over for 8 years; year-specific and industry-mix effects, however, weaken the latter conclusion

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During the late 1990s and 2000, a flurry of investment in Internet and technology companies gave rise to the "dot-com bubble." This financial bubble reached its peak on March 10, 2000, when the NASDAQ (formerly the National Association of Securities Dealers Automated Quotations) attained a level of 5,132, about 4 times higher than it had been 3 years earlier. As the gap between the valuation and the performance of many companies became apparent, Internet stocks tumbled. The NASDAQ reached its low point on October 9, 2002, when it fell to 1,114, roughly one-fifth the level at its peak. "Ground zero" during this period of boom and bust was Silicon Valley, an area centered in and around San Jose, California. The area was home to many of the Internet-based companies that came to typify the dot-com frenzy of the era.

Regarded as the global center of technological innovation,[1] Silicon Valley received prodigious amounts of venture capital investment in the late 1990s and 2000, giving rise to thousands of new businesses in the area. Venture capital investments reached their highest level in 2000, when $32.3 billion was pumped into Silicon Valley.[2] (See chart 1.)

This article examines the cohort of Silicon Valley high-tech businesses born amid the 2000 investment frenzy, during which the dot-com bubble reached its apex. The article tracks the 2000 high-tech cohort through the end of 2009, a period encompassing not only the final runup of the dot-com boom, but also the massive high-tech downturn that followed the dot-com bust, as well as the recession that began in December 2007. First, the 2000 cohort's characteristics are profiled, including the number of businesses and jobs created, categorized by high-tech industry and startup size. Then, the performance of the 2000 high-tech cohort, measured in terms of survival rates and employment growth, is compared with the performance of a typical high-tech cohort. To allow for a fair comparison of the two cohorts, factors influencing the success or failure of high-tech startups, such as year-specific and industry-mix effects, are examined. In other words, the article addresses how the relative success or failure of the cohort was influenced by factors such as the larger business cycle and the life cycle of prominent industries in the cohort. Finally, the 2000 high-tech cohort's employment growth rates are examined by detailed industry to show which industries were most or least successful over the next decade.

Silicon Valley has a reputation for radical technological innovation and has been said

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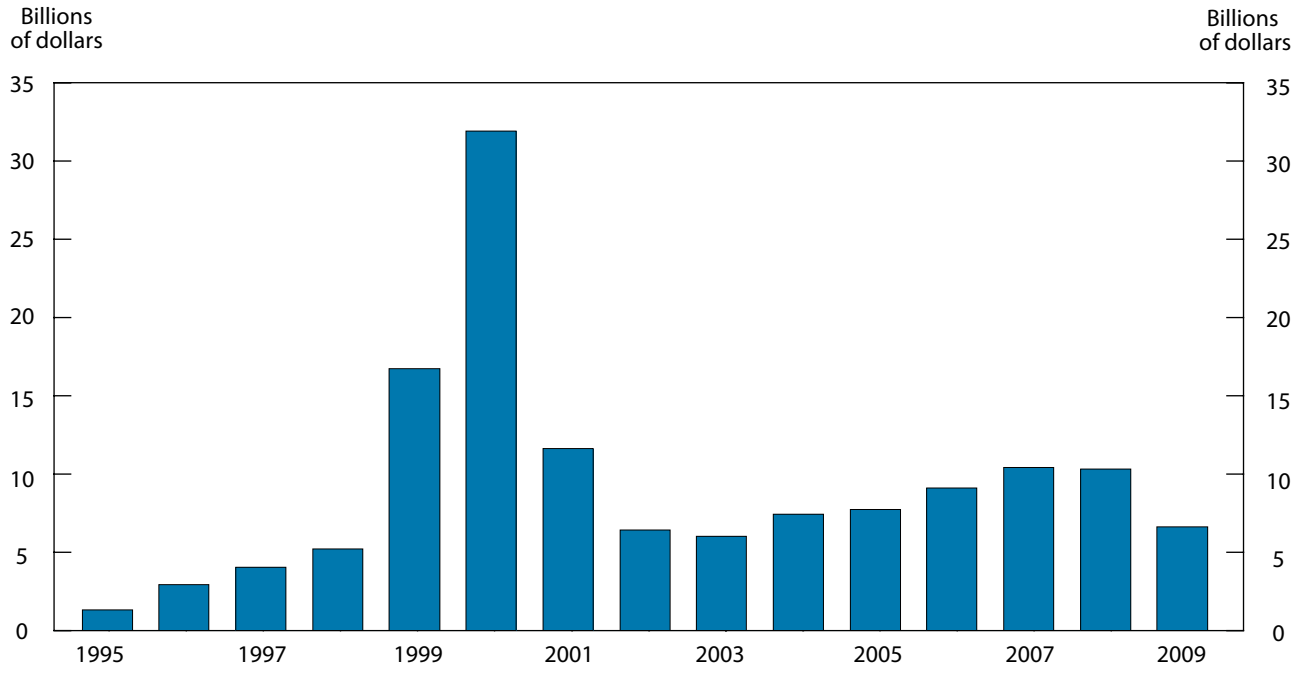
Chart 1. Investment in venture capital for Silicon Valley firms, 1995–2009



SOURCE: *Money Tree Report*™, PricewaterhouseCoopers and the National Venture Capital Association.

to embody the concept of "creative destruction," according to which companies relentlessly reinvent themselves and startups and entrepreneurs challenge established businesses. This competition and constant churning has yielded an evolving landscape of high-tech companies in the Silicon Valley, which remains among the largest and most influential high-tech centers in the world. The analysis presented here will provide measures of the turnover experienced by high-tech startups in the Valley and of factors that influence the survival and growth of new companies, while also assessing the fitness of the 2000 high-tech cohort.

Data

The data presented in this article are based on a microdata extract from the Bureau of Labor Statistics (BLS, the Bureau) Quarterly Census of Employment and Wages (QCEW) program, which has information on roughly 9.1 million U.S. business establishments in the public and private sector. These data are compiled on a quarterly basis for State unemployment insurance tax purposes and are edited and submitted to the Bureau. The QCEW program is a Federal-State cooperative venture between the Bureau and the State Workforce Agencies. The program collects information on approximately 98 percent of all jobs in the United States.

The scope of the study presented comprises six counties[3] that make up what is known as the Silicon Valley and 11 industries[4] classified as high tech according to the 2007 North American Industry Classification System (NAICS)[5] of codes. The article focuses on data elements at the business or firm level. Each business may operate in a single location or have multiple establishments in different areas. Firms are identified by their Employer Identification Number, which aggregates the individual business establishments of each employer. Throughout what follows, a business is considered a survivor if, at any given time, at least one of its establishments is active and has positive employment in the database at that time. By definition, for a business to be considered part of the 2000 birth cohort, it cannot exist in the database or have positive employment prior to the year 2000. These definitions of death and birth reflect the establishment survival methodology developed for Business Employment Dynamics (BED) data.[6]

Although this article discusses primarily the 2000 birth cohort, QCEW microdata on businesses births, deaths, and employment between 1991 and 2009 are used to construct a baseline, or typical, cohort. This typical cohort's rates of

survival and employment growth are compared with rates for the 2000 cohort. Businesses that were acquired or that merged with another firm made up about 1.1 percent of all businesses over the 1991–2009 observational window, but are excluded from the analysis in order to avoid skewing the results for employment growth and survival rates.[7]

2000 birth cohort

In the year 2000, about 2,600 high-tech businesses were born in the Silicon Valley, adding over 27,000 jobs to the local economy. The average birth size of these high-tech businesses was 10 employees; however, employment in these newly formed businesses ranged from 1 to more than 1,000.

Nearly half of all Silicon Valley high-tech startups in 2000 were in computer systems design and related services, and more than one-quarter of businesses were in Internet, telecommunications, and data processing. Businesses in these two industries also made up 62 percent of the cohort's employment in the first year. (See table 1.)

Nearly 91 percent of new high-tech businesses established in 2000 were service-providing businesses, while only 5 percent were goods producing and the remaining ones were businesses operating in multiple industries. In terms of new employment, however, goods-producing businesses made up 20 percent of the total, while service-providing businesses made up 76 percent of the total, with the remainder found in multiple industries. Other studies also have shown that goods-producing firms tend to have higher levels of initial employment than service-providing ones.[8]

The following tabulation shows that, although businesses which started with four or fewer employees made up 64 percent of all new high-tech firms in 2000, these smaller firms accounted for only 11 percent of new high-tech employment from the 2000 cohort's birth year:

	Percent distribution	
Birth size	*Businesses*	*Employment*
4 or fewer (small).....	63.8	11.4
5 to 49 (medium).....	32.3	39.0
50 or more (large).....	3.9	49.6

By contrast, larger firms born with 50 or more employees accounted for just 4 percent of all businesses, but made up half of all new employment in 2000.

The rest of this article tracks the cohort of about 2,600 Silicon Valley companies born in 2000 from that year through the final quarter of 2009. As will be shown, changes in this cohort were greatly affected by year-specific and industry-mix effects.

Employment and survival

Among the businesses in the 2000 cohort of high-tech startups, employment grew from about 27,000 in 2000 to a peak of nearly 34,500 in 2001. (See chart 2.) Despite this growth for startups, existing high-tech firms shed approximately 16,000 jobs that year.[9]

In 2002, the cohort had its steepest decline in employment, losing over 11,500 jobs, more than than it had gained in 2001. The year 2002 also saw the steepest decline in Silicon Valley's entire high-tech sector.[10] The 2000 cohort's employment losses continued in each subsequent year, and by the end of 2009 the cohort employed fewer than 9,400 employees, only 34 percent of the initial employment level in 2000.

The majority of high-tech businesses born in 2000 did not survive past 2003. (See chart 2.) By 2009, fewer than 1 in 5 high-tech startups born in 2000 were still in business. The 2000 cohort's highest annual survival rate, 93 percent, occurred in its first year. This finding is consistent with those from previous studies, which also show that businesses generally have higher survival rates in their first year. The reason is that new businesses often have enough initial reserves to survive for at least 1 year.[11] Given the large pool of venture capital financing that was available to year-2000 startups, it is understandable that they were able to survive the first year and, as noted in the preceding paragraph, even add jobs. The lowest annual survival rates for the 2000 cohort were experienced in 2002 and 2003 (their third and fourth years, respectively). Between 2004 and 2008 (their fifth through ninth years), annual sur-

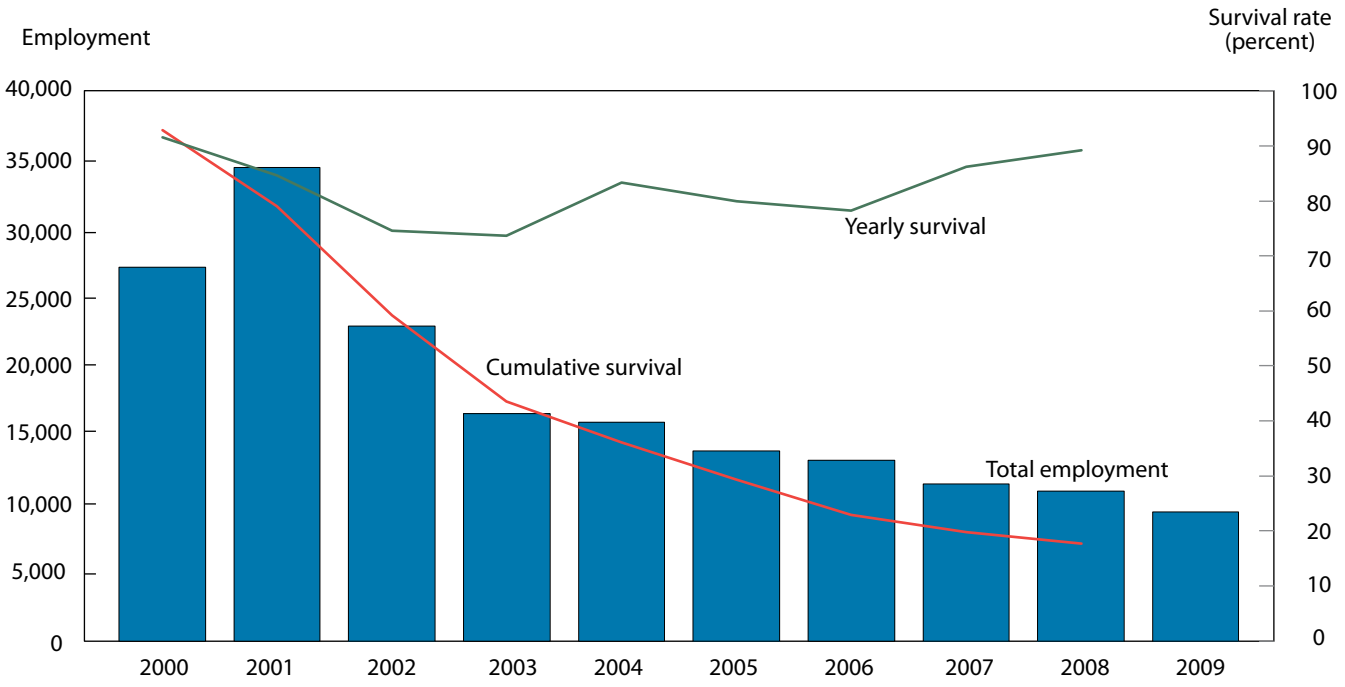
Table 1. Distribution of businesses and employment among Silicon Valley high-tech startups, by major industry, 2000

[In percent]

Industry	Business	Employment
All business and employment startups	100.0	100.0
Computer systems design and related services	46.6	36.0
Internet, telecommunications, and data processing	25.7	25.9
Architecture and engineering services	11.1	5.9
Software publishers	4.5	5.4
Scientific research and development services	3.1	2.9
Semiconductor and electronic component manufacturing	2.8	11.7
Electronic instrument manufacturing	1.2	2.6
Computer and peripheral equipment manufacturing	.5	4.3
Communications equipment manufacturing	.5	.9
Pharmaceutical and medicine manufacturing	.2	.1
Aerospace product and parts manufacturing	.0	.0
Businesses operating in multiple industries	3.9	4.4

SOURCE: U.S. Bureau of Labor Statistics; Quarterly Census of Employment and Wages.

Chart 2. Employment and cumulative survival of 2000 birth cohort of Silicon Valley high-tech firms, 2000–2009



SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

vival rates were generally increasing. The U-shaped curve traced by the annual survival rates of Silicon Valley's 2000 high-tech cohort is consistent with similar patterns found in other studies.[12]

Among the high-tech companies from the 2000 cohort that survived, employment had, on average, doubled by 2009. Like this article, previous studies on business survivorship and growth have shown that surviving companies tend to grow their employment.[13] (See chart 3.) In the first year, surviving firms grew their average employment from 10.4 to 14.4 employees per firm. Following this initial surge, in 2002 average employment in surviving firms dropped to nearly the same level as in their startup year of 2000. After 2003, however, surviving firms had, on average, consistent employment growth, and by 2009 they had an average of 20.4 employees per firm.

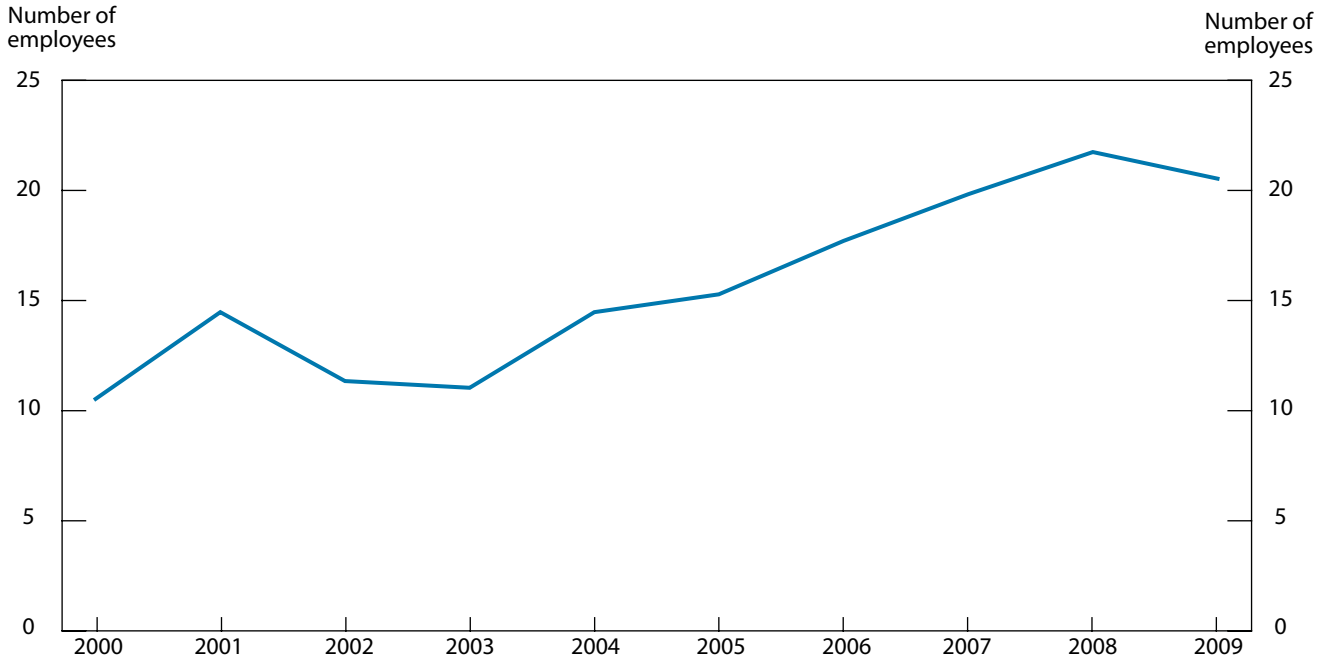
Both survival and employment growth rates varied greatly with the birth size of the firm, a finding also observed in previous studies.[14] (See chart 4.) Surviving firms with small birth sizes had much larger employment growth, but lower survival rates, than firms of larger birth size. Despite a survival rate of only 17 percent, small businesses that survived averaged a nearly threefold increase in their employment over the period examined.

As a result of this growth among survivors, small firms, which made up 11.4 percent of the 2000 cohort's initial employment level, accounted for 23.4 percent of total employment by 2009. (See chart 5.) In contrast, businesses of large birth size experienced higher survival rates (29 percent), but those which did survive tended to contract their employment levels, resulting in a loss in employment share. The contribution to 2000 cohort employment from large firms decreased from 49.6 percent in 2000 to 38.5 percent in 2009. For businesses of medium birth size, the share of 2000 cohort employment also decreased, from 39.0 percent to 38.1 percent. However, average employment in surviving medium-sized business grew by 50.1 percent.

Comparative analysis

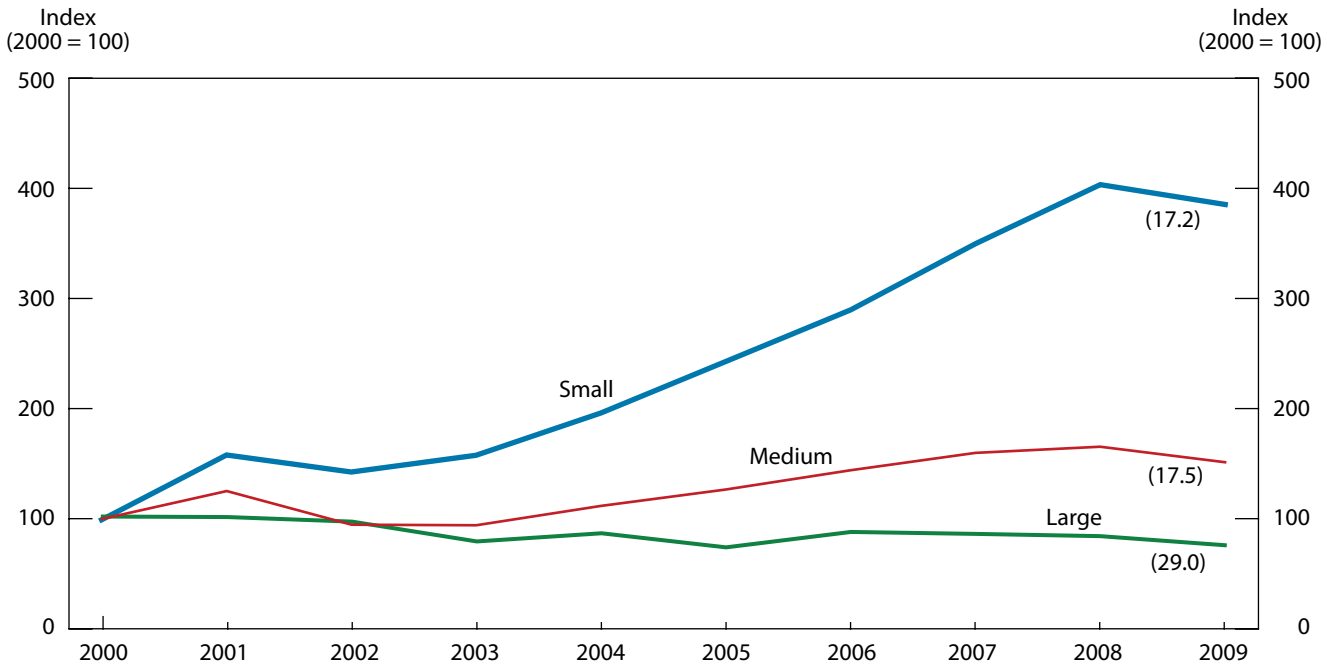
Overview of methodology. The 2000 cohort experienced considerable levels of attrition, as evidenced by the drop in survivors and employment. Silicon Valley, however, is renowned for the creation of new companies following the destruction of old ones.[15] To gauge whether the survival and growth observed for the 2000 cohort is normal or unusual, a comparison can be made between the relative performance of 2000 high-tech startups with that of what we might call the typical or average cohort.

Chart 3. **Average employment in 2000 birth cohort of Silicon Valley high-tech firms, 2000–2009**



SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

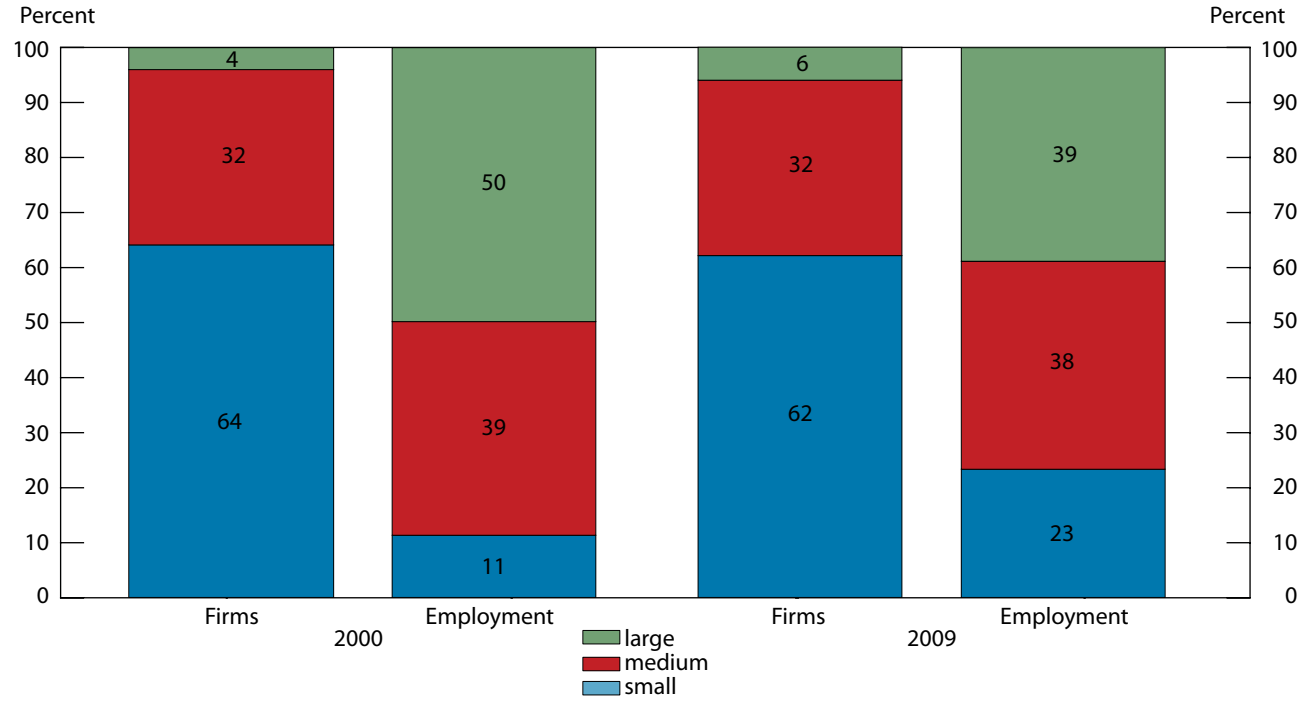
Chart 4. **Index of employment in 2000 birth cohort of Silicon Valley high-tech firms, by birth size, 2000–2009**



NOTE: Cumulative survival rates, in percent, from 2000 to 2009 are shown in parenthesis.

SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

Chart 5. Proportion of employment and firms in 2000 cohort of Silicon Valley high-tech firms, by birth size, 2000 and 2009



SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

To construct the typical cohort, the following factors that could affect the survival and growth of a high-tech firm are considered: (1) the natural life cycle of a business, (2) year-specific fixed effects, and (3) industry (mix) effects. The life cycle of a business captures the average survival and employment growth rates as a function of age. In other words, the life cycle captures what, on average, are the survival and employment growth rates of high-tech firms at different times in their lives. Next, year-specific effects capture the macroeconomic impact of a particular year on the rates of survival and growth. For example, a firm that is born in or that exists during a time of economic prosperity will generally have better prospects than one that is born in or that functions during a slowdown. Finally, the industry factor captures how survival and growth rates vary with differences in the cohort's industry mix. Companies in different industries have significant differences in their expected survival and employment growth rates. For example, one would expect a cohort that has a high concentration of companies in the architecture and engineering industry to have generally higher survival rates, because architecture and engineering firms tend to be more stable than those in other high-tech industries. All three of the foregoing factors must be considered for a fair evaluation of the performance of the 2000 cohort. (See the appendix for methodological details.)

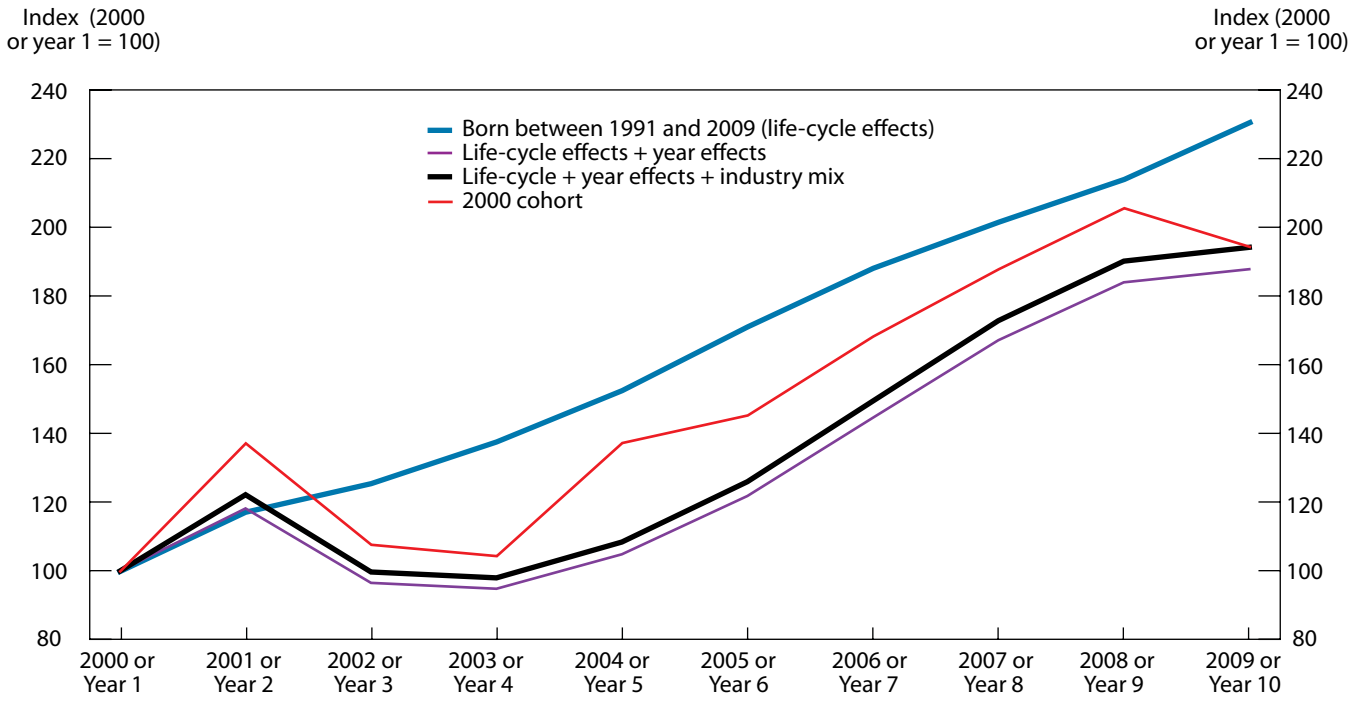
After correcting for these three factors and effectively leveling the playing field, the residual, or the difference between the actual survival or growth rate of the birth cohort and the sum of the three factors, provides an indication of the superior or inferior performance of a birth cohort. Another way to interpret the predicted rate is that it shows how a typical cohort would have performed, in terms of survival and growth, if it had been born in 2000 with the same industry mix that appears in the 2000 cohort.

Results

Employment. On average, a surviving Silicon Valley high-tech firm that was born between 1991 and 2009 had an expected employment growth of 130 percent over the first 10 years of its life. (See chart 6.) The 2000 cohort of Silicon Valley high-tech companies that survived to 2009 had a *lower* average employment growth of 94.5 percent over the first 10 years of their life cycle. On the basis of this comparison alone, the successful year-2000 startups were subpar in terms of growth or did not flourish as much as might have been expected.

This conclusion does not appear as strong, though, when

Chart 6. Index of employment growth of surviving firms born between 1991 and 2009 and surviving firms from the 2000 cohort



NOTE: Calendar years refer to 2000 cohort; ordinal years refer to firms born between 1991 and 2009.

SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

year and industry-mix effects over the 2000–2009 period are considered. Adjusting for confounding effects reveals that surviving firms in the 2000 cohort grew at a rate similar to that expected from the theoretical, or typical, cohort. (See chart 6.) Thus, a theoretical surviving firm born in 2000 and with the same industry mix as the 2000 birth cohort would have seen its employment grow by 93.6 percent, similar to the 2000 cohort's 94.5-percent growth rate.

The 2000 cohort had stronger-than-expected growth in its first year: surviving firms grew their employment by 37 percent, compared with an expected rate of growth of 22 percent for firms from the typical cohort (again, taking year and industry-mix effects into account). One of the factors that contributed to the 2000 cohort's early employment gains may have been the mammoth amounts of venture capital investment in Silicon Valley during and around the year 2000. Dot-com-era startups are often associated with having high "burn rates": how quickly they burn through capital reserves before, if ever, becoming profitable.[16] The unusual spike in the cohort's employment in 2001 may have been due to startups burning through their investors' capital reserves.[17]

A typical cohort subjected to the same year and industry-mix effects as the 2000 cohort actually would have lagged the 2000 cohort in terms of employment growth through most of the decade. An employment shock to the 2000 cohort occurred in 2009, when surviving firms contracted, rather than following the expected pattern of growth, in response to the recession that took hold among high-tech companies. This shock led the indexes of employment growth for the 2000 cohort and the theoretical cohort to converge.

The analysis shows that, after 10 years, the 2000 cohort performed about as well as would be expected, following adjustment for both year-specific and industry-mix factors. The positive impacts on employment growth due to the cohort's industry mix were more than offset by negative year-specific effects, which dampened growth prospects for high-tech companies born in 2000.

Survival. Applying the methodology described in the appendix also led to the development of survival rates for the theoretical, or typical, Silicon Valley cohort. About 28 percent of a typical cohort of high-tech firms survive past 9 years; however, only 17.1 percent of the 2000 cohort survived that long. (See chart 7.)

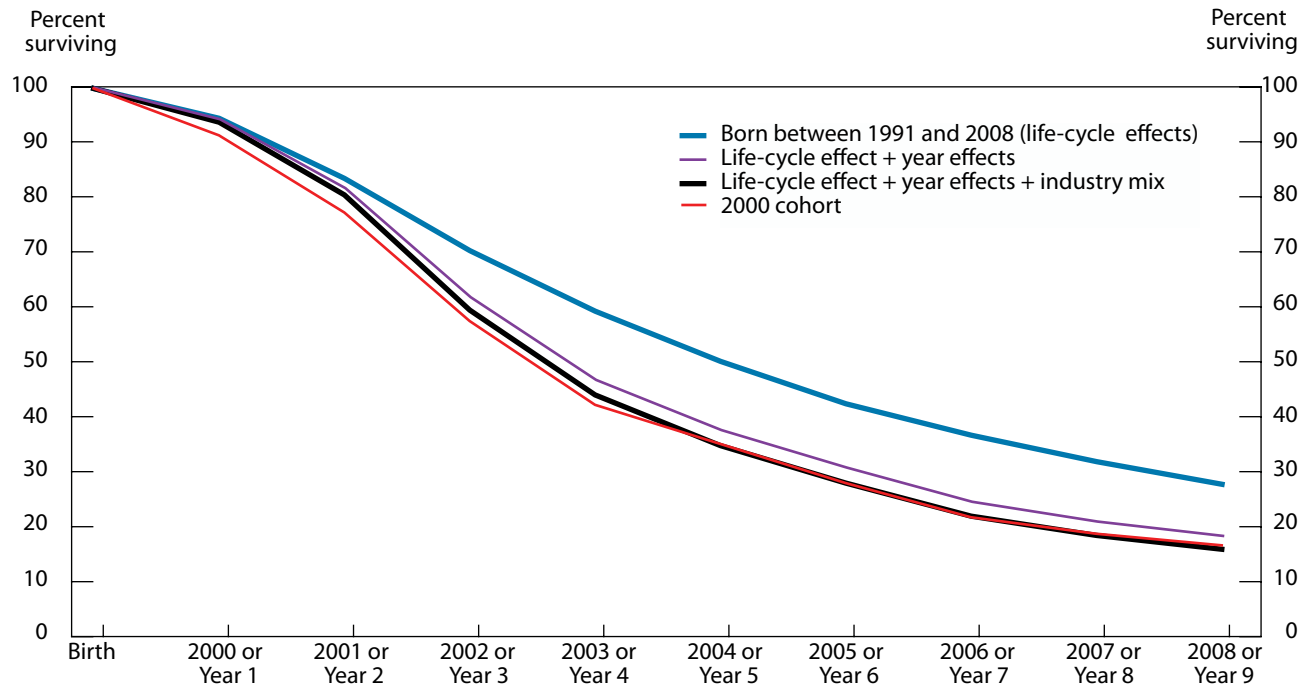
After adjustment for year-specific effects, however, the survival rate of the typical cohort converged toward that of the 2000 cohort, dropping to 18.7 percent. This finding indicates that if a typical cohort were born in 2000 and were subjected to the macroeconomic effects of years 2000 to 2008, 18.7 percent of that cohort would have survived to 2009. Adding industry mix differences to the adjusted rate yields an even lower survival rate of 16.4 percent for the typical cohort. The 16.4-percent figure is the rate that adjusts for known exogenous factors that affect survival. Another interpretation of this rate is that it describes the theoretical survival of a typical cohort born in 2000, subjected to the 2000-to-2008 effects, and having the same industry mix as the 2000 cohort. In comparison, the 2000 cohort's survival rate after year 9 was 0.7 percent higher than the theoretical survival rate.

Incidentally, survival rates for both the 2000 cohort and the typical cohort were not markedly different from survival rates found for other industries and years: another study found that survival rates for service-providing and goods-producing industries ranged from 19 percent to 26 percent over the first 9 years of their lifetime.[18]

Unlike the employment growth analysis, which showed opposite effects due to the year and industry-mix factors, an analysis of survivorship reveals that both year and industry-mix factors acted as headwinds for the 2000 cohort. Still, given the large amounts of venture capital financing floating around Silicon Valley during the early part of the decade, it is somewhat surprising that high-tech startups in the 2000 cohort did not fare considerably better than those in the typical cohort. (The study did not analyze how well the typical cohort would have performed, given the widespread availability of venture capital in 2000.)

While cumulative survival rates allow for an analysis of the long-term survivorship of a cohort, the survival rate of previous year's survivors allows for an evaluation of survival rates in intervening years. (See chart 8.) For the 2000 cohort, survival rates were lower than those of the typical cohort in every year except for year 9. Both the typical cohort and the 2000 cohort exhibit a U-shaped pattern (the typical cohort's "U" is flatter) in yearly survival, a result that is consistent with findings obtained in previous research on startups across different industries. Note also that, while the 2000 cohort's yearly survival rates generally lie below those of the typical cohort, the latter rates converge toward those of the 2000 cohort when corrected for year and industry-mix effects. These effects are most evident during the 2001-to-2003 timeframe, when mac-

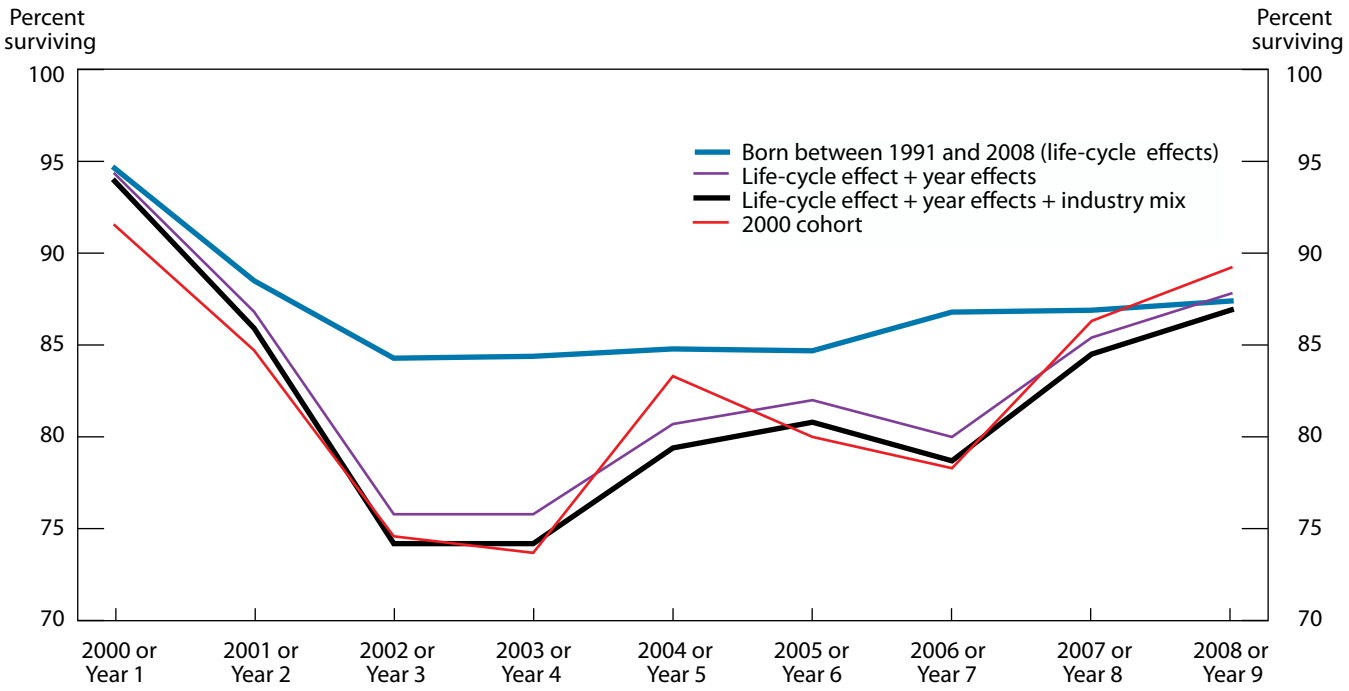
Chart 7. Cumulative survival rate of firms born between 1991 and 2008 and firms from the 2000 cohort



NOTE: Calendar years refer to 2000 cohort; ordinal years refer to firms born between 1991 and 2008.

SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

Chart 8. Survival rate of previous year's survivors for firms born between 1991 and 2008 and firms from the 2000 cohort



NOTE: Calendar years refer to 2000 cohort; ordinal years refer to firms born between 1991 and 2008.

SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

roeconomic effects greatly depressed the typical cohort's yearly survival rates to a level similar to that of the 2000 cohort. Year-specific macroeconomic effects played the largest role in damping not only survival rates, but also (as shown earlier) employment growth, for the 2000 cohort of Silicon Valley high-tech startups.

Industry employment performance

The previous section examined employment and survival in the 2000 cohort and in a typical cohort. This section analyzes the 2000 cohort alone for differences in total employment growth across industries. Employment growth of high-tech businesses varies greatly by industry. (See table 2.) Between 2000 and 2009, employment growth in various high-tech industries for the cohort ranged from an increase of 61 percent to a loss of all employment in an industry.

Computer systems design. More than 46 percent of all high-tech businesses born in 2000 were in the computer systems design industry. (See table 1.) Although this industry had the largest total employment in both 2000 and 2009, nearly 7,000 jobs were shed by the industry's 2000 cohort during that period.

Internet, telecommunications, and data processing. The Internet, telecommunications, and data-processing industrial group was the second-largest high-tech industry in the 2000 cohort in respect of both the number of new businesses and the number of new employees. Of the 7,000 employment births in the industry in 2000, fewer than 1,200 were left in 2009 from surviving firms. This industry, more than any other, was home to many of the e-commerce startups that came to symbolize the excesses of the dot-com boom.[19]

Architecture and engineering services. The architecture and engineering services industry had the third-largest number of births in 2000, but had about average employment attrition. Since 2000, the industry has been one of the strongest and fastest growing areas in the national high-tech picture, but has grown at a below-average rate in the Silicon Valley.[20]

Goods-producing industries. High-tech goods-producing industries are characterized by lower numbers of births, but larger firm sizes. Thus, although goods-producing (manufacturing) industries made up only 5 percent of all births, they accounted for 20 percent of new employment. (See table 1.) Employment growth varied across goods-

Table 2. Employment growth of Silicon Valley high-tech businesses, by industry, 2000–2009

Industry	Total employment		Percent change
	2000	2009	
All businesses	27,163	9,159	–66.3
Computer systems design and related services	9,770	2,793	–71.4
Internet, telecommunications, and data processing	7,045	1,161	–83.5
Semiconductor and electronic component manufacturing	3,168	914	–71.2
Architecture and engineering services	1,601	554	–65.4
Software publishers	1,454	420	–71.1
Computer and peripheral equipment manufacturing	1,172	975	–16.8
Scientific research and development services	784	195	–75.1
Electronic instrument manufacturing	717	155	–78.4
Communications equipment manufacturing	231	0	–100.0
Pharmaceutical and medicine manufacturing	([1])	([1])	([1])
Aerospace product and parts manufacturing	([1])	([1])	([1])
Businesses operating in multiple industries	1,195	1,927	61.2

[1] Data do not meet BLS or State agency disclosure standards.

SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

producing industries, with businesses in communications equipment, semiconductor, and electronic instrument manufacturing exhibiting below-average employment growth and those in computer and peripheral equipment manufacturing showing favorable employment growth.

Multiple industries. Businesses operating in multiple high-tech industries were the only businesses in high tech that had, on average, employment growth between 2000 and 2009. These businesses tended to be slightly larger than businesses operating in only a single industry, a factor that could help explain their higher employment growth.[21] Of all births among high-tech industries in 2000, employees of businesses in multiple industries made up 4.4 percent of employment. (See table 1.) By 2009, employment in these businesses accounted for 21.0 percent of the cohort's total employment.

AT FIRST GLANCE, THE SURVIVAL AND EMPLOYMENT growth picture for the 2000 birth cohort appears bleak, with only 18 percent of high-tech businesses surviving, and employment falling by 66 percent, by 2009. Nonetheless, after adjustment for year-specific and industry-mix effects, the cohort is seen to have had indistinguishable differences from all high-tech firms existing from 2000 to 2009 as regards rates of survival and growth. One unique characteristic, however, was the 2000 cohort's abnormally high employment growth in the first year of business, a result that may be related to the large amount of startup funds available to some high-tech companies during the 1998-to-2000 timeframe. □

Notes

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[1] Ross C. DeVol, Kevin Klowden, Armen Bedroussian, and Benjamin Yeo, "North America's High-Tech Economy: The Geography of Knowledge-Based Industries, Executive Summary" (Santa Monica, CA, Milken Institute, no date), see p. 4, **http://www.milkeninstitute.org/pdf/NamericaHiTechExecSmmry_Final.pdf** (visited Sept. 15, 2011).

[2] PricewaterhouseCoopers and the National Venture Capital Association, *MoneyTree™ Report*, **https://www.pwcmoneytree.com/MTPublic/ns/nav.jsp?page=historical** (visited Sept. 15, 2011).

[3] The six Silicon Valley counties are Alameda, Contra Costa, San Francisco, San Mateo, Santa Clara, and Santa Cruz.

[4] The 11 industries are computer and peripheral equipment manufacturing; computer systems design and related services; semiconductor and electronic component manufacturing; Internet, telecommunications, and data processing; software publishers; scientific research and development services; electronic instrument manufacturing; architecture and engineering services; communications equipment manufacturing; pharmaceutical and medicine manufacturing; and aerospace product and parts manufacturing. The approach taken is based on Daniel Hecker, "High-tech employment: a NAICS-based update," *Monthly Labor Review*, July 2005, pp. 57–72, **http://www.bls.gov/opub/mlr/2005/07/art6full.pdf** (visited Sept. 15, 2011).

[5] The North American Industry Classification System (NAICS) groups establishments into industries on the basis of the activities in which they are primarily engaged.

[6] See Akbar Sadeghi, "The births and deaths of business establishments in the United States," *Monthly Labor Review*, December 2008, pp. 3–18, **http://www.bls.gov/opub/mlr/2008/12/art1full.pdf** (visited Sept. 15, 2011); and James R. Spletzer, "The Contribution of Establishment Births and Deaths to Employment Growth," *Journal of Business & Economic Statistics,* January 2000, pp. 113–26. National and State-level data on establishment survival are available through the BLS BED program for major industries, **http://www.bls.gov/bdm/bdmage.htm** (visited Sept. 15, 2011) and **http://www.bls.gov/opub/ils/summary_10_09/younger_older_business_establishments.htm**

(visited Sept. 15, 2011).

[7] A similar issue and treatment of data appears in Amy E. Knaup, "Survival and longevity in the Business Employment Dynamics data," *Monthly Labor Review*, May 2005, pp. 50–56, **http://www.bls.gov/opub/mlr/2005/05/ressum.pdf** (visited Sept. 15, 2011).

[8] *Ibid.*, p. 54.

[9] Amar Mann and Tian Luo, "Crash and reboot: Silicon Valley high-tech employment and wages, 2000–08," *Monthly Labor Review*, January 2010, pp. 59–73, **http://www.bls.gov/opub/mlr/2010/01/art3full.pdf** (visited Sept. 15, 2011).

[10] The sector lost 84,500 jobs in 2002. (See Mann and Luo, *ibid.*)

[11] See Josef Bruderl and Rudolf Schussler, "Organizational Mortality: The Liabilities of Newness and Adolescence," *Administrative Science Quarterly*, September 1990, pp. 530–47; and Mark Fichman and Daniel A. Levinthal, "Honeymoons and the Liability of Adolescence: A New Perspective on Duration Dependence in Social and Organizational Relationships," *Academy of Management Review*, April 1991, pp. 442–68.

[12] See Bruderl and Schussler, "Organizational Mortality"; and Joel Popkin, *Business Survival Rates by Age Cohort of Business* (U.S. Department of Commerce, Small Business Administration, 2001).

[13] Amy E. Knaup and Merissa C. Piazza, "Business Employment Dynamics data: survival and longevity, II," *Monthly Labor Review,* September 2007, pp. 3–10, **http://www.bls.gov/opub/mlr/2007/09/art1full.pdf** (visited Sept. 15, 2011).

[14] See David S. Evans, "The Relationship Between Firm Growth, Size, and Age: Estimates for 100 Manufacturing Industries," *Journal of Industrial Economics*, June 1987, pp. 567–81, and "Tests of Alternative Theories of Firm Growth," *Journal of Political Economy*, August 1987, pp. 657–74; Rajshree Agarwal and David B. Audretsch, "Does Entry Size Matter? The Impact of the Life Cycle and Technology on Firm Survival," *Journal of Industrial Economics,* March 2001, pp. 21–43; and David B. Audretsch and Talat Mahmood, "The Rate of Hazard Confronting New Firms and Plants in U.S. Manufacturing," *Review of Industrial Organization*, vol. 9, no. 1, pp. 41–56, and "New Firm Survival: New Results Using a Hazard Function," *Review of Economics and Statistics*, February 1995, pp. 97–103.

[15] Junfu Zhang, *High-tech Start-ups and Industry Dynamics in Silicon Valley* (San Francisco, Public Policy Institute of California, 2003); see especially p. 4.

[16] Michael Wolff, *Burn Rate: How I Survived the Gold Rush Years on the Internet* (New York: Simon and Schuster, 1998), see front flap.

[17] Michael S. Malone, "High-Tech Industry Isn't the Solution to the Recession," *Money* (ABC News, Aug. 14, 2009), **http://abcnews.go.com/Business/Technology/story?id=8322044&page=1** (visited Sept. 15, 2011).

[18] John Baldwin and Guy Gellatly, *Innovation Strategies and Performance in Small Firms* (Ottawa, Statistics Canada, 2003); see especially p. 43.

[19] Mathew Honan and Steven Leckart, "10 Years After: A Look Back at the Dotcom Boom and Bust," *Weekly Wellness Magazine*, Feb. 17, 2010, **http://www.wired.com/magazine/2010/02/10yearsafter/all/1** (visited Sept. 15, 2011).

[20] Mann and Luo, "Crash and reboot" (see especially p. 66).

[21] Some studies have found a positive correlation between firm size, on the one hand, and survival rates and employment growth, on the other. (See, for example, Agarwal and Audretsch, "Does Entry Size Matter?" and Evans, "The Relationship Between Firm Growth, Size, and Age.")

APPENDIX: Methodology

The methods used in the text of this article apply to one or both of the key concerns of the article: *business survival* and *employment growth* among high-tech firms born between 2000 and 2009 in the Silicon Valley.

Survival

Business life cycle. The life cycle of a business can be expressed in two ways: the cumulative survival function and the yearly survival rate (the survival rate of the previous year's survivors). The cumulative survival function is estimated with the Kaplan-Meier product limit estimator,[1] a nonparametric maximum likelihood estimator given by

$$\hat{S}(t) = \prod_{t_i \le t} \frac{n_i - \delta_i}{n_i},$$

where $\hat{S}(t)$ is the estimate of the probability of surviving past time t, n_i is the number of firms that are "at risk" at time t, and δ_i is the number of deaths at time t. The nonparametric form of this estimator allows yearly survival rates to vary across followup times.

The number "at risk" is defined as

$$n_i = s_i - \gamma_i,$$

where s_i is the number of firms that survived during the previous period and γ_i is the number of losses (here, right-censored cases; firms that were still alive in the fourth quarter of 2009, the last quarter of the observational window, are right censored). Finally, the yearly survival rates can be derived from the cumulative survival function with the formula

$$\hat{s}(t) = \frac{\hat{S}(t)}{\hat{S}(t-1)}.$$

Chart A–1 shows that less than half of Silicon Valley's high-tech business startups since 1991 survived past age 5. Chart A–2 indicates that businesses tend to have relatively higher survival rates in their initial year (95 percent) and the worst survival rates in their third year (84 percent). After 3 years, the annual survival rates of previous year's survivors increase throughout a firm's life.

Year-specific effects. Economic conditions during each year affect the survival of all businesses. In addition to the natural life cycle of a business, businesses may face harsher or easier survival conditions in certain years. The year-specific effect, an adjustment factor, is calculated as the percent difference between each year's hazard rate[2] and the average rate for all years. This adjustment factor is applied to the hazard rates derived from the natural life cycle of a business in order to adjust for macroeconomic effects. The resulting measure indicates how a typical cohort would survive if it were born in the year 2000.

Chart A–3 shows that hazard rates of high-tech firms in the Silicon Valley tended to be lower in the 1990s than in the 2000s.

Industry-mix effects. The survival rates of various high-tech industries are heterogeneous. For example, businesses in the Internet, telecommunications, and data-processing industry tend to have the lowest survival rates, while those in electronic instrument manufacturing and in architecture and engineering services have the highest. (See table A–1.) Because each birth cohort has a different high-tech industry mix, some cohorts may under- or overperform in terms of survival. To adjust for the industry-mix effects, an adjustment factor is computed that takes into account how each industry survives relative to other industries and how the industry mix for the 2000 birth cohort differs from that of an average birth cohort.

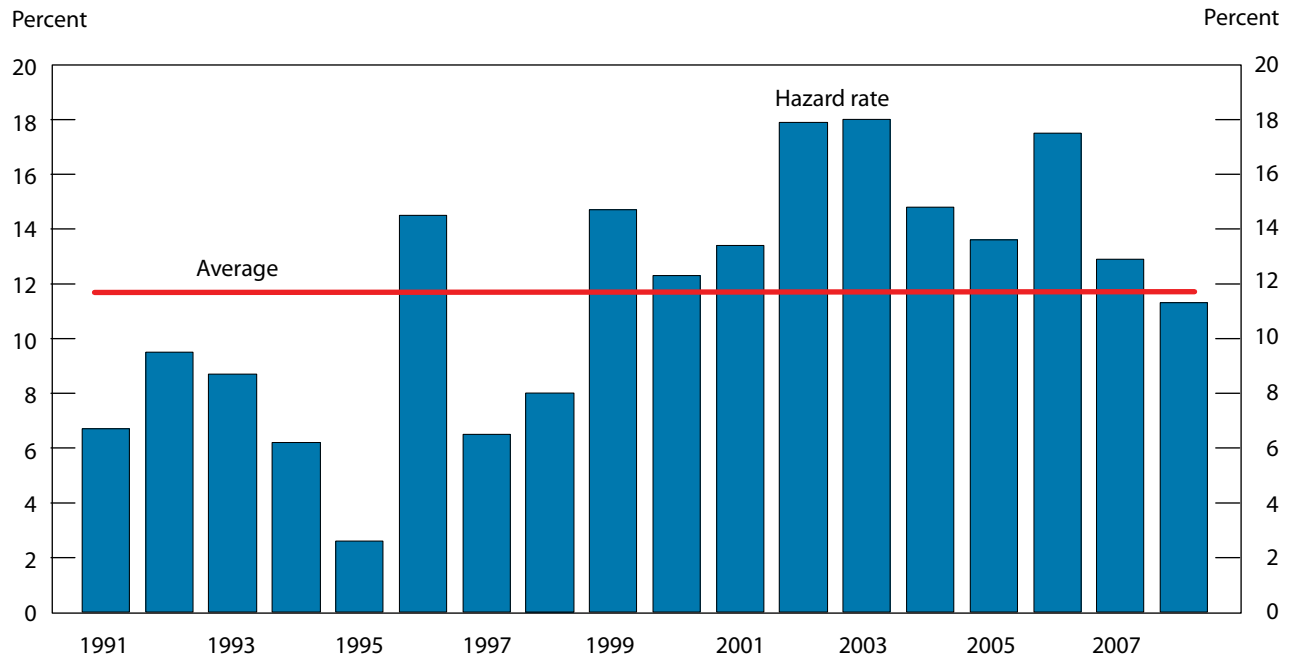
The relative hazard rate, or hazard ratio, of each industry (relative to a baseline industry) is derived with the use of the Cox proportional hazard model,[3] a semiparametric model with hazard function

$$\lambda(t, \boldsymbol{x}) = \lambda_0(t)e^{\boldsymbol{X\beta}},$$

where $\boldsymbol{\beta}$ is a vector of parameters for each industry. This model allows a baseline hazard rate to vary as a function of followup time, but assumes that the hazard rates of different industries are proportional over followup time.

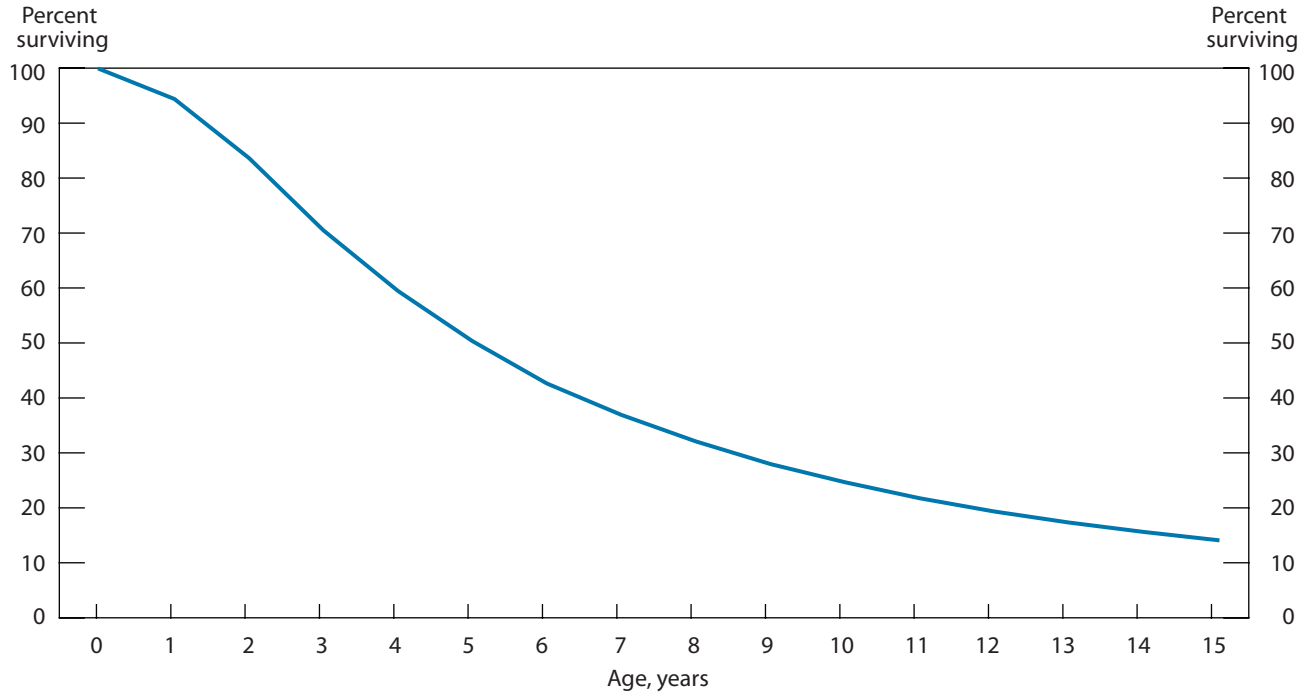
The weighted average (the average, weighted by the number of businesses in each industry) of the hazard ratios is calculated to determine a baseline hazard number.

Chart A–3. Hazard rate of all Silicon Valley high-tech businesses, 1991–2008



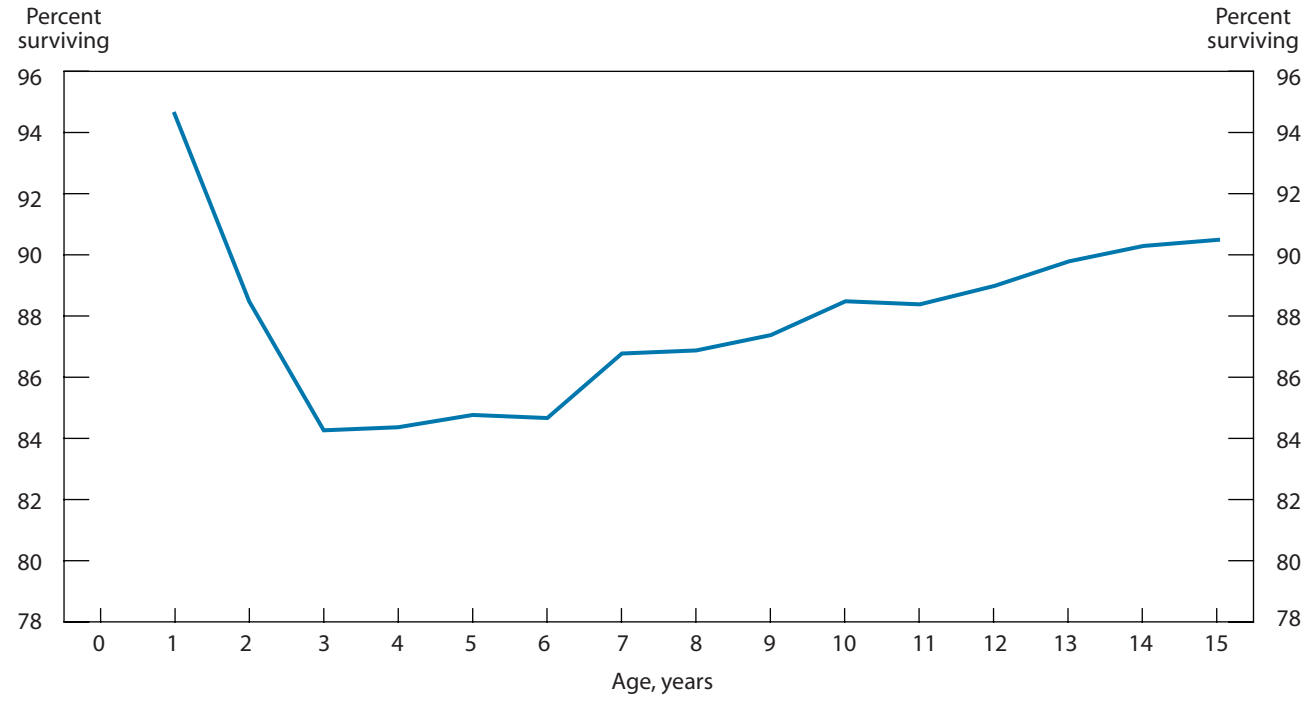
SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

Chart A–1. Cumulative survival rate of Silicon Valley high-tech firms, by age of firm, 1991–2009



SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

Chart A–2. Annual survival rate of Silicon Valley high-tech firms, by age of firm, 1991–2009



SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

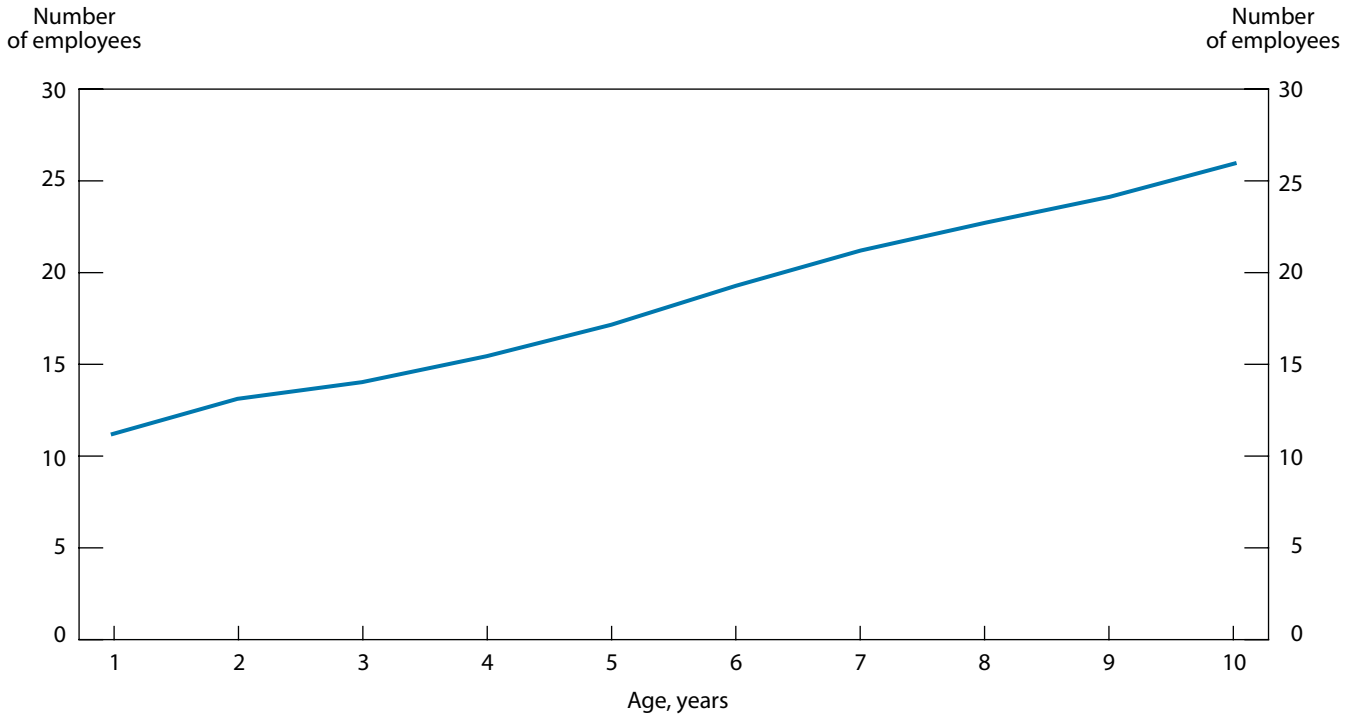
Table A–1. Regression results

Industry	Parameter estimate	Hazard ratio[1]	*p*-value
Aerospace product and parts manufacturing	1.12	3.06	< .0001
Architecture and engineering services	.70	2.01	< .0001
Communications equipment manufacturing	.98	2.66	< .0001
Computer and peripheral equipment manufacturing	1.05	2.87	< .0001
Computer systems design and related services	.99	2.69	< .0001
Electronic instrument manufacturing	.72	2.05	< .0001
Internet, telecommunications, and data processing	1.31	3.69	< .0001
Pharmaceutical and medicine manufacturing	.76	2.13	< .0001
Scientific research and development services	.83	2.30	< .0001
Semiconductor and electronic component manufacturing	.90	2.45	< .0001
Software publishers	1.04	2.83	< .0001

[1] Ratio of hazard rate of industry to that of multiple industries.

SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of

Chart A–4. Average employment of Silicon Valley high-tech firms, by age of firm, 1991–2009



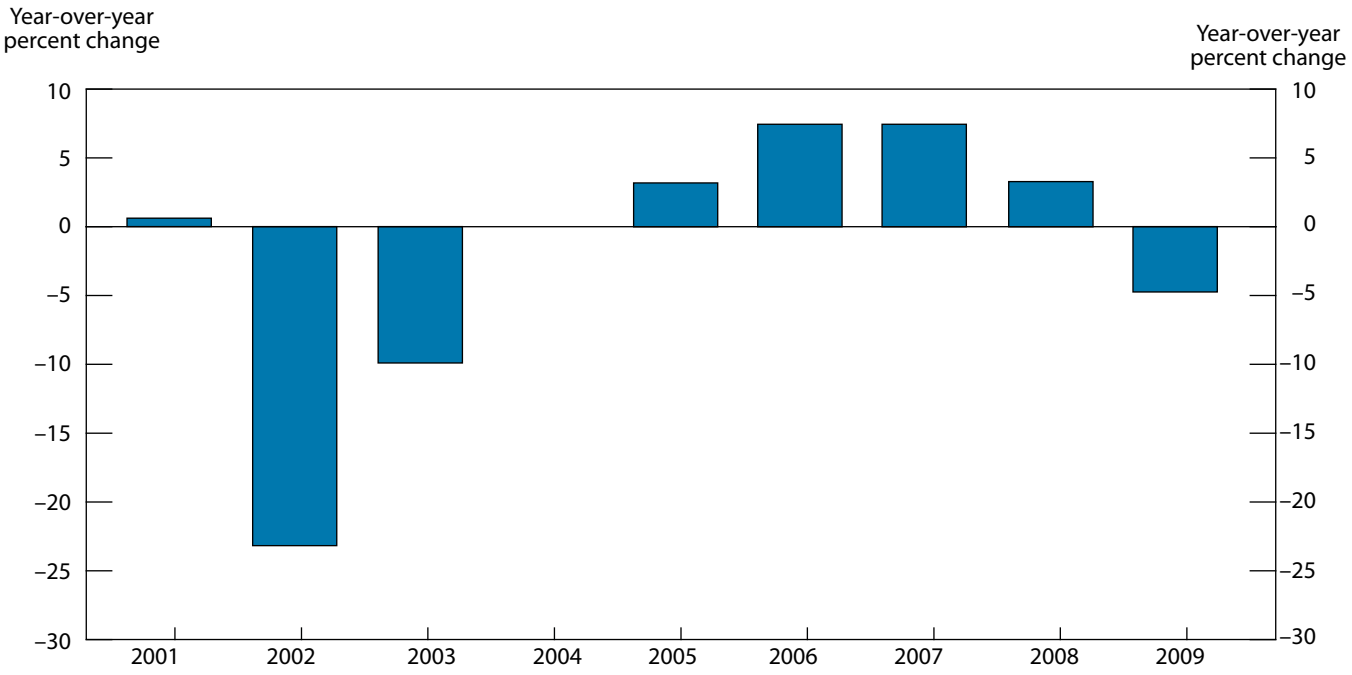
SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

For the 2000 birth cohort, a number is calculated with the weighted average of the birth cohort industry mix. The adjustment factor for the industry mix is determined by the percent difference between the number calculated for a birth cohort and the baseline number. For the 2000 birth cohort, the adjustment factor is 1.068, indicating that we expect the hazard rate for businesses in the cohort to be 6.8 percent higher than that of an average cohort at any given time. The primary contribution to this elevated hazard rate is from the higher levels of Internet, telecommunications, and data-processing businesses among year-2000 startups.

Employment growth

Baseline employment growth. The baseline, or average, employment growth of Silicon Valley's high-tech businesses born between 1991 and 2009 over the life cycle of a busi-

Chart A–5. Percent change in business employment of Silicon Valley high-tech firms, 2001–2009



SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

Table A–2. Annualized employment growth and proportion of employment for Silicon Valley high-tech firms, by Industry, 2000–2009

Industry	Annualized growth	Proportion of employment	
		Average cohort	2000 birth cohort
Aerospace product and parts manufacturing	–7.1	0.1	0.0
Architecture and engineering services	6.1	16.8	11.1
Communications equipment manufacturing	8.7	.8	.5
Computer and peripheral equipment manufacturing	8.0	1.4	.5
Computer systems design and related services	11.1	50.5	46.6
Electronic instrument manufacturing	7.0	1.7	1.2
Internet, telecommunications, and data processing	9.6	12.0	25.7
Pharmaceutical and medicine manufacturing	6.9	.4	.2
Scientific research and development services	7.0	6.4	3.1
Semiconductor and electronic component manufacturing	6.8	3.8	2.8
Software publishers	10.7	3.2	4.5
Businesses operating in multiple industries	9.9	2.8	3.9

SOURCE: U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

ness is calculated as the average employment (of survivors) in each year of the business' operation. High-tech businesses started with an average of 11.3 employees and saw their average employment grow to 25.9 employees, as long as the businesses survived to age 10. (See chart A–4.)

Year-specific effects. The year-specific effects, manifested in the average annual employment change, take into account the macroeconomic impact of the total employment change in each year due to the overall movement of the high-tech labor market. The average annual employment change is calculated as the annual percent change in total Silicon Valley high-tech employment for businesses born since 1991. (See chart A–5.)

Industry-mix effects. Industries such as computer systems design and software publishers tended to have greater employment growth throughout a firm's life, whereas aerospace product and parts manufacturing tended to have business employment declines. The weighted average of each industry's average employment growth is used to determine the average employment growth for the high-tech group. An adjustment factor for the 2000 cohort is calculated as the percent difference between the expected employment growth of a cohort with the industry mix of the 2000 cohort and that of a typical high-tech cohort. For the 2000 cohort, this factor is 3.4 percent per year, indicating that a typical cohort with the same industry mix as that of the 2000 cohort would be expected to have 3.4 percent higher employment growth per year than a cohort with an average high-tech industry mix. Table A–2 shows the annualized business employment growth and the proportion of employment, by industry, for an average high-tech Silicon Valley cohort and the 2000 birth cohort over the 2000–09 period.

Notes to appendix

[1] Edward L. Kaplan and Paul Meier, "Nonparametric Estimation from Incomplete Observations," *Journal of the American Statistical Association*, vol. 53, no. 282, 1958, pp. 457–81.

[2] The hazard rate is the rate at which firms exit the marketplace (that is, die—mathematically, 1 minus the survival rate).

[3] David R. Cox, "Regression Models and Life-Tables," *Journal of the Royal Statistical Society, Series B (Methodological)*, vol. 34, no. 2, 1972, pp. 187–220.