bioentrepreneur

BUILDING A BUSINESS

The biotech living and the walking dead

A detailed look at the economic impact of university-licensed life science startups across the United States reveals vast differences in the effectiveness of different regions to create ventures and sustain them as viable entities.

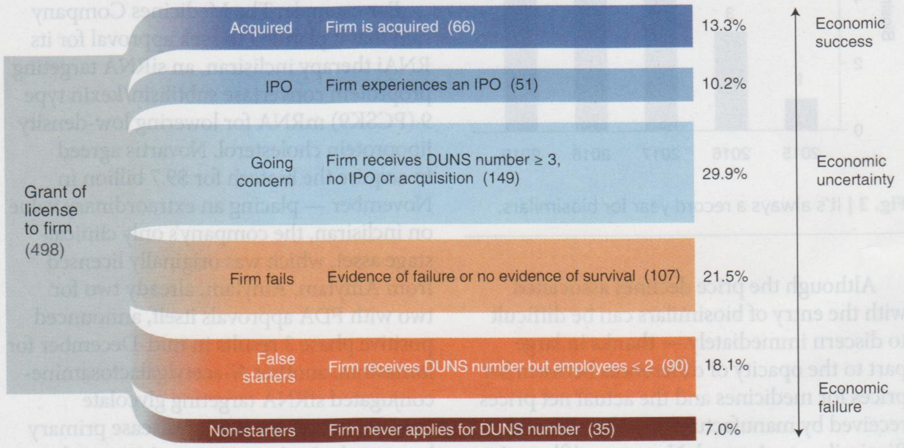

Fig. 1 | Final disposition of ULS startups through 2017. Credit: Libby Thomas

Universities expend substantial money, time and institutional energy on research. For 2016, the US National Science Foundation pegged total university life science research and development spending at $40.9 billion, with ~$22 billion[1] from the federal government, just over $10 billion from local fundraising and the rest from state and municipal governments, private foundations and corporations[2,3]. As part of the effort to both underwrite future research and fulfill the university's community mission of economic development, university technology transfer offices (TTOs) are increasingly seeking to generate revenue for their parent institutions either by licensing their intellectual property to existing companies or through exclusive licenses to locally spun-out startups[4]; indeed, our data reveal a tenfold increase in university licenses to entrepreneurial firms between 1990 and 2005.

The track record of TTOs in translating university intellectual property into products and revenue has been checkered. According to Valdivia et al.[2], as many as 87% of TTOs do not cover even their own operating costs. Many TTOs use company creation or licensing revenues to measure their performance; however, whether a company exits through an initial public offering (IPO) or an acquisition would arguably be a better measure of startup commercialization success. In most cases, the road to those riches for university startups is much longer and more perilous than income streams that follow from licenses to established biotech companies and multinationals. Very often, unless these new firms are located in a life science cluster such as Boston, San Francisco or San Diego[5–7], they lack local access to critical resources necessary for venture success (for example, a pool of entrepreneurs and experienced management, state-of-the-art lab space, access to knowledgeable risk capital, or easy access to service companies and pharmaceutical partners). As a result, some entrepreneurs relocate their operations, running counter to the university's local economic development mission.

Despite sustained growth and interest from both entrepreneurs and university administrators in licensing technology to startups, a clear understanding of the texture of success of these firms remains elusive. It has always been hard to say, beyond anecdotal examples, how well firms from particular institutions do; indeed, stories focus on firms at the tails of the distribution, either sparkling successes of flame-out failures. The lack of comprehensive data on the life histories and dispositions of life science university–licensed startups (here referred to as ULSs) has precluded a robust understanding of successes, failures, economic impact and the role of location in the life of these firms. To overcome that lack of data, we have invested 8 years to compile, to our knowledge, the most accurate census of ULS firms available. Our data allow us to provide answers to the following important questions: what are the outcomes of ULS activity; how many firms succeed, fail or lie somewhere in between; what is the economic impact of these firms, for employees, investors and the economy in general; and what role does geographic location play in these outcomes?

Data and measures

We drew our census from the US National Science Foundation's top 50 patent-producing US universities between 1969 and 2008. Patents from these schools accounted for 69.7% of all university patents over those four decades; by comparison, the next 50 universities on the list generated barely over one-quarter as many patents (18%), and the remaining 472 schools produced the final 12%.

Our present analysis of the data also supports a skewed distribution in terms of life science firms founded at the top 50 universities. The top five universities accounted almost one-third (32%) of the total, and the top ten almost half (49%). The bottom seven universities (only 47 of the top 50 universities produced life science startups in the years we studied) produced only 13 (3%) of the startups. This pattern gives us confidence that we have captured the overwhelming majority of ULS firms in our data.

To identify ULS firms, we relied first on TTO reports, which we verified and supplemented with lists of startups created by University Tech Watch (*The Guide to University Startups*; data available from P.C.G. on request) and a survey of universities conducted jointly by the Association of University Technology Managers (AUTM) and the National Council of Entrepreneurial Tech Transfer (NCET2). We define a ULS as a firm formed to commercialize a life science technology developed at a university. To be included in our ULS sample, the startup had to license at least one technology from the university. We verified the completeness of our sample by contacting university TTOs to verify our list and pick up any missing firms. Although we realize that we likely missed some firms,

Table 1 | Average and maximum time for a ULS firm to reach an exit in different founding-year cohorts (excluding non-starters)

Cohort	False starters		Failed		Going concern		IPO		Acquisition	
	Mean (years)	Maximum (years)	Mean (years)	Maximum (years)	Mean (years)	Maximum (years)	Mean (years)	Maximum (years)	Mean (years)	Maximum (years)
1990–1991	19.00	21.00	17.67	26.00[a]	NA	27.00	5.60	8.00	4.80	9.00
1995–1996	9.80	17.00	10.90	21.00	NA	21.00	8.27	19.00[a]	11.33	18.00
2000–2001	7.80	15.00	9.05	16.00	NA	17.00	8.77	15.00	8.66	16.00[a]
2005–2006	6.03	13.00	6.69	12.00	NA	12.00	8.12	11.00	6.70	12.00[a]
2010–2011	4.83	8.00	4.74	7.00[a]	NA	7.00	4.00	4.00	3.40	6.00

[a]Companies in cohort reached exit within the entire time period of study (up to 2017).

our efforts created, to our knowledge, the most comprehensive census of firms founded by these schools — successes and failures — for the years 1980–2013.

Once we had our list of startups, we then set about ascertaining the 'life history' of these firms: whether they were still going, had ceased operations or had exited through a 'liquidity event' (acquisition or IPO). We tracked firms through 2017. To determine which firms were still active and when inactive firms ceased operations, we matched our list of ULS firms with the National Establishment Time-Series (NETS) database (a derivative of the large dataset using Dun and Bradstreet's Data Universal Numbering System (DUNS number) that acts as a unique identifier for firms and is required by many government agencies to receive grants or serve as an approved vendor). For firms not listed as active, we hand-searched state corporate dissolution databases and press releases to verify the year when a firm ceased operations. If we lacked hard evidence of failure, we searched the internet for evidence of activity (i.e., a company website, LinkedIn profile or media mentions for indications of business activity). Absent any clear evidence of continued operations, we presumed these firms were inactive. We consulted the Pitchbook database, and supplemented our search through press releases, to determine which firms had experienced an IPO or had been acquired.

Measuring the economic impact of ULS firms proved challenging, and so we focused our efforts on understanding the employment impact of ULS activity. The NETS data provided yearly employment numbers through 2016. We consulted other sources (LinkedIn, press releases and company websites) to fill in any missing data, where possible. Using these data, we estimated the economic impact of life science ULS firms in terms of employment, wages and federal income taxes. To determine direct wages, we searched LinkedIn for the self-identified job titles for each employee for all life science ULS firms founded in 2005 and 2006. This time slice allowed us to observe employment when these firms had been active for a decade or more and reached a mature level of employment. We then reconciled self-reported job titles with the closest matching job title in the US Bureau of Labor Statistics 'Employment and Wages Occupational Employment Statistics Survey' for 2015. This reconciliation allowed us to estimate the average annual salary for each position, from which we created a weighted average wage across the sample. We corroborated data from the Bureau of Labor Statistics dataset with available salary data from Glassdoor and other sources.

Venture capital (VC) databases Pitchbook and Venture Expert provided data on VC amount invested in each firm in each round, and the total funding over all rounds. For firms experiencing an IPO, we captured the firm's market value (share price multiplied by number of shares outstanding) at the end of the first day of trading. Data on acquisition prices came from press releases, business press articles or the Pitchbook database. We measured returns to investors by subtracting the amount of VC invested from the positive returns from these liquidity events.

To ascertain the role of geographic location in success or failure of the firms in our census, we relied on location data in the NETS data. NETS listed the primary address of each firm for each year. By comparing these address data with the location of the university granting the license, we determined which firms remained local, which ones moved to an economic cluster (which we defined as Boston, San Diego, or San Francisco), and which ones moved to other locations.

Our methodology

Our complete data set contains observations from 1980 to 2013 and holds data on all startup firms across a range of economic sectors. For this study, we examined ULS firms producing products and/or services in biopharma, medical devices or traditional pharma. We note that ULS firms may sell their products to different customer segments, and their choice of customer is likely to drive their strategy for overall growth, the acquisition of venture capital and the final disposition of the firm. For example, some firms develop products or services for very large customer segments, such as a new skin care product. Other firms may provide products or services to a much smaller segment, such as the academic and scientific research community. These firms may choose to eschew rapid growth or scale and never experience an IPO or acquisition; however, they may become valuable producers of jobs and revenue in their local communities.

We created a sample of ULS firms founded in five two-year slices: 1990–1991, 1995–1996, 2000–2001, 2005–2006 and 2010–2011. We took our first slice in 1990, a decade after passage of the Bayh-Dole Act of 1980. By 1990, the number of firms born out of technology licenses was sufficient to observe more than anecdotal patterns. Our slices span different economic climates, from benign (1995–1996 and 2005–2006), high growth (2000–2001) to recessionary (1990–1991 and 2010–2011). Our method allowed us mark emerging trends, identify discrete, discontinuous movements between time slices and incorporate larger macro-economic effects on ULS activity.

We begin with a report of the disposition, as of 2017, of each firm in our sample. We place a firm in one of six dispositional categories (Fig. 1).

1. Non-starters. A technology license to a ULS firm, but the firm created no DUNS number (it never needed business credit) or had no evidence of any business activity, such as employees or reported transactions.

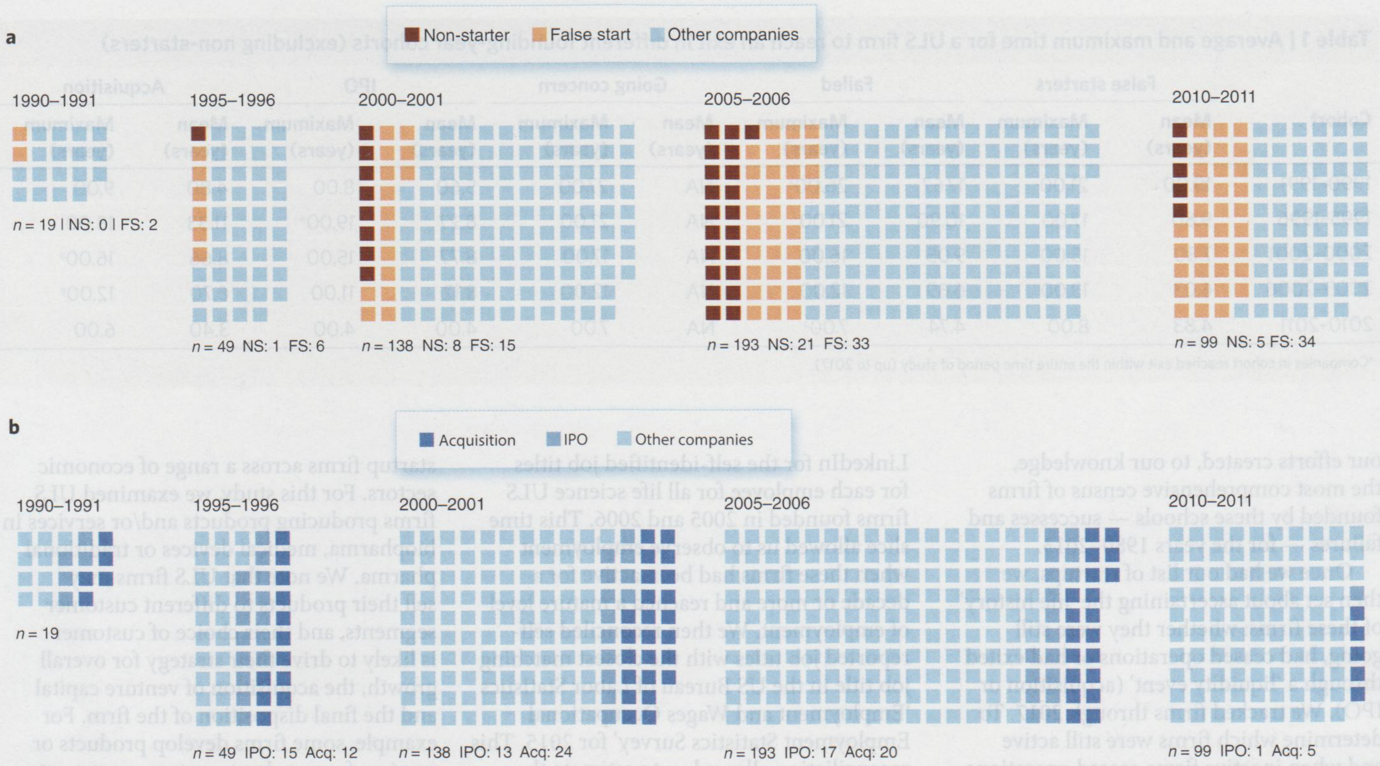

Fig. 2 | Final disposition of selected ULS firms, by cohort. a, Non-starter (NS) and false-start (FS) firms, by cohort. **b**, Growth of non- and false start firms, by cohort. Acq, acquisition. Credit: Libby Thomas

2. False starters. Evidence of business activity, primarily a DUNS number and employees, but the firm never listed more than two employees. One of these was often the scientific founder and the other the CEO. With two or fewer employees, these firms lacked the human capital needed to develop the technology and build a meaningful business.

3. Failed firms. Evidence of activity, three or more employees at one time, and evidence of demise, either hard (bankruptcy or dissolution of corporate entity) or soft (no website, no press clippings or no current employees on LinkedIn or other sources).

4. Going concerns. Evidence of activity, three or more employees, evidence of ongoing operations (current employees, or website or press announcements).

5. Acquisitions. Evidence that the ULS was acquired by another entity.

6. IPOs. Evidence that a ULS firm completed an initial stock offering and became a publicly traded company.

In Fig. 1, we provide a breakdown of the category dispositions of these firms as of 2017, and in Table 1 show the longevity of these firms. This life history analysis is the foundation for the findings we report below.

Finding 1: rise of the walking dead and gaming of the system

Sociologists John Meyer and Brian Rowan[8] argued that when organizations experience a new demand from external stakeholders, leaders engage in symbolic actions that provide the illusion of compliance but lack any substantive commitment to meet these demands. We found evidence of such symbolic activity by universities and their TTOs over the course of our five time snapshots. In Fig. 2 we illustrate the growth of firms that failed to gain traction, non-starters or false starters. The large jump in the number of these firms in 2005–2006 represents a significant difference in the formation of these firms from previous time periods. The number of these firms continued to climb in 2010–2011, when almost two of five ULS firms failed to gain traction. Results of χ^2 tests for the prevalence of these firms across the cohorts revealed the rise of these symbolic firms as a significant phenomenon (Table 2).

Although the number of non-starter firms, clearly never born, increased slightly, in Fig. 2a we highlight the growth of false starters, which we refer to as the 'walking dead,' or startups that became real but never grew and, importantly, remained in the landscape for long periods of time. The oldest of the walking dead, founded in 1991, remained 'active' for 21 years (Table 1), without any significant contribution to employment, patents or commercial products. It may be the case that over time, the number of walking dead can be traced to incompetent licensees; however, Meyer and Rowan[8] suggest a story with university administrators at the center. The walking dead represent symbolic action by universities, a transfer that made the TTO and others look good in the short term, the time horizon of annual budget fights and resource allocation decisions. Over the long term, however, no real business or economic development occurred. We saw the significant rise in the number of these firms as driven by university administrators attempting to game the system, to claim, but not create, economic development.

To illustrate our assertion in more detail, the travails of the University of Utah are instructive. Administrators at the university probably jumped for joy in February of 2010, when a local newspaper, *The Deseret News*, ran the following headline: "University of Utah, MIT lead nation in new companies founded"[9]. The newspaper article reported that for 2008, Utah's TTO formed 20 new startups, the same number as national powerhouse Massachusetts Institute of Technology. Those same officials likely ran for cover when a competing local newspaper, *The Salt Lake Tribune*, ran the following headline a year later: "Fits and startups: Is U. tech transfer flawed?"[10]. This article went on to explain that of the 20 startups listed in 2008, most listed the university's TTO office as the corporate headquarters and the director of the TTO as the registered agent or a corporate officer. Data from a larger sample we collected for another project indicates that over one-half of these firms would be classified as walking dead.

The larger take-home message, though, is that our findings suggest that the University of Utah was by no means the only rogue gamer; the behavior seems to have been replicated across the country by other schools. Creating formal companies with no employees or business expertise exemplifies Meyer and Rowan's idea of symbolic action: a university gets the short-term benefit of transferring technology and the credit for economic development. Over the long term, however, these zombies contribute little to either technology or economic development.

Table 2 | Differences in prevalence of non-start and false-start firms (χ^2 statistics), by cohort

	1990–1991	1995–1996	2000–2001	2005–2006
1995–1996	0.169			
2000–2001	0.470	0.152		
2005–2006	2.711*	3.887**	5.769**	
2010–2011	5.859**	9.646**	15.414****	3.928**

χ^2 statistics: *P < 0.10; **P < 0.05, ***P < 0.01, ****P < 0.01.

Table 3 | Highest degree earned by employees

Degree	ULS startup	Worldwide	United States	Dow 30 companies
JD	1.59%	0.24%	0.81%	0.55%
PharmD	0.97%	0.03%	0.09%	0.21%
MD	2.79%	0.23%	0.44%	0.27%
PhD	12.61%	0.75%	1.09%	2.25%
MBA	6.56%	1.32%	1.89%	7.62%
Master	12.92%	5.95%	5.69%	15.76%
Bachelor	31.35%	9.32%	15.35%	28.60%
Associate	1.32%	0.95%	2.55%	2.55%
None	29.88%	81.22%	72.10%	42.20%
Total	100%	100%	100%	100%

Finding 2: economic impact is driven by liquidity events

We found evidence of positive economic impact by ULS firms; however, inherent limitations in our data constrain our ability to comprehensively address this issue. A robust economic impact analysis would begin with overall ULS spending for goods and services in the economy, combined with direct wages, to derive the total direct and indirect impact of these firms on spending, job creation and tax revenues. Just under 90% (89.76%) of the ULS firms in our sample never operated as public companies and did not report revenues, expenses, direct labor costs or direct taxes paid; hence, a full economic impact analysis exceeds our grasp.

Our data provide us with the number of employees for each year of a firm's existence as an independent company. Once a firm was acquired, we could no longer track its employment numbers. As a result, we believe that the total employment numbers for acquired firms is much higher than we report; employees remain but they now work for a new owner. Thus, our wage and tax figures underestimate the likely impact of ULS firms.

As we described above, we estimated the average wage (scaled to 2016 dollars) for the ULS firms in our sample. Our estimate of $125,600 mirrors an estimate by the Pharmaceutical Research Manufacturers Association of $123,107 in 2014 dollars[11]. Our data show that ULS firms pay workers, on average, 2.5 times the economy-wide annual wage of $48,642 (ref. [12]). ULS firms thus create well-paying jobs. In the course of estimating the average wage, we captured the self-reported level of educational attainment for the same group of employees described above. Data in Table 3 provide evidence that ULS firms provide jobs for individuals with bachelors and advanced degrees. ULS firms employ double the percentage of bachelor's and master's degree holders than the US economy at large, six times the percentage of MDs, ten times the number of PharmDs and 11.5 times the number of PhDs.

In Fig. 3, we show the pattern of IPO and acquisition over time, and in Fig. 4 the average employment data, from the year of founding to 2017, for each cohort; firms founded in the early cohorts have larger averages because they are older and have had longer to grow. In Table 4 we present data on the total employment of ULS firms by category and cohort year, and then multiply total employment by our average wage in Table 5 to estimate the total economic impact of direct wages, in 2016 dollars. Our slice of ULS firms combines to produce almost $13.8 billion in total wages over the years. If we use a standard tax rate for this level of income of 20%, then the employees of the 498 ULS firms paid $2.76 billion in federal income taxes. IPO firms drive employment, while they constitute just 13.25% of the total sample, they account for 68% of total employment.

Employment and wages represent one economic impact, and returns to investors another. In Tables 5 and 6, we show the distribution of VC across categories and cohorts. These tables provide further evidence of our first finding about the nature and role of walking-dead firms: they represented 8.5% of firms receiving VC, but their total take was only 0.6%: many firms but little impact and little engagement with risk capital. In contrast, firms experiencing an IPO constituted 17% of firms that received VC, but 44% of total VC dollars invested, and they created two of every three jobs in the sample. To some extent, this result is expected as firms pursuing an IPO will naturally participate in more rounds of funding and hire more people. Accounting for that natural tendency, however, we still see an efficient market for VC funding, where funds flow to firms with the greatest likelihood of positive returns, going concerns that will experience an IPO.

VC returns on invested capital are not always large (Tables 7 and 8). Firms pursuing an IPO consume copious amounts

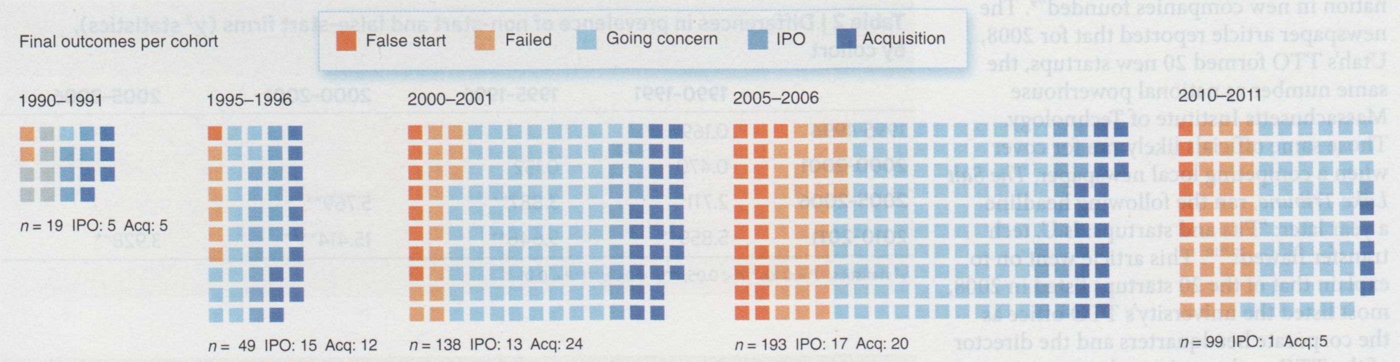

Fig. 3 | IPOs and acquisitions, by cohort. Credit: Libby Thomas

of venture funding, but the liquidity event does not — on average or even in the majority of cases — generate a positive return for investors. The total amount raised in IPOs falls short of VC invested by $2.57 billion, a per-firm shortfall of $42 million. As we examined these firms more closely, it confirms that an IPO is often merely another round of funding, one that places tradeable equity on the balance sheet, which opens a pathway to debt financing. Indeed, public record data for 41 of the IPO firms in our analysis show that only 12 firms turned a profit at any time, and those firms averaged only 2.3 profitable years — a point that has been made before[13]. Acquisitions, in contrast, produce a profit for investors, as proceeds for acquisitions with a known price (60% of the total) provided investors with an average return of $76.6 million. The take-home message is acquisitions pay off for investors much more frequently than IPOs.

Finding 3: the role of geography and the power of clusters

Our data allowed us to address questions not only about what happened to each firm but also where those outcomes occurred; we can trace a firm from the cradle (the location of the university granting the license) to the grave (where the firm ceased operations). Our data provide a window into the role of location in ULS success and failure, specifically the role of economic clusters, dense agglomerations of startups, specialized equipment, VC firms, and the supporting ecosystem of qualified employees and specialized accounting and law firms in startup success and failure rates[14–18].

Firms trace their heritage to a university located in a cluster or one located outside. Each firm has three location options: remain where founded, move to a cluster or move elsewhere. We categorized the migration patterns of firms as follows with the following descriptors.

1. Founded in cluster and stayed local (FCSL): a firm licensing technology from a university located in a cluster that remains within that cluster.
2. Founded in cluster and moved different cluster (FCMDC): a firm licensing technology from a university located in a cluster that migrates to a different life science cluster.
3. Founded in cluster and moved non-cluster (FCMN): a firm licensing technology from a university located in a cluster that migrates outside of any life science cluster.
4. Founded in non-cluster and stayed local (FNSL): a firm licensing technology from a university not located in a life science cluster that remains local to that university where the technology originated.
5. Founded in non-cluster and moved to cluster (FNMC): a firm licensing technology from a university not located in a cluster that migrates to a life science cluster.
6. Founded non-cluster and moved non-cluster (FNMN): a firm licensing technology from a university not located in a cluster that migrates elsewhere outside the cluster.

Across the five time slices we studied, 116 firms (23%) licensed technology from one of the six universities located in the three major life science clusters: Boston

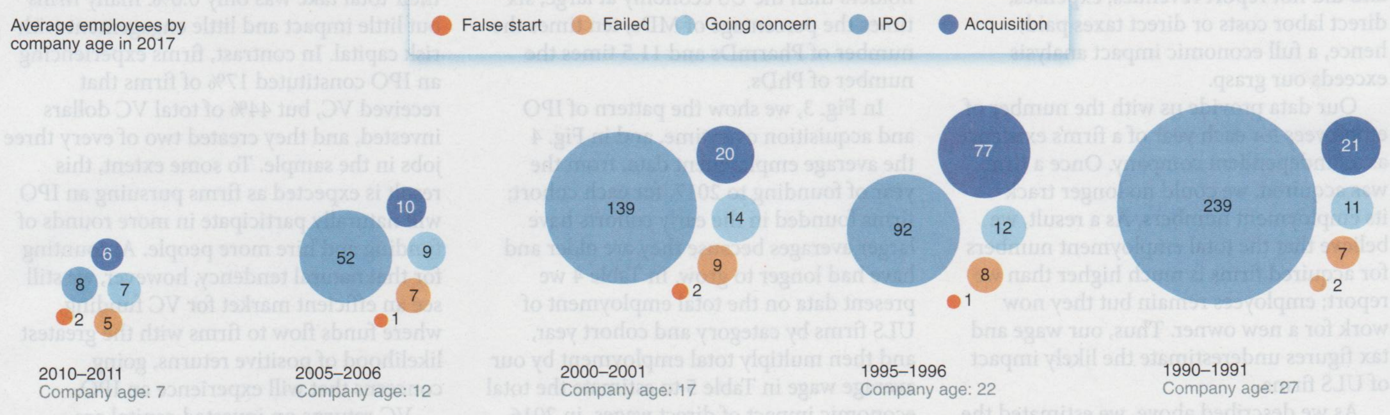

Fig. 4 | Average number of employees, by category and cohort. When a firm was acquired, it ceased to report data, so we could not collect data about employment growth in the former ULS firms, likely making these results an underestimate. Acq, acquisition. Credit: Libby Thomas

(Harvard University, MIT), San Diego (University of California (UC) San Diego), the San Francisco Bay area (UC Berkeley, Stanford University, UC San Francisco). The remaining 382 startups (77%) licensed technology from universities outside these clusters. Of the 498 firms, 340 (68%) stayed local, within 60 miles of the founding university, whereas 158 migrated.

The advantages of locating in an economic cluster come, in large measure, from the close physical proximity of firms and others in the ecosystem to each other. This proximity facilitates deep and rich human interactions that help solve technical problems and strengthen commercial activities[17]. We used a 60-mile radius based on research in the finance literature, which showed that when a stock analyst covered firms within 60 miles of their office, the quality of the analysis and resulting earnings estimates improved by a significant amount[19]. The improvement most likely comes from the ability of the analyst to engage in the same types of rich interactions that underlie cluster success.

In Fig. 5 we illustrate the dynamics of migration and the resultant effect on final firm dispositions. In Table 9 we display detailed data on location and outcomes, and in Table 10 provide summary statistical, χ^2, tests that allow us to identify significant differences between migration behaviors and success.

Our data show a clear and significant positive effect for firms locating in a life science cluster. Firms located in clusters experienced success twice as often ($\chi^2 = 18.682$, $P < 0.0001$), and failed half as often ($\chi^2 = 9.886$, $P < 0.005$) as firms located elsewhere. These aggregate findings evidence the power of clusters to improve outcomes for ULS firms. A measure of the impact of a cluster location, Cohen's d, indicates that cluster membership makes a large difference ($d = 2.985$, large effect). That is good news for clusters but bad for non-cluster communities; however, when we dive deeper into the outcomes recorded in Tables 9 and 10, we find a more nuanced story that bears better news for non-cluster communities.

The association between positive firm outcomes (both success in terms of liquidity events but also reduced failure rates) provides prima facie support for the core logic of the rich academic literature on clusters. Regardless of where they are founded, startups begin life with relatively similar endowments (of financial, human, institutional social and technological capital), and it is the access to subsequent resources that determines eventual success[14]. Cluster firms enjoy clear advantages in that regard as they have convenient and sustained access to demanding customers, high-caliber potential employees, savvy investors, adroit suppliers and the knowledge spillovers that are byproducts of concentrated economic activity. Cluster membership presents a powerful 'treatment effect' that leads to higher success rates.

If this treatment effect hypothesis explains success, we would predict two other results.

First, startups founded outside a cluster that relocated to a cluster (FNMC companies) should perform as well as startups founded in a cluster (FCSL). This prediction holds (43% success for FNMC firms compared with 30% success for FCSL firms is not statistically significant, $\chi^2 = 1.963$); but FCMDC companies significantly outperform FCSL firms (60% versus 30%, $\chi^2 = 20.155$, $P < 0.00001$; Table 10). The treatment effect explanation does not account for this result; if all firms in the cluster have access to the same accelerants, then move-ins should do as well, but no better, than locals. This suggests that firms moving from cluster to cluster may be better able to access the relevant resources of a particular cluster than cluster locals. Migrants may be simply better firms, ones with the resources they need to succeed regardless of location.

Second, the 'treatment-effect' narrative predicts that FCMN companies should do worse than FCSL companies, as emigrants trade the advantages of a dense agglomeration of valuable resources for more dispersed resources elsewhere. Again, migration patterns do not support this prediction: FCMN companies

Table 4 | Total employee years in ULS firms by category in indicated founding-year cohorts (excluding non-starters)

Cohort	False-starter	Failed	Going concern	IPO	Acquired	Total
1990-1991	33	276	1,076	25,978	493	27,856
1995-1996	39	651	1,168	15,213	6,966	24,037
2000-2001	184	2,996	7,789	24,354	3,435	38,758
2005-2006	257	1,794	5,069	9,337	1,337	17,794
2010-2011	252	407	1,399	56	96	2,210
Total	765	6,124	16,501	74,938	12,327	110,655

Employee years are the summed number of employees for each year, over the reported life of the company.

Table 5 | Number of ULS firms receiving VC by category in indicated founding-year cohorts (excluding non-starters)

Cohort	False-starter	Failed	Going concern	IPO	Acquired	Total
1990-1991	1	0	2	3	0	6
1995-1996	0	3	3	12	9	27
2000-2001	0	8	22	12	16	58
2005-2006	7	27	43	16	15	108
2010-2011	13	9	23	1	3	49
Total	21	47	93	44	43	248

Table 6 | ULS firms receiving VC funding amounts by category in indicated founding-year cohorts (values in $ millions)

Cohort	False-starter	Failed	Going concern	IPO	Acquired	Total
1990-1991	3	0	29	265	0	297
1995-1996	0	178	127	1,143	378	1,825
2000-2001	0	390	717	1,752	906	3,764
2005-2006	30	542	1,434	1,299	404	3,709
2010-2011	27	54	451	8	18	558
Total	60	1,163	2,758	4,467	1,706	10,154

Table 7 | Risk capital investor returns from ULS firm acquisitions (financial figures in millions)

VC investment		Acquisition pricing		VC return from acquisition	
Number of acquisitions	66	Number of acquisitions	66	Number of acquisitions	66
Number of acquisitions with VC	45	Number with disclosed pricing	37	Number with disclosed pricing	37
Total VC invested	$1,705.00	Percentage with disclosed pricing	56%	Percentage with disclosed pricing	56%
Average VC invested	$37.89	Average time to acquisition (years)	7.96	Total acquisition profit	$2,835.13
Standard deviation VC invested	$50.84	Total amount raised from acquisition	$4,540.13	Average acquisition profit	$76.63
Maximum amount VC invested	$216.30	Average acquisition amount	$122.71	Number of profitable acquisitions	33
Minimum amount VC invested	$0.30	Standard deviation of acquisition amount	$152.75	Number of unprofitable acquisitions	4
		Maximum price of acquisition	$567.00		
		Minimum price of acquisition	$1.00		

Table 8 | Risk-capital investor returns from ULS firm IPOs (financial figures in millions)

VC investment		IPO liquidity		VC return from IPO	
Number of firms with IPOs	51	Number of IPOs	51	Number of IPOs	51
Number of IPOs with VC investment	44	Number of IPOs with available data	45	Number of IPOs with available data	45
Percentage of firms with VC investment	86	Percentage of IPOs with data	88	Percentage of IPOs with data	88
Total VC invested	$4,467.0	Total IPO funding raised	$2,568.8	Total surplus (loss) VC investment	($1,898.2)
Average VC invested	$101.5	Average IPO amount	$57.1	Average surplus (loss) VC investment	($42.2)
Standard deviation VC invested	$80.61	Standard deviation of IPO amount	$39.06	Standard deviation of surplus (loss) VC investment	($70.22)
Maximum amount VC invested	$395.6	Maximum IPO amount	$200	Maximum surplus VC investment	$69.3
Minimum amount VC invested	$0	Minimum IPO amount	$2.7	Minimum surplus (loss) VC investment	($392.6)

succeeded more often than FCSL (41% versus 30%). That said, the χ^2 test revealed this difference is not significant ($\chi^2 = 0.615$). Both results differ from the theoretical prediction of statistically discernable worse performance.

An opposite explanation, the antithesis of the treatment effect, proffers that firms located in clusters succeed because of a 'selection effect.' Under this view, if ULS firms in a cluster differ in terms of whether they were founded in a cluster or non-cluster (FCSL or FNMC firms), then those firms with superior resource endowments seek to leverage the cluster's rich resources. In the case of a treatment effect, cluster-based universities generate better technology because of their proximity to the intense commercial and innovative activity in the cluster. In the case of the selection effect, the leaders of FNMC firms make better predictions about which technologies will achieve commercial success or they have a better understanding of the risk-reward tradeoffs that accompany moving to a cluster. Under the selection effect view, it is not that being in a cluster caused the startups' success, but rather that better firms were more likely to locate in a cluster, and these firms were more likely to succeed wherever they located.

The selection effect forecasts that, in general, cluster-based firms (FCSL, FCMDC or FNMC firms) will outperform non-cluster firms (FNSL, FNMN or FCMN firms), which our high-level results confirm. FNMC and FCMDC firms should do no worse but may do better — if they have some type of superior endowment — than FCSL companies.

So far, so good, but the selection story does not explain the following result: FCMN companies do as well, statistically, as FCMDC (41% versus 60%, $\chi^2 = 1.129$, not significant; Table 10). If the selection logic prevails, then FCMDC companies moved because they had superior initial resources and wanted the additional benefits of a cluster location. Do FCMN firms have superior endowments as well? If so, why did they move at all, and if they moved, why not to another cluster? Why forego the dense agglomeration of resources a cluster provides? This conundrum suggests a third alternative, a synthesis of treatment and selection, we refer to as 'assortative matching', or that success follows migration to best fit.

Assortative matching models the link between firm success and location as analogous to connecting jigsaw puzzle pieces with 'tabs' and 'blanks' (for actual descriptors of a jigsaw puzzle piece, see https://english.stackexchange.com/questions/47667/what-do-you-call-the-interconnecting-bits-of-a-puzzle-piece-in-english; accessed 19 July 2019). When the blanks of a location's resources match with the tabs in a firm's resource profile, the 'fit' is strong and the likelihood of success improves. A new location's assets extend strengths and mitigate weaknesses of the FCMN or FNMN firm. Local firms must rely on whatever resource blanks the founding location offers, which may or may not provide the best fit. FCMDC firms, in contrast, improve the odds of best fit as they actively seek locations with resources that match their particular needs. That search and resultant matches increase the likelihood of success. Assortative matching suggests that, at the highest level, ULS firms that move will outperform those that say local. The results in Table 9 sustain this prediction, as movers succeed significantly more often than locals (34% versus 19%, χ^2 for success = 14.695, $P < 0.0005$). Cohen's d suggests that moving has a large impact on success ($d = 2.661$, large effect).

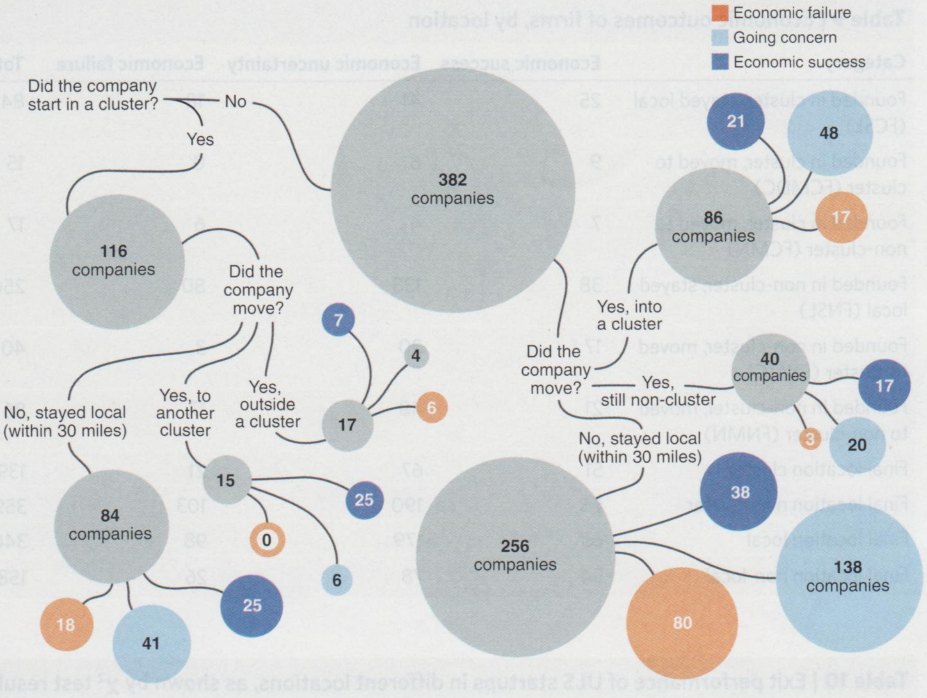

Fig. 5 | Founding, migration and final disposition, by category. Credit: Libby Thomas

The assortative matching story suggests that firms succeed because they have the right resource match, which may entail staying local or moving. The worst performers, under the assortative matching story, should be FNSL companies; these firms have to make the best of what they got at birth, and live or die with the level of fit available to them. Data in Table 9 reveal that, at 15%, FNSL companies had the worst success rate. The improving success rates of types of company, from FCMN firms up to FCMDC firms, come from the ability of management teams to identify where critical resources reside and migrate to them.

In summary, the treatment effect explains some of our results, as does the selection effect. But the assortative matching story fits all our results.

Implications for policy

Our data allow us to move beyond anecdotal stories of success and failure in the ULS startup ecosystem. Some of what we found confirms suspicions and widely held informal beliefs, such as the growing prevalence of zombie firms, the ability of ULS firms to generate well-paying jobs and positive economic contributions to their communities, and the apparent role of life science clusters in abetting firm success. Our findings also confirm that acquisitions trump IPOs as vehicles for investor returns. Finally, the data support the counterintuitive finding that right location matters more than locating to a cluster. Below, we consider the implications of our findings for entrepreneurs, faculty inventors, leaders of TTOs, university administrators, public policy makers, and anyone else hoping to foster economic development.

Solve the walking dead problem. Management scholar Steve Kerr[20] wrote almost a half-century ago about the folly of rewarding 'A' while hoping for 'B'. Our data, combined with anecdotal accounts, such as the University of Utah example, suggest that universities, legislators and economic development officials all hope for technology transfer that creates economic development (B), but they reward startup formation (A). Aligning rewards with desired outcomes should reduce the walking dead infestation. Most university systems, public or private, offer neither incentive-based or deferred compensation for TTO managers or other relevant administrators; thus, income perks that incentivize long-term commitments probably are not possible. Former Supreme Court Justice Louis Brandies provides another potent, and far more possible, carrot in his statement that "sunlight is said to be the best of disinfectants; electric light the most efficient policeman."[21]. Sunlight comes through reporting.

University TTOs should no longer only report the number of licensing agreements consummated, or the number of startups created, in a single year, but a broader set of data over longer time horizons. A focus on economic impact data, such as number of employees, total wages, other expenditures, VC raised and any liquidity events does two things: first, it readily exposes the walking dead; second, these impacts capture substantive, not merely symbolic, contributions to economic development. Longer time horizons show economic impacts in time, for each period, and over time as well. Our categories may provide a helpful starting point for reporting, but the spirit of the implication is that TTOs better fill their economic development mission when they report longer-term economic impact, rather than short term metrics like startup creation, for what gets measured and reported gets done.

Acquisitions and IPOs play different roles. IPOs generate positive returns for employees, tax authorities and communities, but by and large negative returns for risk capital investors in ULS firms[13]. Acquisitions represent the flip side for investors, and although the overall community impact appears positive, our inability to track post-acquisition outcomes precludes a definitive answer here. Research into the technology transfer process shows that how TTOs configure their own resources — financial, human, and institutional resources — influences the success rate of IPOs[22]. University administrators may face

Table 9 | Economic outcomes of firms, by location

Category	Economic success	Economic uncertainty	Economic failure	Total	Success (%)	Uncertain (%)	Fail (%)
Founded in cluster, stayed local (FCSL)	25	41	18	84	30	49	21
Founded in cluster, moved to cluster (FCMDC)	9	6	0	15	60	40	0
Founded in cluster, moved to non-cluster (FCMN)	7	4	6	17	41	24	35
Founded in non-cluster, stayed local (FNSL)	38	138	80	256	15	54	31
Founded in non-cluster, moved to cluster (FNMC)	17	20	3	40	43	50	8
Founded in non-cluster, moved to non-cluster (FNMN)	21	48	17	86	24	56	20
Final location cluster	51	67	21	139	37	48	15
Final location non-cluster	66	190	103	359	18	53	29
Final location local	63	179	98	340	19	53	29
Final location non-local	54	78	26	158	34	49	16

Table 10 | Exit performance of ULS startups in different locations, as shown by χ^2 test results

	Founded in non-cluster, stayed local (FNSL)	Founded in non-cluster, moved to cluster (FNMC)	Founded in non-cluster, moved to non-cluster (FNMN)
Founded in cluster, stayed local (FCSL)	9.324**	1.963	0.615
Founded in cluster, moved to different cluster (FCMC)	20.155**	1.340	7.744**
Founded in cluster, moved to non-cluster (FCMN)	8.030**	0.009	2.014

*P < 0.10; **P < 0.01.

a hard choice between the dual goals of technology transfer: emphasizing economic development and investment income. Trying to maximize both goals may yield mediocre performance.

The general understanding for most investors, university administrators and the general public is that an IPO represents a 'success' for a startup. Our data support this claim, in terms of employment and wages, but not in terms of investor returns. If universities want to maximize their economic investments in ULS firms — in terms of both licensing revenue and the appreciation of their equity stake — then they should set up ULS ecosystems that encourage acquisition. This likely necessitates a change of focus for two critical ULS inputs: executive talent and venture funding. Managing a venture for acquisition versus IPO entails a different set of activities (for example, technology development and expansion rather than sales and market share growth), which invites a different skill set among venture managers and outlook among investors. We cannot tell administrators which outcome to emphasize; we can say, however, that the choice matters as each path leads to different outcomes.

Leverage location. ULS success improves when management teams have the freedom and flexibility to co-locate next to critical resources, wherever they may be. In that vein, university, local or state policies that impair movement, such as claw-back provisions, represent poor policy choices. In fact, any subsidies that create incentives to keep firms local likely limit benefits to the firm, the community or the university over the long term. Economic development occurs when firms get started and fail (these firms release patents, talented employees and dedicated equipment back into the ecosystem to fuel new ventures), get started and keep going or get started and succeed. To the extent that a firm finds the best location, the likelihood of sustained success improves. We believe that universities are better off creating economic development somewhere than creating local walking dead firms.

Economic development happens most often, and probably best, when assortative matching occurs. Our data and findings argue that firms succeed when they locate close to the resources they need, not necessarily near the founding university or — and this is a striking insight — in a major life science cluster. This reveals two poor community-level strategies: investing nothing in ecosystem development or attempting to compete with Boston's Route 128 or San Francisco's Biotech Bay. Assortative matching implies that becoming a 'micro cluster' — a community with sufficient and well-developed resources that support a specialized technology or product area — should be sufficient to help local firms prosper and invite in-migration. Communities should not focus on being good in the 'life sciences'; they should create and develop resources around some narrow slice of the sector and become best-in-class in that area. Universities should focus less on building strong colleges (for example, life science or medicine), and specialize more on outstanding departments (for example, genetics or ophthalmology).

Orange County, California, lies 400 miles to the south of Biotech Bay. Since the 1980s, Orange County has become the world's leading hub for startups and large companies in eye care, with several hundred start-ups, going and growing concerns, and big corporate players in close proximity to fuel innovation and commercial success[23]. Scientists and equipment move easily between firms, and knowledgeable accountants, attorneys, consultants and investors contribute to a strong ecosystem. OCTANe, the Orange County Technology Acceleration Network, sits at the center of this bustling community and facilitates the transfer of new knowledge, investor contacts, potential acquirers, and links to key suppliers and potential employees (https://octaneoc.org/). In 2013, the University of California at Irvine opened its new $39.5 million Gavin Herbert Eye Institute building. Herbert was the founder and chairman of optical giant Allergan. Orange County does not try to beat Biotech Bay across the board, only in eye care. We believe that other communities can adopt this niche strategy to create meaningful high-tech growth.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. ◻

Paul C. Godfrey[1]*, Gove N. Allen[1] and David Benson[2]

[1]*Marriott School of Management, Brigham Young University, Provo, UT, USA.* [2]*Woodbury School of Business, Utah Valley University, Orem, UT, USA.*
**e-mail: paul_godfrey@byu.edu*

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References

1. National Science Foundation. Higher Education Research and Development Survey, 2018 https://www.nsf.gov/statistics/srvyherd/#tabs-2 (accessed 5 July 2019).
2. Valdivia, W.D. University start-ups: critical for improving technology transfer. (Brookings, 2013).
3. Rubens, A., Spigarelli, F., Cavicchi, A. & Rinaldi, C. *J. Enterprising Communities People Places Glob. Econ.* **11**, 354–372 (2017).
4. Kotha, R., Crama, P. & Kim, P. H. *Acad. Manag. J.* **61**, 1307–1342 (2018).
5. Moore, G. & Davis, K. in *Building high-tech clusters: Silicon Valley and beyond* (eds. Bresnahan, T. F. & Gambardella, A.) 7–39 (Cambridge Univ. Press, 2004).
6. Folta, T. B., Cooper, A. C. & Baik, Y. *J. Bus. Venturing* **21**, 217–242 (2006).
7. Pe'er, A. & Keil, T. *J. Bus. Venturing.* **28**, 354–372 (2013).
8. Meyer, J. W. & Rowan, B. *Am. J. Sociol.* **83**, 340–363 (1977).
9. Leonard, W. University of Utah, MIT lead nation in new companies founded. *The Deseret News* https://www.deseretnews.com/article/700009951/University-of-Utah-MIT-lead-nation-in-new-companies-founded.html (16 February 2010; July 2019).
10. Maffly, B. Fits and startups: is U. tech transfer flawed? *The Salt Lake Tribune* https://archive.sltrib.com/article.php?id=51619785&itype=cmsid (16 May 2011; accessed 5 July 2019).
11. TEConomy Partners. The economic impact of the U. S. biopharmaceutical industry: national and state estimates http://phrma-docs.phrma.org/sites/default/files/pdf/biopharmaceuticaul-industry-economic-impact.pdf (2016; accessed 5 July 2019).
12. Social Security Administration. National average wage index https://www.ssa.gov/oact/cola/AWI.html (accessed 5 July 2019).
13. Booth, B. & Salehizadeh, B. *Nat. Biotechnol.* **29**, 579–583 (2011).
14. Jacobs, J. *The Economy of Cities* (Vintage Books, 1969).
15. Jacobs, J. *The Nature of Economies* (Vintage Books, 2000).
16. Feldman, M. P. & Audretsch, D. B. *Eur. Econ. Rev.* **43**, 409–429 (1999).
17. Lerner, J. *Boulevard of Broken Dreams: Why Public Efforts to Boost Entrepreneurship and Venture Capital Have Failed and What to Do about It* (Princeton Univ. Press, 2009).
18. McCann, B. T. & Folta, T. B. *J. Bus. Venturing* **26**, 104–123 (2011).
19. Ivkovic, Z. & Weisbrenner, S. *J. Finance* **60**, 267–306 (2005).
20. Kerr, S. *Acad. Manag. J.* **18**, 769–783 (1975).
21. Roberts, A. Where Brandeis got "sunlight is the best disinfectant." https://aroberts.us/2015/03/01/where-brandeis-got-sunlight-is-the-best-disinfectant/ (2015, accessed 5 July 2019).
22. Powers, J. B. & McDougall, P. P. *J. Bus. Ventur.* **20**, 291–311 (2005).
23. Flanigan, J. If it's eye care technology, this must be Orange County. *The New York Times* https://www.nytimes.com/2008/05/15/business/smallbusiness/15edge.html (15 May 2008; accessed 5 July 2019).

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Competing interests

The authors declare no competing interests.