



## The Inherent Risks Associated With Newly Traded Biopharmaceutical Firms

By: **David R. Williams** and Trent J. Spaulding

### Abstract

Here, we provide a comprehensive study related to the risks of all biopharmaceutical firms going public in the USA between 1996 and 2015. We found 355 firms that met our requirements for being in the sector that focuses on creating drugs for humans. Collectively, these firms spent approximately US\$86.9 billion on research and development (R&D) during this time. They also lost approximately US\$69.3 billion in combined net income. We also examine the de-listing of these firms from a public market, their number of collaborators at the initial public offering (IPO), and estimate the percentage ownership by other biopharmaceutical firms at the IPO.

**Williams, D.R.** and Spaulding, T.J. (2018). "The inherent risks associated with newly traded biopharmaceutical firms." *Drug Discovery Today*. 23(9): 1680-1688. Publisher version of record available at: <https://www.sciencedirect.com/science/article/pii/S1359644618300515>



# The inherent risks associated with newly traded biopharmaceutical firms

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Here, we provide a comprehensive study related to the risks of all biopharmaceutical firms going public in the USA between 1996 and 2015. We found 355 firms that met our requirements for being in the sector that focuses on creating drugs for humans. Collectively, these firms spent approximately US\$86.9 billion on research and development (R&D) during this time. They also lost approximately US\$69.3 billion in combined net income. We also examined the delisting of these firms from a public market, their number of collaborators at the initial public offering (IPO), and estimated the percentage ownership by other biopharmaceutical firms at the IPO.

## Introduction

The biopharmaceutical sector is characterized by high levels of risk because of the scientific uncertainty surrounding industry endeavors and the unusually intensive R&D (see [Glossary](#)) nature of the enterprise [1,2]. We use the term 'biopharmaceutical sector' to mean the sector comprising the merging biotechnology and pharmaceutical industries. Although many large, established biopharmaceutical firms, representing most of the market capitalization of the industry, are able to achieve normal profits over the long run [3], this is not the case with most firms in the sector. The most common type of biopharmaceutical firm, numbering in the hundreds or thousands, is the small firm, engaged in R&D but with no drug product on the market. Yet, these firms are an important part of the wider industry landscape [4].

Biopharmaceutical firms are largely equity financed [5]. The equity financiers of private biopharmaceutical firms include scientist-entrepreneurs, venture capitalists, and other biopharmaceutical firms [6]. They are part of a growing ecosystem in the biopharmaceutical industry, where new smaller firms and larger publicly traded firms are developing symbiotic relationships. For example, it has been reported that GlaxoSmithKline is investing nearly half of its R&D efforts into academia and small biotechnology firms [7]. Many scientist-entrepreneurs would prefer to maintain the control associated with a privately held firm [8,9].

However, because of the extraordinary time [10] and expense of bringing a chemical-based or biological product to market [11,12], and the low probability of developing a profitable product [13,14], they are unable to achieve this goal of remaining private, even with funding from large biopharmaceutical firms. To increase their funds and mitigate their risks, many firms undergo an IPO, itself a timely and expensive process [15,16]. Much research has been done on the success rates of individual drugs and therapeutic classes, yet much remains unknown about the collective activity surrounding firms that have gone public over time.

The IPO is the process by which a firm sells its securities or stock for the first time on an open, public market. A public market is a place or system that allows for the exchange of the stock of a firm between entities and individuals, such as the Nasdaq stock market or the New York Stock Exchange [17]. Private firms undertake an IPO for several reasons, including (i) raising money for internal growth; (ii) diversification into related and unrelated areas; (3) raising public awareness of the firm and its products; (4) increasing financial transparency; and (5) survival [18,19]. For many firms, an IPO represents the most efficient means to raise capital.

Various recent academic and practitioner-oriented studies have examined biopharmaceutical IPO activity. For example, Williams and Young, studying biopharmaceutical IPOs from 1996 to 2005, found that, for those firms that survived, their stock price rose only 7.7% [20]. Booth showed that the average investor in biopharmaceutical IPOs from 2003 to 2007 lost money in terms of the return

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## GLOSSARY

**Annual report** A document used by most publicly traded firms to disclose corporate information to their shareholders

**Collaborations** Agreements among entities in which each party commits complementary resources or capabilities to achieve a common set of objectives. They can include joint ventures, equity-based alliances, or licensing arrangements

**Delisting** When the stock of a firm ceases to trade on an open, public market

**Initial public offering (IPO)** Process by which a firm sells its stock for the first time on an open, public market, such as the New York Stock Exchange or Nasdaq. 'IPO' can also refer to the firm itself

**Net income** The profit of a firm in a given fiscal period. It comprises total revenues earned in the period less total expenses incurred in the period. When revenues exceed expenses, the firm has a net profit. When expenses exceed revenues, the firm has a net loss

**Prospectus** A document required by the SEC providing details about the securities of a specific firm offered for sale to the public

**Research and development (R&D)** Investigative activities a firm conducts to lead to the development of new products and procedures or to improve existing products and procedures

**R&D intensity** Expenditures by a firm on its R&D efforts divided by its sales or revenues. Revenues can include monies received from collaborations

**Standard industrial classification (SIC) codes** Four-digit codes that categorize companies by the type of business activities in which they engage

**Venture capital** Equity or equity-linked investment in privately held companies or publicly traded companies, where the investor is a financial intermediary who typically invests the monies of other individuals or entities and often acts as a director, manager, or advisor to the firm

on their invested capital [21]. Carter *et al.*, studying biopharmaceutical IPOs from 2010 to 2014, found that small-molecule firms comprised the majority of biopharmaceutical firms going public [22]. Comparing two similar times of high biopharmaceutical IPO

activity, McNamee and Ledley found biopharmaceutical IPOs between 2012 and 2014 raised significantly less monies on average than their counterparts did in 1999 and 2000 [23]. Given this, several scholars have questioned whether the current business model of biopharmaceutical research and development, which includes the IPO process, is sustainable [24,25].

Here, we provide a comprehensive analysis over a 20-year period of key areas related to the financing of biopharmaceutical IPOs, which has not been previously undertaken. The trade press has made much of the relatively recent success of a handful of biotechnology firms, such as Amgen and Genentech, ignoring much of the uniqueness of their success. To better understand activity in this market, we analyzed the Security & Exchange Commission's (SEC) filings for all biopharmaceutical firms primarily engaged in the development of human drugs or their complements that went public between 1996 and 2015. Our interest was in understanding the total collective amount spent by the firms on R&D, their profitability, collaborative arrangements, and delisting from a public market, because this is a growing sector of the biopharmaceutical market that is receiving increased attention from biopharmaceutical firms, investors, policy makers, and others.

### Approach

The names of potential biopharmaceutical firms were collected from various Internet sources, including but not limited to: [biospace.com](http://biospace.com), [hoovers.com](http://hoovers.com), [ipomonitor.com](http://ipomonitor.com), and [SEC.gov](http://SEC.gov). Here, the firms are presented as grouped by standard industrial classification (SIC) codes, which is a common practice in the business literature. Other studies include different SIC codes, firm types (i.e., nonholding companies, etc.), and IPO dates (i.e., date of prospectus compared to date stock first offered), and offer price floors for inclusion in their studies, which results in different counts for the number of firms going public and other results. Here, we exclude firms primarily engaged in products created for agriculture (i.e., seeds companies) and animals regardless of SIC codes. For most firms, individual SEC filings were inspected to ensure that the firms were engaged in the biopharmaceutical segment. External experts in the biopharmaceutical arena were

TABLE 1

Firm years by year and SIC code

SIC code	Year																				Total %	
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015		
2833	1	1																			2	0
2834	10	17	16	20	44	48	48	50	67	72	82	97	81	79	84	86	89	106	143	168	1407	68
2835	2	3	3	2	3	3	3	3	3	2	2	2	2	1					1	1	36	2
2836	3	9	9	9	11	13	13	15	17	17	19	19	16	14	13	11	10	14	22	28	282	14
3826	1	1	1	1	4	4	4	4	3	4	4	4	4	3	5	5	5	5	6	5	73	4
3829					1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	18	1
3841		1	1	1	1	1	1	1	1	1	4	4	3	3	3	3	3	4	6	45	2	
3842	1	1										1	1	1	1	1	1	2	3	14	1	
7389										1	1	1	1	1	1	1	1	1	1	1	11	1
8071										1	1	1	1	1	1	1	2	4	6	20	1	
8731	1	2	4	5	14	11	10	8	8	8	9	8	7	6	7	8	7	6	7	6	142	7
8734					1	1	1	1	1	1	1	1	1	1	1						11	1
Total	19	35	34	38	79	82	81	83	102	109	124	139	118	111	117	117	118	139	191	225	2061	100
%	1	2	2	2	4	4	4	4	5	5	6	7	6	5	6	6	6	7	9	11	100	

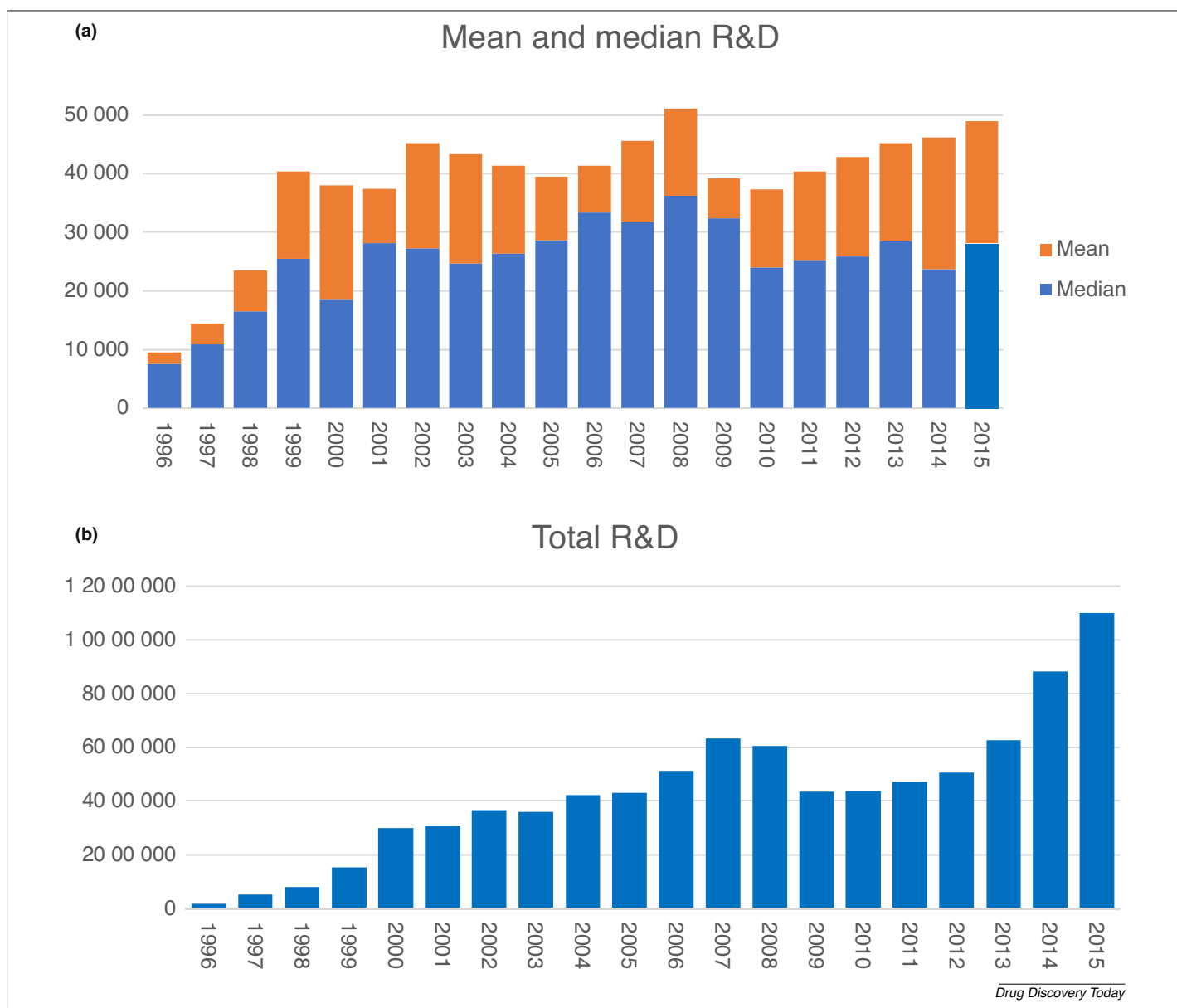
**BOX 1**

**SIC codes for the firms in the study**

- 2833: Medicinal Chemicals and Botanical Products
- 2834: Pharmaceutical Preparations
- 2835: *In vitro* and *In vivo* Diagnostic Substances
- 2836: Biological Products, Except Diagnostic Substances
- 3826: Laboratory Analytical Instruments
- 3829: Measuring and Controlling Devices, Not Elsewhere Classified
- 3841: Surgical and Medical Instruments and Apparatus
- 3842: Orthopedic, Prosthetic, and Surgical Appliances and Supplies
- 7389: Business Services, Not Elsewhere Classified
- 8071: Medical Laboratories
- 8731: Commercial Physical and Biological Research
- 8734: Testing Laboratories

also consulted as to which firms should be included or excluded from the study. Firms occasionally changed SIC codes in their filings. We attempted to use the most appropriate code. Dates of IPOs for the firms were found in the above Internet sites, the SEC filings of the firms, EdgarPro IPO, [yahoo.finance.com](http://yahoo.finance.com), or [ipo.findthecompany.com](http://ipo.findthecompany.com).

Financial data were collected from the annual reports of each firm (i.e., 10K forms). Firms are required by the SEC to file annual reports specifying particular information related to the financial condition of the firm. Financial data were electronically collected or ‘scraped,’ with each field in the data set being individually examined for missing or abnormal results. When an issue was identified with the data collected through scraping, the researchers individually reviewed the SEC filing itself and corrected any missing or incorrect data. These data were collected over the last



**FIGURE 1**  
R&D spending by year

**TABLE 2**  
**R&D intensity by year and SIC code**

Year	Firm years	Mean by firm year	Median by firm year	SIC	Firm years	Mean by firm year	Median by firm year
1996	18	4.08	1.51	2833	2	0.06	0.06
1997	33	5.99	1.89	2834	1131	38.04	2.02
1998	29	8.40	2.16	2835	34	76.74	3.14
1999	33	7.27	2.00	2836	252	84.09	2.93
2000	70	53.62	2.48	3826	73	1.68	0.24
2001	74	49.31	2.74	3829	18	0.74	0.69
2002	73	55.30	2.58	3841	44	38.55	1.55
2003	74	6.98	1.93	3842	5	0.26	0.00
2004	93	20.93	2.38	7389	8	0.22	0.27
2005	100	46.31	2.19	8071	20	2.55	0.26
2006	115	26.05	2.40	8731	132	5.62	1.71
2007	119	34.02	1.81	8734	11	0.30	0.03
2008	102	172.89	1.95	Total	1730	40.14	1.83
2009	99	34.68	1.37				
2010	101	23.52	1.07				
2011	99	36.22	0.98				
2012	95	32.49	1.26				
2013	113	31.87	1.73				
2014	134	21.46	1.89				
2015	156	41.83	2.13				
Total	1730	40.14	1.83				

quarter of 2016, with an examination of the continuation of filing by the firm with the SEC occurring into mid-January of 2017. Here, the data are presented as inflation-adjusted. An Internet US inflation calculator was used to adjust these data based on the consumer price index, and these data were calculated on an annual basis (and, thus, are not as precise as the other data reported) using means and total amounts. Data related to the number of strategic partners or collaborators, and ownership interest of other biopharmaceutical firms were individually collected from the prospectus of each firm; all data of these types were pre-IPO. Data for collaborations were estimates. We defined collaborations as being between the IPO and other biopharmaceutical firms (i.e., not universities or government agencies). The prospectus of a firm typically has a collaboration section, which is where data for this variable are usually found. When this section was absent, a word search using 'collaboration', 'strategic alliances', and 'partnerships' was performed. At times, the prospectus language was not specific as to the number of collaborators. We used our best efforts to estimate these numbers based on the given information in the prospectus.

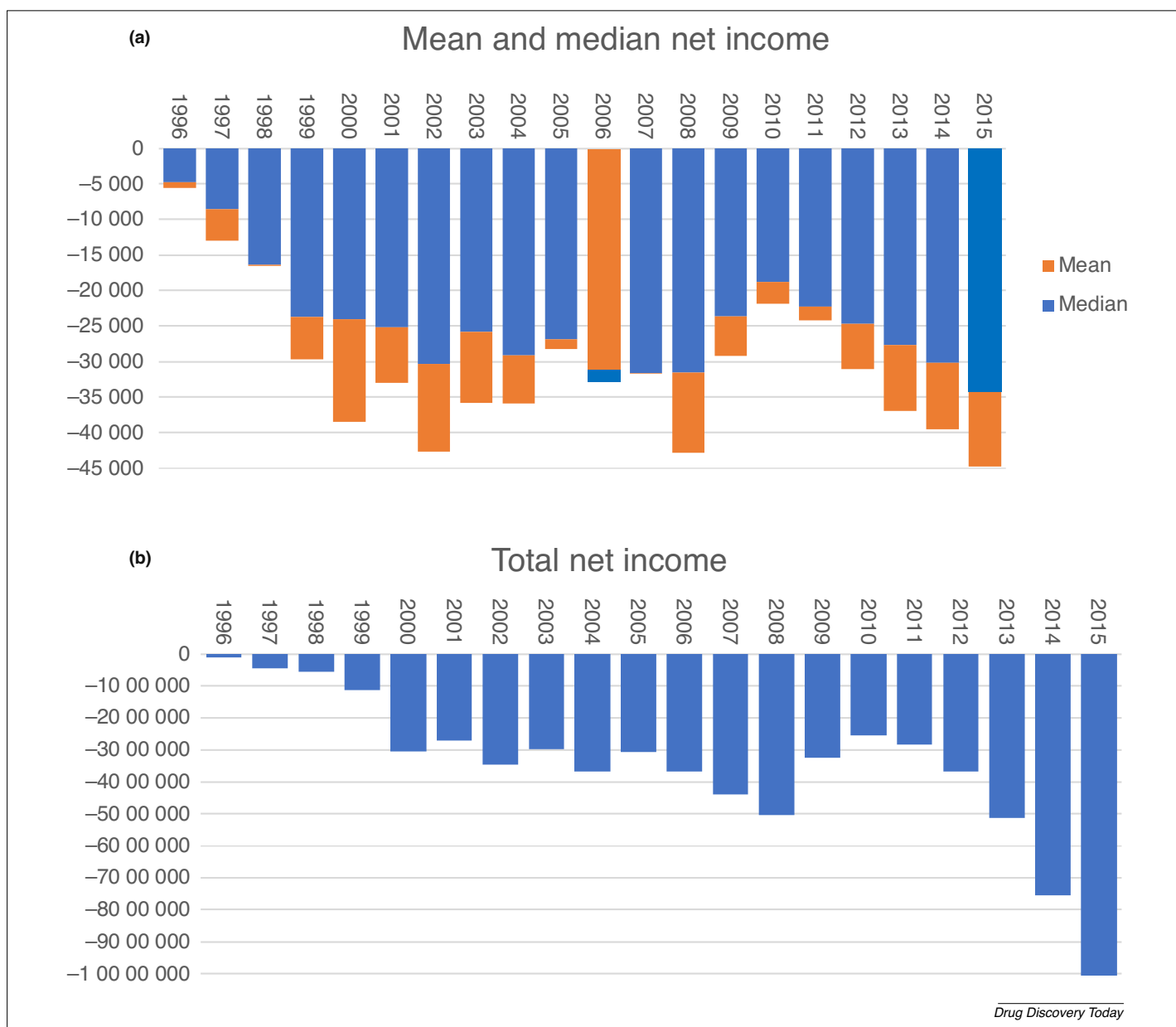
The ownership interest was derived from the principal stockholder section of the prospectus. Ownership interest occurs before the IPO (i.e., before IPO dilution of ownership). The ownership of biopharmaceutical firms was determined if the biopharmaceutical firm was owned directly or through a biopharmaceutical firm-owned venture capital firm (e.g., Amgen Ventures or Lilly Ventures). Names of biopharmaceutical-controlled venture capital firms were compared with *Pratt's Guide to Venture Capital* [26], GEN's *Top 20 Corp Venture Capital Funds* [27], and Internet searches. We viewed survival as a firm filing an annual report (10K) in 2015. For those firms that did not survive, other SEC filings (and Internet searches) were read to determine the reason

for this (e.g., mergers and acquisitions, or financial distress). We used data from the *National Venture Capital Yearbook* [28] and Jay Ritter's Internet site [29] to derive the percentage of biopharmaceutical IPOs compared with all IPOs.

Overall, 355 biopharmaceutical firms went public from 1996 through 2015, representing 2061 firm years (Table 1). Firm years represent the collective life of a firm while it is publicly traded (excluding over-the-counter trading). We often calculated the means and medians based on firm years, because this is a good way of showing entry and exit from the market. Table 1 shows the number of firm years by year and SIC code. These 355 biopharmaceutical firms represent 9% of all firms going public in the USA regardless of industry [28,29]. We focus on the three largest SIC codes by firm years: 2834, 2836, and 8731. SIC code 2834 (pharmaceutical preparations) represents 68.0% of all firm years. SIC code 2836 (biological products) represents 13.7% of all firm years, and SIC code 8731 (Services-Commercial Physical & Biological Research) represents 6.8% of all firm years. Box 1 lists the description of all SIC codes used in the study. Firm years peaked in 2007 and then again in the latter years of the study.

### Research and development investment

Most firms in this study were drug or therapy research and development firms, as opposed to complements in this industry. Overall, the 355 firms spent US\$86.9 billion on R&D during the 20-year period. Figure 1 depicts the mean, median, and R&D expenditures by year. Table S1 in the Supplemental information online lists R&D spend by year and SIC codes. R&D spending fairly closely followed firm years. The 355 firms spent US\$244.2 million per firm or US\$42.4 million per firm year on average. The overall median was US\$26.4 million per firm year.



**FIGURE 2**  
Net income by year

Firms in SIC code 2834 spent US\$62.1 billion over the 20-year period or US\$44.2 million per firm year on average. Firms in SIC 2836 spent US\$12.6 billion over the 20-year period or US\$44.6 million per firm year on average. Firms in SIC code 8731 spent US \$5.1 billion over the 20-year period or US\$43.1 million per firm year on average. In terms of mean and median by firm year, R&D expenditures peaked in 2008, with firms spending US\$51.3 million on average. Perhaps because of the recession, mean, median, and total R&D spending declined to pre-2008 levels in 2009 and slowly rose over the ensuing years. From 2008 to 2009, total R&D expenditures declined by 28%. By 2015, the mean amount spent on R&D was nearing the 2008 level; however, the total R&D spent in 2015 was almost US\$11 billion or an 82% increase from the 2008 level. In total US dollars, R&D spending in 2015 was approximately 60 times more than in 1996. When adjusted for inflation to 1996 US

dollars, total R&D spending in 2015 was nearly US\$7.3 billion or 40 times more than in 1996. When 2015 total R&D US dollars were inflation-adjusted to 1999 levels (i.e., the first year that total R&D spending exceeded US\$1 billion dollars), then the total R&D spending in 2015 was over five times the total amount spent in 1999.

An important financial indicator for technology industries is R&D intensity [30–33]. R&D intensity is typically calculated by dividing R&D expense by revenue. For many firms, including many IPOs, revenue is derived from the selling of goods and/or services to an end-user. For biopharmaceutical IPOs directly involved with creating drugs and therapeutics, this is seldom the case. Excluding the financing from owners (which can be substantial and goes through multiple rounds) [34,35], revenues for many biopharmaceutical firms at this stage are derived from collabora-

TABLE 3

## Continued trading by year and SIC code

Year	All firms (N = 355)		SIC	All firms (N = 355)		Firms with IPO on or before 2012 (N = 220)	
	No. of firms	Mean surviving		No. of firms	Mean surviving	No. of firms	Mean surviving
1996	19	0.32	2833	1	0.00	1	0.00
1997	16	0.31	2834	253	0.66	152	0.47
1998	4	0.00	2835	5	0.20	4	0.00
1999	8	0.63	2836	49	0.57	28	0.25
2000	44	0.36	3826	6	0.83	5	0.80
2001	6	0.33	3829	2	0.50	2	0.50
2002	4	0.00	3841	8	0.75	5	0.60
2003	7	0.00	3842	3	1.00	1	1.00
2004	22	0.32	7389	1	1.00	1	1.00
2005	13	0.38	8071	6	1.00	1	1.00
2006	21	0.48	8731	20	0.30	19	0.26
2007	18	0.44	8734	1	0.00	1	0.00
2008	0	–	Total	355	0.63	220	0.43
2009	3	0.67					
2010	14	0.71					
2011	9	1.00					
2012	12	0.75					
2013	29	0.93					
2014	62	0.97					
2015	44	1.00					
Total	355	0.63					

tive agreements [36,37] or not at all. Total revenue for the 2064 firm years was US\$63.4 million per firm year on average. Interestingly, a few firms reported negative revenue, which is derived from collaboration loss (and is different from collaboration expense). A significant portion of firms also reported having no revenue at all, with many firms noting they were a 'development-stage company'.

As Table 2 suggests, the R&D intensity of this segment was high. Overall, for those firms with revenue (firm years 51 730) the R&D intensity was 40.1 per firm year (median 1.8). This means that, for the average firm, for every US\$1 received in revenue, it was spending US\$40 dollars on R&D. Firms in SIC code 2834 had an average R&D intensity of 38.1 per firm year. Firms in SIC code 2836 had an average R&D intensity of 84.1 per firm year. Firms in SIC code 8731 had an average R&D intensity of 6.3 per firm year. R&D intensity peaked in 2008 at 172.9. As reference points, the National Science Foundation noted that R&D intensity in 2014 for all US industries was 0.035, and 0.134 for all US pharmaceutical firms [38].

### IPO firm profitability

Relatively young firms tend to be unprofitable and this is particularly true for biopharmaceutical firms that have gone public [10]. The 355 firms in the study collectively lost US\$69.3 billion in net income. When this was adjusted for inflation to 1996 US dollars, this represents a total net loss of US\$52.1 billion. This translates to the 355 firms losing on average US\$195.4 million per firm or US

\$33.6 million per firm year. If one compares 2015 inflation-adjusted mean or median net income to that in 2008, then one sees US\$40.6 million lost on average in 2015, comparable to that in 2008. The 355 firms had a median net loss of US\$26.7 million per firm year. Of the 2061 firm years, only 245 firm years (or 11.9%) had positive net incomes and two firm years reported breaking even. Broadly speaking, 88% of the time, the firms under study lost money. For most biopharmaceutical firms, sustained losses are the norm. Of the three SIC codes with the most firms and firm years, firms within SIC code 2834 proportionally lost the most money at US\$48.4 billion in total or US\$34.5 million per firm year. This was followed by firms within SIC code 2836 losing US\$12.1 billion in total or US\$42.8 million per firm year. Firms within SIC code 8731 lost US\$3.8 billion in total or US\$26.9 million per firm year.

Figure 2 illustrates the mean, median, and total net income of the firms by year. Losses by year initially peaked in 2008. This lagged by 1 year the peak year (2007) for R&D total spend, which is reasonable. When adjusted for inflation to 1996 US dollars, this represent a net loss of US\$28.3 million per firm year or more than a fivefold increase from 1996. Similarly, adjusting for inflation to 1996 US dollars, total net loss represents US\$3.7 billion in 2008. Net losses peak again in 2015, with the average firm losing US\$44.7 million per firm year or US\$10.1 billion total for the year or US\$6.7 billion when adjusted for inflation to 1996 US dollars. Comparing Fig. 1 on R&D spending and Fig. 2 (and the tables in the Supplemental information online) on net income, one can see the general trend of both spending and net losses increasing up to

**TABLE 4**  
**Estimate of collaborators before IPO by year and SIC**

Year	All Firms <sup>a</sup>		Only Firms with collaborators <sup>b</sup>		Total collaborators	SIC	All firms <sup>a</sup>		Only firms with collaborators <sup>b</sup>		Total collaborators
	Firms	Est. mean	Firms	Est. mean			Firms	Est. mean	Firms	Est. mean	
1996	18	1.89	15	2.27	34	2833	1	2.00	1	2.00	2
1997	16	3.06	13	3.77	49	2834	252	1.77	172	2.60	447
1998	4	1.75	3	2.33	7	2835	5	1.20	2	3.00	6
1999	8	2.50	7	2.86	20	2836	49	2.22	38	2.87	109
2000	44	2.64	37	3.14	116	3826	6	2.00	5	2.40	12
2001	6	2.83	5	3.40	17	3829	2	0.50	1	1.00	1
2002	4	1.00	3	1.33	4	3841	8	1.38	5	2.20	11
2003	7	0.71	3	1.67	5	3842	2	3.00	1	6.00	6
2004	22	1.68	18	2.06	37	7389	1	0.00	–	–	0
2005	13	1.54	6	3.33	20	8071	6	0.67	3	1.33	4
2006	21	3.33	19	3.68	70	8731	20	2.90	16	3.63	58
2007	18	1.50	9	3.00	27	8734	1	4.00	1	4.00	4
2008	0	–	0	–	–	Total	353	1.87	245	2.69	660
2009	2	0.50	1	1.00	1						
2010	14	1.64	10	2.30	23						
2011	9	2.00	5	3.60	18						
2012	12	1.58	9	2.11	19						
2013	29	2.48	21	3.43	72						
2014	62	1.26	39	2.00	78						
2015	44	0.98	22	1.95	43						
Total	353	1.87	245	2.69	660						

<sup>a</sup>N = 353.

<sup>b</sup>N = 245. Collaborations could not be determined for two firms.

the financial crisis of 2008, falling sharply in 2009, and then slowing rising back to 2008 levels in 2015.

### Delisting

Of the firms in the study, 63% continued to file an annual report with the SEC in 2015. However, because firms in 2013, 2014, and 2015 represent a significant percentage of all 355 firms, the data are somewhat skewed. If we eliminate firms going public after 2012, only 43% continued to file an annual report in 2015, with 84% of these operating at a net loss in 2015. [Table 3](#) depicts the percentage of firms that continued to remain publicly traded by year and SIC code.

To further examine the data, we inspected firms that continued to file annual reports 10, 5, and 3 years at different segments in time. When examining firms that filed their first annual report in 2006 or before and continued to file annual reports over the following 10 years, we found that 70 out of 164 firms (42.7%) continued to file annual reports for the following 10 years. This was consistent with our findings presented in [Table 3](#). For these same firms, 123 out of 164 firms (75.0%) continued to file annual reports for 5 years or more, and 141 out of 164 firms (86.0%) continued to file annual reports for 3 years or more. For firms that filed their first annual report in 2010 or before, we found that 148 of 199 firms (74.4%) continued to file for 5 years, and 172 out of 199 firms (86.4%) also filed annual reports for 3 years or more.

When we examined firms that filed their first annual report in 2012 or before and continued to file annual reports for 3 years, we found 192 out of 220 firms (87.3%) survived for 3 years. Broadly speaking, we can say that there is a fairly consistent decline in the number of firms continuing to file annual reports over the following 3- or 5-year period. This is true whether we examine firms at the beginning of our 20-year study period or at the end.

### Collaborations

A series of studies have shown the importance of strategic alliances and other forms of collaboration to the young biopharmaceutical firm [39–42]. Reasons for strategic alliance formation among biopharmaceutical firms include to: (i) reduce uncertainty, particularly technological uncertainty; (ii) transfer technology from one firm to another; (iii) facilitate technology exchange between firms; (iv) reduce the risks and costs of R&D; (v) learn from other firms; (vi) provide legitimacy; and (vii) gain access to facilities [41]. Strategic alliances can take several forms. These include: (i) technology development alliances, which are design to expand technology know-how between firms; (ii) commercialization alliances, which are designed to expand the manufacturing and marketing capabilities of a firm; and (iii) financial alliances, which allow a firm to pursue technological and commercialization strategies [43,44]. Among small firms, alliance experience might initially encourage a firm to go public rather than be acquired [43].



**TABLE 5**  
**Estimate of biopharmaceutical ownership before IPO by year and SIC**

Year	All firms <sup>a</sup>			Firms with biopharmaceutical owners <sup>b</sup>			SIC	All firms <sup>a</sup>			Firms with biopharmaceutical owners <sup>b</sup>		
	Est.	Mean	Max.	Est.	Mean	Median		Est.	Mean	Max.	Est.	Mean	Median
1996	19	11.11	47	10	21.11	19.05	2833	1	0.00	0.00	–	–	–
1997	16	11.31	60	6	30.17	22.00	2834	251	8.77	100.00	109	20.19	14.50
1998	4	26.00	80	3	34.67	16.00	2835	5	4.73	23.66	1	23.66	23.66
1999	8	11.75	47	3	31.33	24.00	2836	49	11.02	80.00	23	23.48	17.00
2000	44	2.89	19	13	9.78	9.00	3826	6	13.01	47.00	3	26.02	22.50
2001	6	18.00	83	3	36.00	19.00	3829	2	0.00	0.00	–	–	–
2002	4	67.25	100	4	67.25	65.50	3841	8	4.13	18.00	2	16.50	16.50
2003	7	3.86	20	2	13.50	13.50	3842	3	0.00	0.00	–	–	–
2004	22	8.27	60	10	18.20	10.50	7389	1	0.00	0.00	–	–	–
2005	13	3.85	16	4	12.50	12.00	8071	6	1.50	9.00	1	9.00	9.00
2006	21	4.33	17	8	11.38	10.50	8731	20	4.30	29.00	7	12.29	8.00
2007	17	5.41	36	5	18.40	17.00	8734	1	5.00	5.00	1	5.00	5.00
2008	0	–	–	0	–	–	Total	353	8.43	100	147	20.24	15.00
2009	2	48.55	97	1	97.10	97.10							
2010	14	6.61	28	7	13.22	12.50							
2011	9	1.12	10	1	10.10	10.10							
2012	12	14.00	98	4	42.00	32.10							
2013	29	7.58	29	14	15.70	15.05							
2014	62	10.26	45	35	18.17	16.40							
2015	44	4.90	40	14	15.41	13.60							
Total	353	8.43	100	147	20.24	15.00							

<sup>a</sup> N = 353.

<sup>b</sup> N = 147. Ownership by biopharmaceutical firms could not be determined for two firms.

Table 4 shows an estimate of the number of collaborators between a firm and other biopharmaceutical firms (not universities) before the IPO by year and SIC code for all firms in the study. This is an estimate based on information clearly stated in the prospectus as an arrangement that is a collaboration, alliance, or partnership (with the firm stating it as such), and on a count of the number of collaborations (and not the US dollar amount or a qualitative measure of the collaboration). An in-licensing arrangement can be a collaboration (or not) depending on whether the firm declared it as such. The year depicts the first annual report.

As can be seen, 353 firms had usable data. Given the almost routine losses experienced by these firms on an annual basis, continuous R&D expenditures would be difficult for many without the support of larger established firms, either through working partnerships or some sort of financial backing. Of the 353 firms, there were 660 total collaborators for a mean of 1.9 collaborators per firm. There were 245 IPOs that reported collaborations (or 108 IPOs without reported collaborators). Of these 245 IPOs, the mean was 2.7 collaborators per IPO.

Table 5 shows the percentage ownership interest by biopharmaceutical firms prior to the IPO by year and SIC code. The results show an average percentage ownership of 8.4% for all firms and 20.2% for those that have biopharmaceutical ownership. These data come from the prospectus of each firm.

## Concluding remarks

The development of innovative drugs and therapies remains risky and rife with failure [45,46], yet investors and scientists remain optimistic about the therapeutic and financial potential of their efforts. Much of the trade press focuses on the success (and subsequent cost of drugs) of a few firms. Our results, taken together, confirm that the biopharmaceutical IPO market remains a R&D intensive market fraught with inherent risks. For every successful firm, there are hundreds, if not more, of small public (and private) firms that spend billions of dollars seeking to create drugs and therapies to improve individuals' lives, yet might never see a profit or survive.

Specifically, the data in our study show that these firms absorb high financial losses while making large R&D outlays in the quest for new drug products. Cumulatively, these firms spent US\$86.9 billion on R&D during this time. They also lost US\$69.3 billion in combined net income during this period. This financing in part was borne by other biopharmaceutical firms. For the IPOs that received financing from other biopharmaceutical firms, this ownership investment represented 20% of the value of the firm at the time of the IPO. Clearly, multiple sources of financing are required for these firms to continue to invest in R&D at this rate.

Demonstrating perhaps most vividly the uncertain prospect of firms trying to find success through R&D, of the 355 firms that

underwent an IPO, only 63.4% survived to file an annual report (10K) with the SEC in 2015. It is possible that firms that have completed an IPO over the past few years have not had sufficient time for us to judge their prospect of survival. However, the track record of firms continuing to file annual reports over the course of our study is consistent. Over less than a decade's time, most firms in our study ceased to trade on a public market. Specifically, we found that, if one excludes firms that went public after 2012, then only 42.7% of the firms that went public between 1996 and 2012 continued to trade their stock on a public market in 2015, with 84% of these firms continuing to lose money in 2015. For firms with 10 years or more of filings, they averaged 9.5 years before their

first year of profitability. This does not include losses incurred before the IPO. Our results, taken together with other studies on the costs to develop drugs, show that most firms are increasingly spending billions of dollars on new drug and therapeutic development, with little profit to show for it.

### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.drudis.2018.06.013>.

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