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Underwriter learning about unfamiliar firms: Evidence from the history of biotech IPOS☆

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Abstract

This study examines the ability of underwriters to properly value unfamiliar firms prior to issuance. I use a sample of IPOs in biotechnology, a relatively new but thriving industry. The first American biotech IPO was in 1980. Through the end of 2004, almost 500 biotech IPOs have appeared in the public market. I find that biotechnology differs from other industries in the attributes of individual firms valued by the market. In particular, R&D and the quality of human capital (e.g., star scientists on the staff) are much more important for biotech valuations. I find also that underwriters appeared not to appreciate this distinction for early biotech IPOs; in those cases, first-day market returns were predictable by firm attributes not used by underwriters to establish IPO issue prices. I also find that underwriters have learned over time, albeit slowly. Over the 20+ years of biotech history, IPO issue prices have become more dependent on firm attributes unique to biotechs while first-day market returns have become less predictable.
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0. Introduction

Valuing an early-stage company or IPO is difficult because much of the company's current value depends on expected future revenues from products yet to be marketed. Valuing an IPO in a nascent industry is even more difficult since there is no historical information for comparison. This is a paper about the ability of underwriters to properly value unfamiliar firms. I use biotechnology IPOs as the example. In particular, I study two related issues: first, which attributes of individual biotech firms have been drivers of market value and how do these attributes differ in non-biotech firms? Second, (my study's main focus), given that the biotech industry is relatively new (the first IPO was in 1980) and differs in many respects from other industries, how successful were underwriters in pricing biotech IPOs? Were they aware of important value drivers from the very beginning or did they learn from market experience?

When the first companies in a new industry go public, underwriters have little guidance beyond traditional valuation methods employed in other industries, though they must surely have a vague sense of unease about unfamiliar territory. Market participants are not limited to the information used by the underwriters. Moreover, incentives may induce underwriters to set offer prices below their best estimates of value. For either reason or both, IPOs generally experience sizeable first-day returns. Yet it is hard to think of plausible reasons that cross sectional value drivers within the same industry should impact the first-day return and not the offer price.

For example, prior profitability should be cross-sectionally associated with market value over all IPOs, but it would be very strange indeed if profitability influenced the firm's market value at the end of trading on the first day and yet did not influence the offer value. None of the underwriters' constituents would be satisfied by such a phenomenon since it would yield profits to unassociated first-day traders astute enough to notice and take advantage. The IPO issuing firm and the underwriters' favored clients who receive allocations could be made better off by more rational offer pricing.

The distinction here is between IPO underpricing in general and IPO underpricing that can be predicted cross-sectionally by public information known in advance. The second type of underpricing could be explained by inadequate underwriter valuations prior to the IPO. Such inadequacies are not very surprising for an entirely new and unique industry. Underwriters are professionals trained in valuation, but it is arguable that it would be too much to expect them to price properly every attribute of a strange new firm. Valuation is likely more precise when many comparables are already trading in the market. When a new industry comes along, it seems plausible that underwriters learn something about market valuation from every additional IPO.

Of course, some firm attributes might be systemically mispriced in all IPOs, thereby indicating that they are not just mistakes caused by unfamiliarity with a new industry. For example, if a particular attribute is cross-sectionally related to the first-day trading returns of both biotech and non-biotech IPOs, one might assume that it represents information asymmetry or some other basic influence unrelated to cognitive limitations of underwriters. In contrast, an attribute that affects early IPOs but dies out over time as the industry matures, and is not present in IPOs of already familiar industries, would be a pattern consistent with initial underwriter misvaluation.

The history of biotech IPO issuance provides an opportunity to observe underwriter learning. Biotechnology was an unknown industry 25 years ago and it was quite unlike

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other existing industries. Biotechnology uses living organisms, or parts of such organisms, to make or modify products, to improve plants or animals, or to develop microorganisms for specific use. Biotechnology is not a separate science but rather a mix of disciplines—genetics, molecular biology, biochemistry, embryology, and cell biology—transmuted into productive processes by coupling with such practical disciplines as chemical engineering, information technology, and robotics (Doyle and Perseley, 1996).

Biotechnology is important for many reasons. First, the growing world population calls for enhanced food production. Second, new methods are needed to protect the environment and reduce pollution. Third, non-renewable sources of energy such as oil will someday have to be replaced, possibly with biotechnology-created products. Fourth, there is immediate promise on the medical front. As populations grow older, the desirability of more medical service at lower cost is obvious. But perhaps most intriguing is that biotechnology offers the hope of finding cures for devastating diseases (Oliver, 2000) or perhaps something even more lucrative, pills to overcome the foibles of human nature such as overeating and drug abuse. Thus, this paper concentrates on scientifically oriented biotech firms, small to medium-sized high-tech companies with the development of new drugs as their primary raison d'être.

Valuing an early-stage biotechnology company is difficult because the most of the company's current value depends on expected future revenues from a drug (or drugs) yet to be marketed. Other difficult-to-assess factors in biotech valuation include the costs of drug development, the timing of the regulatory process, and the estimated capture of market shares.

To anticipate the conclusions, I find that biotech firm values are more driven by R&D and by the quality of human capital (key scientists) than are values of non-biotech firms. Underwriters did not recognize this difference when they priced earlier biotech IPOs. IPO offer values were established more or less in conformance with traditional industries and this left a lot of money on the table. In contrast to underwriters, the market did recognize the importance of R&D and of scientific expertise. After twenty+ years of biotech IPO issuance, underwriters now seem to be incorporating R&D into offer prices, albeit in an imperfect manner.

Section 1 presents and discusses various measures that are plausible candidates for cross-sectional value drivers. Section 2 describes the data and provides summary statistics. The empirical results are presented in Section 3 and Section 4 concludes.

1. Determinants of biotech value

The entrant biotech firm must undergo repeated rounds of beauty contests to attract funding from angel investors, venture capitalists, and public investors in order to successfully traverse the long years of research and clinical trials that typically lie between a brilliant idea and marketed, revenue-producing product. Firms that are most likely to pass through rounds of financing and achieve ultimate success are those with the deepest scientific base (Darby and Zucker, 2002). This suggests that predictors of biotech success might include R&D expenditures and the active involvement of star scientists. For IPOs in general, (regardless of industry), there are numerous potential predictors of IPO market values, such as those in the following list; some have been found important in previous IPO research. Each potential determinant listed below will be proxied by an empirical construct in the subsequent analysis of market value.

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1.1. Spending on R&D

Previous literature in industrial economics suggests that innovative activities such as R&D spending may exhibit decreasing output-denominated returns-to-scale (Scherer, 1980; Acs and Audretsch, 1987, 1988; Graves and Langowitz, 1993). Graves and Langowitz (1993) conclude that increased R&D spending in pharmaceutical firms, is positively related to the number of new chemical agreements (NCEs) produced, but at a decreasing rate (Hand, 2003). Graves and Langowitz favor an explanation that the highest absolute R&D spending is by large firms, where bureaucracy, red tape, and conservatism make it difficult for creative and inventive ideas to succeed (Hand, 2003). Nevertheless, Hand (2001) finds that R&D expenditures are associated with increasing returns to scale and that this effect has increased significantly in the 1990s. The larger amount of R & D expenditures leads to a disproportionately higher probability of obtaining a legal or natural monopoly on the innovation arising from R&D.

1.2. Timing of R&D in the biotechnology development chain

The biotechnology development chain is long, as long as fifteen years from discovery through completing the regulatory review process and post-marketing testing. Major technical steps include discovery, pre-clinical testing, phase I trials, phase II trials, phase III trials, and FDA approval. It seems plausible that earlier R&D expenditures will be associated with higher ultimate value. This is because earlier R&D spending is riskier and is associated with more valuable real options (cf. Schwartz and Moon, 2002). Early stage R&D creates more real option value because it includes options to accelerate vs. delay, expand vs. contract, abandon vs. continue, develop in-house vs. subcontract, and go-it-alone vs. secure a strategic alliance—and these decisions may occur several times over the course of development. Hand (2003) predicts that R&D expenditures that lie earlier in the development chain will create more value. Cumming and Macintosh (2000) find that early-stage Canadian biotech firms spend a greater proportion of their expenditures on R&D than do later-stage firms, suggesting a financial statement proxy for location in the development chain; viz., the ratio of R&D expense to revenues.

1.3. Growth in R&D spending

Higher R&D spending growth should be associated with higher value, holding constant the timing of R&D spending. This is because biotech firms are in a race to discover new drugs and secure patent protection. Consequently, R&D growth is a multi-part signal of (1) the imminence of an important discovery, (2) likely success in the competition, (3) higher anticipated market share (and profit.) The natural financial statement proxy is a firm's year-to-year growth rate in quarterly R&D expense (Hand, 2003).

1.4. Value of human capital

Key employees' knowledge and skill has an obvious impact on value; indeed, scientists who have made key discoveries often start biotechs. The intellectual human capital of scientists is an important factor in the success of biotech firms (Darby and Zucker, 1996). Estimates of star scientist quality are positively correlated with biotech equity market

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values (Darby et al., 1999). To measure the quality of human capital, I use selling, general and administrative expense (SG&A) divided by the number of employees. An aspect of SG&A is the salary cost of senior management and scientists. SG&A per employee is roughly proportional to compensation of senior management and scientists, who are often one and the same in young firms (Hand, 2003). To the extent that you get the quality you pay for, this should be at least a crude measure of human capital quality. I tried to devise a better measurement such as pre-IPO stock ownership by and awards to star scientists, but this information is not available from the prospectus.[1] Although SG&A is crude, it is highly significant, implying that the results will be even stronger if I have a better measurement.

1.5. Revenue growth

Many biotech firms lack of a history of profits and meaningful book values; thus investors may rely on a change in revenue as an important financial value indicator. Sales are not a relevant measure in the case of biotechs, as many do not have sales. But they often have some revenue (e.g., from out-licensing, patents, and milestone and up-front payments).

1.6. Gross profit

Gross profit is the primary income statement variable, revenues less cost of sales.[2] Hand (2003) finds that non-operating expense appears entirely unrelated to equity market values of biotech firms. This counter-intuitive result is explained by US accounting rules for intangible assets (Hand, 2000; Zhang, 2000).[3] The result of this is that for intangible-intensive companies such as biotech or other high-tech firms, reported income is depressed because greater expense is being currently recognized than would be the case for firms in other industries. Other literature has shown asymmetries in the relation between the market value of equity and positive and negative earnings (see Hayn, 1995; Hand, 2000). These asymmetries occur because positive earnings are likely to persist, whereas negative earnings are likely to be transitory and therefore less informative about future earnings and cash flows (Basu, 1997). Zhang (2000) argues that when spending on intangibles becomes large enough, particularly by small but fast growing companies, equity market value will become a negative, not a positive, function of reported net income when net income is negative. This is exactly what Hand (2000) finds for Internet firms.

As already indicated, selling, general, and administrative expense (SG&A) and R&D expense are separated here from gross profit (revenue minus cost of sales). US accounting rules recognize revenue in a manner that closely reflects the underlying economics, and cost

[1]Only information about stock options issued to executives and directors is available. Moreover, most IPO prospectuses are available on the SEC Electronic Data Gathering, Analysis, and Retrieval (EDGAR) service only from early May 1996. Prospectuses before that can be obtained only from the firms or from Disclosure's Global Access.

[2]I use gross profit instead of net income because (1) gross profit does not contain large and distortive one-time items relative to net income, and (2) many biotech firms report net losses, which do not reflect financial viability.

[3]All expenditures on intangibles such as R&D, branding, and human capital are required to be expensed as incurred under U.S. GAAP. They cannot be recognized as assets on balance sheets and then amortized into expense over time, as with tangible fixed assets (Hand, 2003).

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of sales are only recognized when revenues are, and also in an amount that reflects the direct cost of the sales made.

In contrast, Hand (2003) argues that only a small portion of R&D spending is truly a current expense. Most R&D represents an asset that has the potential to provide future economic benefits. This is particularly true for biotech firms, where the benefits from R&D are typically obtained many years after the R&D expenditure. Selling, general, and administrative expenses are less clearly assets except the expenses to hire top management and lead scientists.

1.7. Percentage of shares offered

Percentage of shares offered is defined as the shares sold in an IPO as a percentage of total shares outstanding. Prior research implies that IPOs with lower percentage of shares offered are more valuable. There are a number of explanations for why percentage of shares offered predicts first-day returns. First, Schleifer (1986), Leland and Pyle (1977), and Schultz and Zaman (2000) use asymmetric information to explain that greater relative insider ownership should be a positive signal to investors because it indicates that the IPO is not simply a vehicle for the founders to bail out. Greater insider ownership may also produce a higher stock price because of lower agency costs, as the interests of managers and shareholders are better aligned. The second explanation is provided by Barry (1989), Habib and Ljungqvist (2001), and Ljungqvist and Wilhelm (2002). They argue that the opportunity cost of underpricing to issuers is less if the percentage of shares offered is small, and that this cost is greater for pre-issue shareholders who sell shares in the IPO than for those who retain their shares. Finally, Ofek and Richardson's (2003) scarcity value hypothesis argues that if the percentage of shares offered is small, the market price will be higher when there is a negatively sloped demand for shares. This causes high first-day returns if the offer price has not incorporated this scarcity value.

1.8. Final offer price vs. prospectus expected price

Another value indicator found in past research is the final IPO offer price relative to the expected price at the time the prospectus was filed. The partial adjustment phenomenon is directly related to underpricing, and refers to the fact that the change in the final offer price from the initial filing price range predicts the level of initial return. This phenomenon was first observed by Ibbotson, Sindelar and Ritter (1998) and empirically documented by Benveniste and Spindt (1989) and Hanley (1993). Loughran and Ritter (2002) and Edelen and Kadlec (2005) represent the most plausible explanations of partial adjustment in the literature thus far.

1.9. IPO Proceeds

The signaling model of Grinblatt and Hwang (1989) shows a monotonic correspondence between offering price at which the issue is being sold and the degree of IPO underpricing in a separating equilibrium, holding constant the firm's fractional shareholding (or, equivalently, holding constant the fractional size of the IPO). That is, if investors observe an issuer's fractional ownership and can conjecture the value of a benchmark lowest variance-issuer by looking at the relative size of its IPO, they can also infer the degree of

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IPO underpricing for any arbitrary issuer given the issuer's initial offering price and relative IPO size. I include the log of total IPO proceeds as an explanatory variable, which might reflect IPO quality and, if so, should be inversely related to first-day return. IPO proceeds equal the IPO offer price multiplied by the number of shares offered. If more information tends to be available about larger firms and that makes them more easily valued than smaller IPOs, they should exhibit lower first-day returns. Beatty and Ritter (1986), Megginson and Weiss (1991) and Michaely and Shaw (1994) have used gross proceeds as a proxy of ex ante uncertainty and show an inverse relation between underpricing and gross proceeds. However, Jenkinson and Ljungqvist (2001) show that such an inverse relation between underpricing and gross proceeds will exist absent any change in uncertainty.

1.10. Underwriter reputation

Prior evidence suggests that IPOs with more prestigious underwriters earn lower first day returns, consistent with a lower level of risk and lower information asymmetry associated with such offerings (Carter and Manaster, 1990; Megginson and Weiss, 1991). Schultz (1993) finds that the probability of firm failure within either two or three years of an IPO is negatively associated with underwriter prestige. A recent study by Logue, Rogalski, Seward, and Foster-Johnson (2002) finds no evidence of the relation between underwriter reputation and investor returns over different holding periods. Moreover, Doukas and Gonenc (2005) show that underwriter reputation is not linked to post-issue IPO performance when they control for venture capital backing. I use underwriter quality based on modifications of the Carter (1998) rankings as developed by Loughran and Ritter (2004); the rankings are between 0 (low) and 9.1 (high), so there should be a positive association between prestige and total offer value.

1.11. Funds from venture capital

A history of receiving venture capital investments seems likely to increase the probability of eventually going public. By investing, venture capitalists are revealing their expectation of exiting after a few years through a successful public offering. Their due diligence also provides a behavioral signal upon which uninformed investors can cascade (Banerjee, 1992; Bikhchandani, 1992; Welch, 1992). Participation by venture capitalists (Barry, 1990; Megginson and Weiss, 1991) signals issue quality and therefore leads to favorable valuation by the capital market (reducing the perceived uncertainty about firm value).

1.12. Recent market return

Kim and Ritter (1999) report that comparable firm multiples (e.g., book-to-market) are related to IPO valuation. Thus, valuation of IPOs could be more favorable when firms within the same industry are traded at high price levels. The value-weighted NYSE-NASDAQ-AMEX rate of return over a two-week period prior to the IPO is included as an explanatory variable to control for the market and economy-wide sentiment prevailing at the time of the IPO. If market-wide sentiment is trending higher, the IPO price might also be higher.

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1.13. High-risk warning

Klein (1996) finds that firms issuing a boldface risk warning on their prospectus cover page have lower offering prices and prices post-IPO market. A RISK dummy is used here when such a warning accompanies an IPO.

1.14. Nature of offering

Bundled offerings to public investors are packages of common stock and warrants. Previous literature such as Schultz (1993) and Klein (1996) shows that firms with bundled offerings appear to be more risky and receive lower valuations. A WARRANT is used here if the offering is bundled.

1.15. Post-offer institutional holdings

It is well known that underwriters provide institutional investors the ability to cherry-pick IPOs, in return for various benefits (information, brokerage business, future underwriting business, etc.) provided by these investors to underwriters and the firms that employ them (see, for example, Hanley and Wilhelm (1995), Aggarwal (2002), and Ljungqvist and Wilhelm (2002)). I hypothesize that biotech firms that have higher R&D spending and more key scientific personnel, both shown to be determinants of value when trading commences, were more under priced relative to firms that scored lower on these metrics. The alternative hypothesis is that the better biotech IPOs were disproportionately allocated to favored investors and that the pricing decision was deliberate and rational, and not driven by underwriter ignorance.

But if underwriters really were allocating high R&D early biotech IPOs to their best customers, why did they gradually stop doing so over time? It seems plausible that they would have continued the practice, if indeed it was intentional. I test this hypothesis by controlling for IPO allocation, which is difficult to discover. Nevertheless, Hanley and Wilhelm (1995) show that there is a strong positive correlation between institutional IPO allocation and post-IPO institutional holdings, which is publicly available. Therefore, I include post-offer institutional holdings as a control variable to test if underwriters still learn while allocating the better biotech IPOs to their favored customers.

1.16. Cancer Product

Companies with potential cancer treatments are particularly intriguing to investors because of enormous possible earnings. Billion-dollar drugs are likely to be produced by some of these companies, so I include a CANCER dummy for IPOs to test if they are materially distinct.

1.17. Age/maturity

Firm age proxies for the degree of ex ante uncertainty about the IPO firm. Clarkson (1994) and Beatty (1989) find a negative and significant relation between firm age and underpricing for IPOs in the late 1970s and early 1980s. More established biotech firms have some advantages over startup biotech firms. For instance, they tend to have larger

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budget to fund a variety of new projects. As such, they can afford to hire more knowledgable consultants and establish stragic alliances with other parties such as universities, and pharmaceutical/biotech firms. On the other hand, established biotech firms tend to promote scientists to administrative positions, thus leaving discovery research to junior scientists. As a consequence, scientists, who like to maintain their knowledge, are more likely to work for startup biotech firms where they can devote more time to research than management (Graves and Langowitz, 1993).

2. Sample selection and descriptive statistics

2.1. Biotech firms

For January 1980–December 2004, biotech IPOs are identified from the Securities Data Company's (SDC) New Issues database. I have also updated the data from SDC using the corrections listed on Professor Jay Ritter's web page: http://bear.cba.ufl.edu/ritter/SDCCOR.PDF. The initial selection includes all IPOs with an SDC biotechnology indicator variable equal to one. This initial sample is then restricted to include only scientifically-oriented biotech firms, defined as those with one of the following primary SIC industry sector codes: 2833 (medicinal chemicals and botanical products), 2834 (pharmaceutical preparations), 2835 (in vitro and in vivo diagnostic substances), 2836 (biological products, except diagnostic substances), and 8731 (commercial physical and biological research). These SIC codes are consistent with standard industry classifications for scientifically oriented biotech companies (see, e.g., Ernst and Young, 2000).

Since the focus here is on new biotech firms, large pharmaceutical (so-called ''big pharma'') firms in the master list identified from www.phrma.org and Robbins and Roth (2000) are excluded. The selection process results in a sample of 481 US-based, scientifically oriented biotechnology IPOs that went public from the industry's infancy in 1980 through the end of 2004. The sample includes currently traded biotech firms and firms that are no longer publicly traded, typically because of bankruptcy or acquisition.[4] After imposing CRSP data availability constraints, 447 firms remain in the biotechnology sample. Prior studies of IPO pricing usually exclude certain types of IPOs and certain sectors in order to obtain a more homogenous sample. I thus verify that these 447 IPOs are not equity carve-outs, financial companies, ADRs, reverse LBOs, best efforts IPOs, and issues raising less than $5 million. Market values and delisting events are obtained from the Center for Research in Security Prices (CRSP) databases. Data related to IPO deal characteristics and biotech sample identification is taken from the SDC New Issues Database, while financial data is obtained from the Compustat database.[5] Financial data that is missing from Compustat and information about products are hand-collected from issuing companies' prospectuses and S-1 Registration filings. Post-offer institutional holdings data is defined as the number of shares owned by institutions divided by the estimated public float. It is available on 13F institutional holdings forms and in electronic form from Thompson Financial. I collect this data at least one month after the issue and exclude institutions that owned shares prior to the IPO. I omit any institution listed as a

[4]Restricting the sample to surviving biotech firms would induce obvious problems.

[5]Quarterly Compustat's coverage of R&D only begins in the first quarter of 1989. On the contrary, Compustat reports annual R&D expense under Statement of Financial Accounting Standards No. 2 starting in 1974.

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venture capitalist on SDC or whose name suggests it is a venture capitalist (Dor, 2004). Moreover, I ignore any institution that is listed as owning more than 15% of the shares offered in the IPO because normally it is extremely unlikely for any investor to receive such a large allocation in the IPO, implying that it probably owned these shares before the IPO (Field and Lowry, 2004).

Post-offer institutional holdings percentage is computed as the number of shares owned by institutions divided by the estimated public float. The float should be approximately equal to the total number of shares offered in the IPO, which is equal to shares offered as listed in the prospectus plus the over allotment option.[6] The over allotment option must be estimated for some issues since SDC does not provide this information for all issues. Based on Aggarwal (2000), who finds the relation between first-day return and over allotment option, I assume that IPOs that have first-day returns higher than 5% have floats equal to 115% of the shares offered. On the other hand, IPOs that have first day returns less than or equal to 5% have floats equal to 105% of shares offered. Following this procedure, the mean (median) post-offer institutional holdings as a percentage of public float is 23.37% (28.24%) for biotech firms and 32.05% (36.61%) for non-biotech firms.

Finally, underwriter quality is based on rankings originally assigned to underwriters by Carter and Manaster (1990), and Carter, et al. (1998). This study uses modified rankings as developed by Loughran and Ritter (2004); the numerical rankings vary between 1.1 (low) and 9.1 (high).

2.2. *Non-biotech matching firms*

For each biotech IPO in the sample, data are collected for a matching firm that is not a biotech and that had an IPO date within three days of the biotech IPO. By matching within three days of IPO, the market conditions are similar for the two firms. If the IPOs were far apart in time, they would have appeared in different market environments. A matching firm had comparable total offer value, revenue growth, and revenue divided by gross costs in the most recent fiscal year. (Using revenue/costs allows the inclusion of firms with negative earnings or negative EBITDA.) Note that gross costs are always simply revenue minus EBITDA. Total offer value controls for size and revenue divided by gross costs can control for differences in profitability across firms. The first-day IPO market capitalization is not used in matching because it would not be available to an investor or underwriter before the offering date. Since revenue divided by gross costs measures operating profitability, it is a more stable measure of profitability than revenue divided by net costs, which are affected by interest expense. For each biotech IPO, I get a matching firm that is closest in total offer value, revenue growth, and revenue divided by gross costs. In some cases, the matching firms are repeated as there are only a few firms that meet the criteria. This matching method is similar to Kim and Ritter (1999) who argue for controlling for differences in size, growth and profitability.[7]

[6]Field and Hanka (2001) show that shares that are subject to lock-up provisions and Rule 144A restrictions are not part of the float.

[7]I also choose matching firms based on the other two criteria. The first one is based on size. I choose non-biotech firms whose market capitalization as of the prior June or December is closest to the market capitalization of the IPO firm at close on the offering date. The second is based on market capitalization and book-to-market ratio where book value of equity is for the fiscal years following the IPO date. The results are not sensitive to the choice of matching criteria.

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To choose a particular matching firm, I first select all non-biotech IPOs in the SDC database that have an IPO date within three days of the biotech's IPO date. From these firms, REITs, closed-end funds, ADRs, and firms with share prices less than five dollars are deleted. Potential matching firms are expunged unless their total offer value is between 75% and 125% of the biotech's total offer value. From this set, potential matching firms are selected if their revenue growth is between 75% and 125% of the biotech's revenue growth and then, from the final set, the single non-biotech IPOs is chosen, the one whose revenue divided by gross costs is closest to that of the biotech. If I have no firms left, I widen the bands at each step.

2.3. Data Definitions and Sources

Appendix A lists and defines the variables used in the study and gives their quarterly Compustat item numbers when relevant. Income statement variables are shown in panel A, balance sheet variables in panel B, and IPO and biotech information in panel C. R&D expense is set to zero when Compustat indicates it is missing (i.e., immaterial). Since Compustat includes R&D in selling, general and administrative expenses (SG&A), SG&A is redefined to exclude R&D when SG&A is non-missing. All dollar amounts are restated into 2004 dollars using the CPI in December 2004.

2.4. Historical and Summary Statistics

Table 1 presents a frequency distribution of biotechnology IPOs by calendar year. As is evident, there have been several waves of biotechnology IPO "hot issues markets" and the IPOs exhibit clustering patterns over time that are consistent with the general phenomenon documented by Ibbotson and Jaffe (1975), Ritter (1984), and Lowry and Schwert (2002), among others.

Table 2 reports key economic and scientific variables for the US biotech IPOs, under the assumption that the biotech firms in this database comprise the entire US biotech industry. The dollar-denominated variables shown in Table 2 are reported for the year prior to IPO, which is calculated from the quarterly average, and are expressed in real terms using the CPI at the end of December 2004.[8] Of the non-dollar-denominated variables, the number of employees and the number of biotech firms are year-end.

The average (median) market value of biotech stocks at the end of their first day of trading was \$204.64 (135.60) million, which is considerably higher than the \$183.61 (119.36) million value of non-biotech stocks. The average (median) proceeds raised by biotech IPOs was \$35.79 (\$21) million, not significantly different from the proceeds of \$56 (\$24.36) million raised by non-biotech IPOs. The average (median) total offer value of biotech firms was \$175.59 (106.47) million, which is not significantly different from the \$169.08 (112.01) million value of non-biotech firms. While the first-day returns for both samples are positive, first-day returns of biotech IPOs (13.30%) are significantly higher on average than those of the non-biotech IPOs (10.96%). The frequency of VC backing is higher for biotech IPOs, with 87% (35%) of biotech (non-biotech) firms being VC-backed. Investment banking reputation is higher for biotech IPOs, with an average reputation

[8]For some firms for which quarterly data are not available from Compustat, I use the annual data to create a quarterly estimate. Specifically, I calculate the quarterly average financial data for the year prior to IPO.

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Table 1
Biotech IPOs by year, 1980–2004
There are 447 biotech IPOs in the sample, issued by year as shown below.

Year	Number	Biotech IPOs (1980–2004)		
		Cumulative number	Percentage of all IPOs	Cumulative Percentage
1980	2	2	0.45	0.45
1981	8	10	1.79	2.24
1982	5	15	1.12	3.36
1983	24	39	5.37	8.72
1984	3	42	0.67	9.40
1985	3	45	0.67	10.07
1986	21	66	4.70	14.77
1987	10	76	2.24	17.00
1988	3	79	0.67	17.67
1989	3	82	0.67	18.34
1990	5	87	1.12	19.46
1991	30	117	6.71	26.17
1992	32	149	7.16	33.33
1993	22	171	4.92	38.26
1994	21	192	4.70	42.95
1995	22	214	4.92	47.87
1996	39	253	8.72	56.60
1997	21	274	4.70	61.30
1998	9	283	2.01	63.31
1999	11	294	2.46	65.77
2000	48	342	10.7	76.51
2001	23	365	5.15	81.66
2002	13	378	2.91	84.56
2003	28	406	6.26	90.83
2004	41	447	9.17	100.00

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index of 6.80 (6.03) for biotech (non-biotech) firms. Post-offer institutional holdings per public float on average are lower for biotech IPOs, with a percentage of 23.37% (32.05%) for biotech (non-biotech) firms.

Although some financial variables (e.g., EBITDA) are lower for biotech firms, growth of revenues, 37.54% (32.2%), and R&D expenditures, 7.93 (1.32), are higher for biotech (non-biotech) IPOs. Table 2 indicates also that, on average, biotech IPOs are characterized by a higher frequency of VC backing and are larger in terms of market capitalization, (though smaller in the number of employees) at the time of going public. Also, they experience higher first-day returns, have lower dollar proceeds, sell a smaller fraction of shares (percentage of shares offered), and have lower post-offer institutional holdings in the offering.

Some striking observations emerge from Table 3, which provides a few summary statistics by five–year periods. Over biotech history, 1980–2004, the first-day market capitalization per IPO firm rose 473% from $391.47 million during 1980–1984 to $2,245 million during 2000–2004, inflation adjusted. Second, while some of this huge increase is due to an increase in pre-IPO tangible assets from $28.94 million to $131.93 million, an

Table 2
Descriptive statistics

There are 447 biotech and 447 non-biotech matching IPOs from January 1, 1980–December 31, 2004. The matching firm is a non-biotech that went public within three days of the biotech IPO and had comparable total offer value, revenue growth, and revenue divided by gross costs (revenue minus EBITDA) in its most recent fiscal year. All variables are for the fiscal year prior to the IPO and their descriptions are in the Appendix. Dollar quantities are in millions. The Z statistic is computed using the Wilcoxson Signed Rank test for the difference in medians. White's heteroscedasticity-adjusted t-statistic provides a test for the difference in means.

Variables	Biotech firms		Non-biotech firms		Difference	
	Mean	Median	Mean	Median	T stat	Z Stat
First-day market value ($)	204.64	135.60	183.61	119.36	2.30	1.92
IPO proceeds ($)	35.79	20.96	55.92	24.36	−1.24	−0.83
Total offer value ($)	175.59	106.47	169.08	112.01	0.34	−0.61
First-day return	13.30%	3.30%	10.96%	9.24%	2.45	−2.20
Percentage of shares offered	26.30%	20.30%	35.72%	28.74%	−2.68	−2.08
Offer vs. Filing price	19.44%	2.05%	4.02%	−0.38%	3.61	3.35
VC backing	0.87	1.00	0.35	0	3.13	3.07
Underwriter reputation	6.80	8.67	6.03	5.37	1.53	1.21
Post-offer institutional holdings	23.37	28.24	32.05	36.61	−1.07	−1.52
Research & development expense ($)	7.93	6.06	1.32	0.31	3.03	2.81
Sales, general, and administrative expense ($)	6.60	5.98	7.03	8.21	−1.67	−1.26
Total assets ($)	14.88	10.16	59.05	27.06	−1.09	−1.18
Long term debt ($)	1.91	1.26	5.19	3.15	−2.69	−1.54
Revenue ($)	4.42	2.27	7.14	2.93	−1.20	−0.85
Growth of revenue	37.54%	25.21%	32.2%	23.48%	1.07	1.32
EBITDA ($)	−6.92	−4.76	−3.08	−2.12	−1.18	−1.47
Revenue/gross costs	0.385	0.307	0.612	0.559	−1.26	−0.93
Net income ($)	−8.46	−6.15	−0.08	0.03	−1.65	−2.94
Warrant	7.09%		6.57%		0.33	
Risk warning	47.12%		39.55%		1.12	
Market rate of return	14.71%	15.28%	12.77%	9.68%	2.86	2.83
Cancer product	0.32					
Firm age (years)	1.61	1.73	2.25	3.26	−1.17	−1.03
Number of employees	152	123	576	750	−1.55	−1.88
R&D/revenue	1.78	2.34	0.24	0.15	3.64	3.89
Growth of R&D	22.25%	16.12%	3.57%	4.16%	3.04	3.02
SG&A/number of employees	0.0416	0.0358	0.0135	0.0124	2.76	2.87

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increase of 350%, which reflects the increase in pre-IPO R&D spending. R&D spending rose from an annual rate of $11 million during 1980-1984 to $81 million during 2000- 2004, an increase of 633%. It is immediately expensed to firms' income statements rather than capitalized as an asset and then amortized into expense over time Under U.S. GAAP (Hand, 2003). The immediate expensing of the intangible R&D asset each year also explains why biotech firms' retained earnings have become more negative over time (Hand, 2003).

Third, biotech firms have little debt, reflecting the high intrinsic risk of biotech firms as well as the reluctance of banks and other fixed-rate lending institutions to accept R&D as collateral. Fourth, biotech firms do not have sufficient revenue to create

Table 3
Descriptive statistics

Year-by-year averages for 447 biotech IPOs issued from January 1, 1980 – December 31, 2004. Dollar values in millions. Descriptions of all variables are in the appendix.

	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004
First-day market value	391.47	604.23	731.18	1,144.20	2,244.97
Total assets	29.34	33.14	70.12	107.43	131.93
Long-term debt	3.83	3.90	9.28	14.70	15.71
R & D expense	11.05	21.52	35.89	48.71	81.00
Revenue	19.17	16.30	15.00	20.34	39.77
EBITDA	(34.92)	(34.83)	(35.70)	(34.16)	(33.50)
Net income	(41.06)	(41.22)	(42.81)	(43.61)	(42.75)
SG&A expense	8.85	20.21	33.26	39.53	59.26
Number of employees	370.00	430.00	764.71	1,391.00	1,050.56
10*R&D expense/revenue	28.91	69.40	122.37	121.92	102.61
First-day market value/total assets	75.45	96.63	52.34	53.22	86.28
Growth of R&D expense	65.06	89.58	95.23	150.84	166.19
(SG&A*1000)/number of employees	121.16	263.59	226.55	144.26	284.60

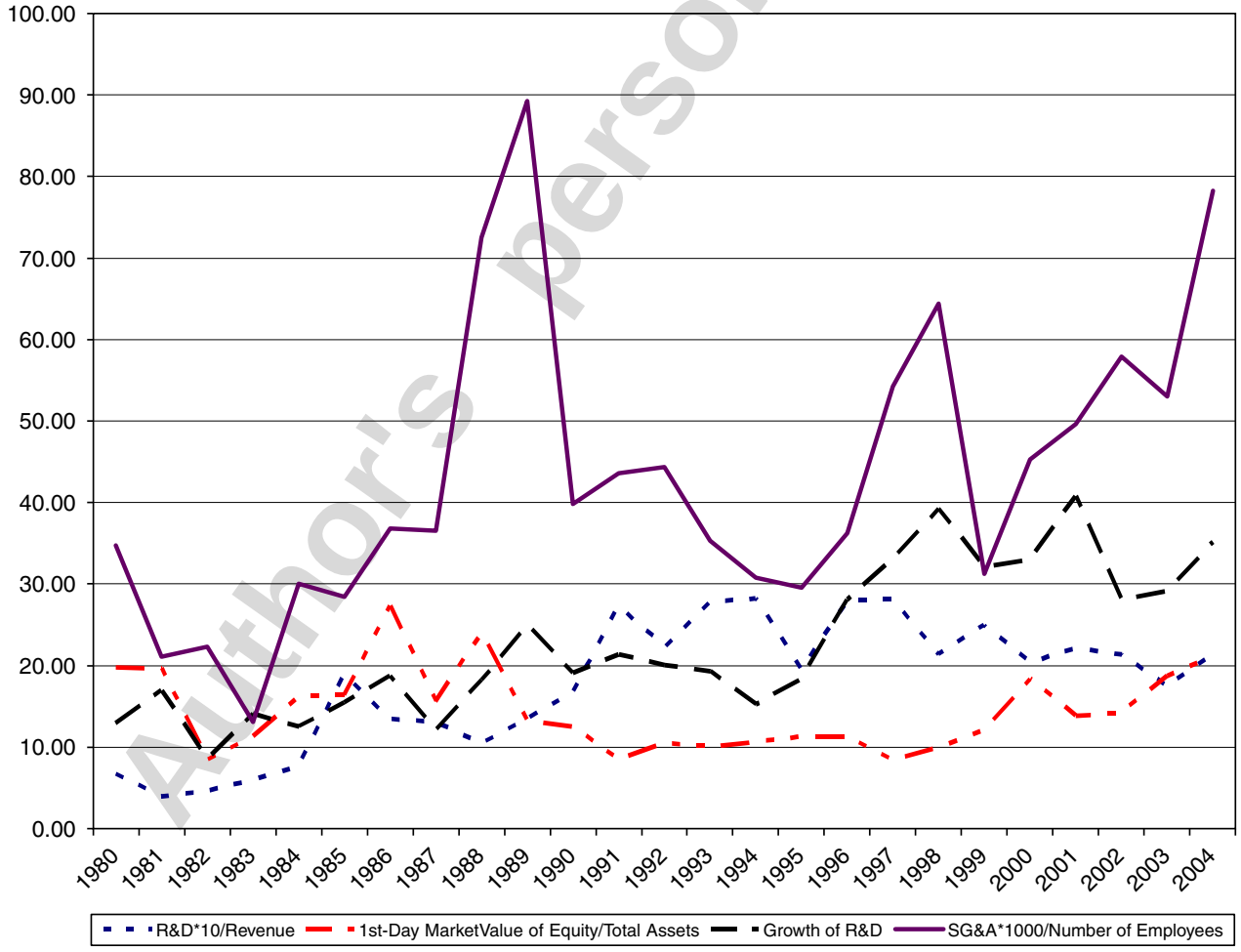

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Fig. 1. This figure plots descriptive statistics of various median biotech IPO attributes over time. There are a total of 447 biotech IPOs issued from January 1, 1980 through December 31, 2004. Descriptions of all variables are in the appendix.

positive net income per year; even though pre-IPO revenues have increased 205% over the period 1980–2004 and 107% from 1980–1984 to 2000–2004. Furthermore, biotech firms are able to raise additional funding due to market potential from future innovation.

An alternative perspective on biotech IPO history is provided in Fig. 1, which plots various median ratios over time. R&D/revenue, growth of R&D, quality of human capital (SG&A/number of employees), and market value/total assets rise and fall together in an almost cyclical pattern during the history of biotech IPOs.

Table 4 presents the Pearson correlation coefficients among the variables used in this study. Of the financial variables examined, revenue and earnings are positively correlated with total offer value and first-day market value. While SG&A and R&D are negatively correlated with these IPO values for non-biotech firms, they are positively correlated for biotech firms. Venture capital backing, underwriter ranking, and partial (float, risk warning, and warrants) are positively (negatively) correlated to IPO values for both biotech and non-biotech firms.

Table 5 concludes the descriptive statistics with percentiles for the data; 79% have positive revenues and 96% spend money on R&D, but only 37% report positive EBITDA. The median firm has been founded for two years before IPO and employs 123 people. The median first-day market value is $136 million. The median real growth rate in revenues is 25.21% per year (see Table 2). Biotech firms have few tangible fixed assets but spend very intensively on R&D. The median firm spends over two times of its revenue on R&D and its R&D spending is growing 16.12% per year. Five percent of biotech firms have R&D growth rates exceeding 130%. A noteworthy feature of the data is that every variable is highly right-skewed.

3. Empirical Results

3.1. Univariate Comparisons

Table 6 categorizes biotech IPOs into high and low scientific groups based on growth of R&D, the timing of R&D spending (R&D expenditure divided by revenue), and the quality of human capital (SG&A expenditures per employees). IPOs with high R&D growth, with R&D spending early in the discovery chain, and with higher quality of human capital have higher first-day market value, first-day return, growth of revenue, SG&A expense, R&D expense and VC funding but lower total offer value. They have lower total assets, number of employees, age, revenue, and EBITDA. The differences of all variables between these two scientific groups are highly significant. These patterns are interesting, but there are so many interactions that only a multivariate approach can sort them all out.

3.2. Cross-Sectional Regression Specifications

Perhaps it would be worthwhile to reiterate first that three separate regressions are presented in all the tables from 7 onward. They differ only in the dependent variables, which are (1) the IPO offer value, the value established by the underwriters, (2) the market value at the end of the first day of trading, and (3) the first-day return, the percentage change between the first day ending market value and the offer value. By comparing a

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Table 4
Correlation coefficients of biotech and non-biotech IPOs

There are 447 biotech and 447 non-biotech matching IPOs from January 1, 1980 – December 31, 2004. The matching firm is a non-biotech that went public within three days of the biotech IPO and had comparable total offer value, revenue growth, and revenue divided by gross costs (revenue minus EBITDA) in its most recent fiscal year. Descriptions of all variables are in the Appendix. Pearson correlation coefficients for biotech (non-biotech) IPOs are reported above (below) the diagonal.

	Total offer value	First day market value	Revenue	Net income	SG&A expense	R&D expense	Percentage of shares offered	VC backing	Underwriter reputation	Risk warning	Warrant	Offer price vs. filing price
Total offer value		0.97	0.14	0.24	0.64	0.73	−0.40	0.16	0.09	−0.13	−0.05	0.46
First-day market value	0.83		0.31	0.12	0.82	0.86	−0.43	0.23	0.10	−0.18	−0.31	0.49
Revenue	0.31	0.16		0.17	0.12	0.32	−0.03	0.12	0.16	−0.17	−0.05	0.07
Net income	0.37	0.49	0.38		−0.03	−0.21	−0.04	0.11	0.08	−0.09	−0.01	0.13
SG&A expense	−0.04	−0.21	−0.17	−0.20		0.13	−0.15	0.15	0.03	−0.01	−0.05	0.12
R&D expense	−0.02	−0.03	−0.30	−0.30	−0.02		0.22	0.35	0.04	−0.03	−0.09	0.15
Percentage of shares offered	−0.17	−0.42	−0.19	−0.05	0.14	−0.29		−0.17	−0.20	0.27	0.16	−0.20
VC backing	0.02	0.04	0.02	0.40	−0.24	−0.17	−0.23		0.35	−0.11	−0.14	0.38
Underwriter reputation	0.16	0.26	0.03	0.02	−0.05	−0.22	−0.19	0.22		−0.03	−0.07	0.20
Risk warning	−0.44	−0.36	−0.21	−0.04	0.03	0.18	0.06	−0.19	−0.03		0.03	−0.30
Warrant	−0.31	−0.33	−0.28	−0.13	0.05	0.03	0.10	−0.22	−0.17	0.24		−0.12
Offer vs. filing price	0.38	0.56	0.27	0.04	−0.14	−0.24	−0.21	0.28	0.13	−0.09	−0.09	

Table 5
Percentiles for biotech IPO attributes

For 447 biotech IPOs in the sample from January 1, 1980 to December 31, 2004, percentiles of various firm attributes are reported below. Values, expenses and income are in $ millions. Descriptions of all variables are in the appendix.

Percentile (%)	1st Day market value	Total assets	Revenue	EBITDA	R&D expense	Firm age (Years)
100	782.13	138.87	24.82	441.67	108.49	8.82
99	680.40	105.15	21.60	29.16	37.93	7.86
95	532.70	99.10	18.83	8.55	26.82	5.26
75	328.75	79.28	13.38	0.66	8.03	3.89
50	135.60	10.16	2.27	−4.76	6.06	1.73
25	52.23	7.10	1.06	−7.47	3.54	0.81
5	10.27	0.90	0.00	−11.61	1.26	0.14
1	0.63	0.05	0.00	−20.89	0.71	0.09
0	0.00	0.00	0.00	−32.17	0.00	0.00
% > 0	100%	100%	79%	37%	96%	100%

Percentile (%)	Number of employees	Market value/total assets	R&D/ Revenue	Growth of R&D (%)	SG&A/Number of employees
100	614	8465.92	1320.10	1000%	0.552
99	579	69.89	84.84	363.50	0.106
95	432	32.18	19.79	129.00	0.087
75	345	25.23	7.45	71.07	0.053
50	123	12.08	2.34	16.12	0.036
25	54	8.83	0.09	8.14	0.007
5	23	3.82	0.00	0.83	0.005
1	19	0.54	0.00	−9.18	0.003
0	5	0.09	0.00	−36.81	0.0007
% > 0	100%	100%	89%	96%	100%

given variable across these three regressions, we can ascertain how the underwriters differed from the market in their valuations and how those differences were resolved over time. Here is a list of possible patterns across the regressions for a single explanatory variable, and what the pattern implies:

Case #1: Insignificance in all regressions: neither the underwriters nor the market thinks the variable is a value driver.

Case #2: Insignificance for offer value but significance for first-day returns and ending market value: underwriters do not think this variable matters for value but the market does.

Case #3: Significance in all three regressions, offer value, market value, and first-day returns: underwriters think this variable is important, but the market thinks it's even more important for value; i.e., the importance (relative to the market's view) is only partially taken into account by underwriters.

Case #4: Insignificance in first day returns but significance in offer value and market value: both underwriters and the market think this variable is a value driver and they agree on the extent of its importance.

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Table 6
Characteristics of biotech IPOs classified according to R&D expense and human capital quality

447 Biotech IPOs from 1980 through 2004 are bifurcated by the following attributes: growth of research and development expenses, quality of human capital (SG&A expense/Number of Employees), and timing of R&D expense in discovery chain (R&D expense/revenue). The table reports within-group medians. *P*-values are for *Z*-statistics based on a Wilcoxson 2-sample rank sum tests for differences in medians (Normal approximation). Descriptions of all variables are in the appendix. The number of IPOs in each group is denoted by *n*. Revenues, expenses, and values are in $ millions.

Classification by R&D growth

	First-day closing market value	Total offer value	First-day return (%)	VC backing	Total assets	Number of employees	Number of years firm founded before IPO	Revenue
High Growth of R&D ($n = 171$)	340.05	102.42	13.76	0.79	4.23	123	1.21	1.86
Low Growth of R&D ($n = 171$)	69.86	248.03	1.30	0.56	24.16	180	2.03	7.06
p-value	0.001	0.001	0.003	0.001	0.001	0.002	0.002	0.001

	SG&A expense	R&D expense	EBITDA	R&D/revenue	Growth of R&D (%)	SG&A/number of employees	Growth of revenue (%)
High Growth of R&D ($n = 171$)	7.71	9.64	−7.48	2.18	66.71	51,638	65.41
Low Growth of R&D ($n = 171$)	5.64	6.22	−6.32	1.39	51.78	34,625	9.39
p-value	0.002	0.001	0.001	0.002	<0.001	0.001	<0.001

Classification by SG&A expense/number of employees

	First-day closing market value	Total offer value	First-day return (%)	VC backing	Total assets	Number of employees	Number of years firm founded before IPO	Revenue
High SG&A/number of employees ($n = 171$)	286.68	125.66	13.15	0.76	8.52	74	1.14	2.81
Low SG&A/number of employees ($n = 171$)	123.13	225.10	1.54	0.54	20.70	229	2.07	6.10
p-value	0.001	0.001	<0.001	0.003	0.001	<0.001	0.003	0.002

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Table 6 (*continued*)

Classification by SG&A expense/number of employees

	First-day closing market value	Total offer value	First-day return (%)	VC backing	Total assets	Number of employees	Number of years firm founded before IPO	Revenue
	SG&A expense	R&D expense	EBITDA	R&D/revenue	Growth of R&D (%)	SG&A/number of employees	Growth of revenue (%)	
High SG&A/number of employees ($n = 171$)	7.95	9.62	−7.56	2.23	63.08	53,271	72.50	
Low SG&A/number of employees ($n = 171$)	5.39	6.23	−6.26	1.35	55.42	32,992	2.33	
p-value	0.003	0.002	<0.001	<0.001	0.001	<0.001	<0.001	

Classification by R&D Expense/Revenue

	First-day closing market value	Total offer value	First-day return (%)	VC backing	Total assets	Number of employees	Number of years firm founded before IPO	Revenue
	SG&A expense	R&D expense	EBITDA	R&D/revenue	Growth of R&D (%)	SG&A/number of employees	Growth of revenue (%)	
High R&D/revenue ($n = 171$)	281.72	133.46	14.59	0.77	6.12	108	1.10	2.17
Low R&D/revenue ($n = 171$)	128.10	216.90	1.07	0.58	22.84	195	2.13	6.75
p-value	<0.001	0.001	0.001	0.002	0.001	0.003	0.004	0.001
High R&D/revenue ($n = 171$)	7.77	9.67	−7.41	2.06	71.29	52,874	61.12	
Low R&D/revenue ($n = 171$)	5.58	6.18	−6.42	1.51	47.20	33,389	13.88	
p-value	0.001	0.004	<0.001	0.001	<0.001	0.001	0.001	

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All these cases occur for various explanatory variables in regressions reported in Table 7 and beyond. Underwriter learning over time, ranging from completely ignoring the variable to ultimately taking it into account to the same extent as the market, would be indicated by Case #2 above initially, then Case #3 in later IPOs, and finally Case #4 in even later IPOs. Table 7 presents cross-sectional regressions for total offer value scaled by total book assets, scaled first-day closing market value, and first-day returns, using all biotech IPOs during 1980-2000 inclusive. All explanatory variables are taken from the complete fiscal year prior to the IPO. To reduce the impact of skewness, the first two regressions use logs of the scaled values. Separate regressions are reported for biotechs and matched non-biotech IPOs. The significance of the differences between each pair of corresponding coefficients is indicated by a p value.[9]

3.3. Offer value regressions

In the regressions for offer value (scaled by total assets), human capital quality and revenue growth are significant for biotech firms but not for non-biotech firms and the difference is significant at the 10% level.

There are also differences at the 10% level with biotech firms having the smaller positive (negative) coefficient for positive profit margin, (risk warning), and (warrant). These latter results suggest, respectively, that biotech firms need not have had positive profits, risk warnings damage them less, and attached warrants represent a less negative signal for them.

There are also differences at the 5% level with biotech having the larger negative coefficient for percentage of shares offered but the larger positive coefficient for offer vs. filing price, post-offer institutional holdings, and ln(proceeds). These coefficients of nonbiotech firms are significant, but smaller in absolute terms than those of biotech firms. This result indicates that IPOs with a lower percentage of shares offered but higher offer price adjustment, higher post-offer institutional holdings, and higher ln(proceeds) are also more valued by underwriters.

3.4. First day returns and first day market value regressions

The second and third regressions in Table 7, where the dependent variables are, respectively, the total scaled market value at the end of the first day of trading and the first day's total return, have many similarities, as could have been anticipated. R&D/Revenue, R&D growth, and SG&A/Employees are positive and highly significant for biotech firms but not for non-biotech firms. This points to the overwhelming importance of patents and other proprietary capital for biotech firm valuations. Note that all the R&D related variables and the cancer product indicator are insignificant in the offer value regression; this seems to indicate that underwriters are not properly accounting for the significance of R&D (or a cancer product) in the eyes of investors when they establish the IPO offer price.

At the offer, it also seems that underwriters are underestimating the significance of human capital quality (i.e., SG&A/number of employees) and of revenue growth. These variables are significant for biotech firms in the offer value regressions but have strong

[9]To test the differences between coefficients, the regressions are recalculated with a slope dummy on each variable for biotech firms (and no dummy for the matched non-biotech firms.) The p-value is for the slope dummy.

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Table 7
Determinants of offer value, first-day closing market value, and first-day return

This table presents regressions of total offer value (scaled by total assets), scaled first-day closing market value, and first-day returns of 342 biotech and non-biotech IPOs that went public from January 1, 1980 to December 31, 2000. The non-biotech IPOs are matching firms that went public within three days of the biotech's IPO date, had comparable total offer value, revenue growth, and revenue divided by gross costs (revenue minus EBITDA) in its most recent fiscal year. White's heteroscedasticity-adjusted t-statistic is shown under each coefficient. *P* (Diff) is the *p*-value from a *t*-test for the difference between corresponding coefficients of biotech and non-biotech firms. *** Indicates statistical significance at the 1% level. ** Indicates statistical significance at the 5% level. * Indicates statistical significance at the 10% level.

Explanatory variable	Ln[offer value/total assets]			Ln[1st-day closing market value/total assets]			First-day return		
	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)
Revenue growth	0.424	0.018	0.087*	0.737	0.053	0.029**	0.368	0.027	0.164
	1.759*	0.040		2.515**	0.082		1.597	0.035	
Positive	0.340	0.943	0.075*	0.482	1.733	0.036**	0.034	0.854	0.167
Profit margin	0.966	1.853*		1.558	2.716**		0.371	1.484	
Negative	−0.319	−0.085	0.235	−0.013	−0.019	0.259	0.434	0.031	0.148
Profit margin	−0.164	−0.308		−0.110	−0.189		0.185	0.335	
% of Shares offered	−0.817	−0.156	0.048**	−0.946	−0.276	0.004***	−0.432	−0.109	0.006***
	−2.304**	−1.856*		−2.678**	−1.943*		−2.226**	−1.917*	
Offer vs. filing price	0.378	0.357	0.030**	1.038	0.683	0.041**	0.497	0.268	0.004***
	2.396**	2.093**		2.583**	2.040**		2.366**	1.812*	
Ln(proceeds)	1.087	0.710	0.023**	0.974	0.596	0.028**	−0.176	−0.234	0.125
	2.453**	1.791*		2.425**	2.105**		−1.174	−1.008	
Underwriter	1.067	0.229	0.178	0.762	0.133	0.134	−0.302	−0.175	0.126
Ranking	1.711	1.768*		1.167	0.849		−1.154	−1.276	
Venture capital	−0.718	−0.059	0.164	−1.554	−0.277	0.061*	−0.634	−0.219	0.165
Backing	−1.165	−0.173		−1.969*	−1.663		−1.685	−1.671	
Market return	0.507	0.143	0.196	1.532	0.334	0.065*	0.990	0.119	0.298
	0.971	0.393		1.922*	0.726		1.439	0.392	
Risk warning	−0.185	−0.370	0.072*	−0.497	−0.674	0.008***	−0.174	−0.172	0.162
	−1.056	−3.080***		−1.642	−2.241**		−1.066	−1.583	

Warrant	−0.221	−0.265	0.064*	−0.595	−0.465	0.034**	−0.375	−0.285	0.173
	−0.141	−2.408**		−0.801	−2.315**		−0.493	−1.440	
Institutional	0.839	0.542		1.200	0.808		0.151	0.200	
Holdings	2.157**	1.966*	0.031**	2.732**	2.121**	0.024**	2.134**	2.159**	0.008***
Cancer product	0.252			1.903			1.447		
	0.572			2.833***			2.329**		
R&D/revenue	0.233	−0.179	0.106	1.240	−0.237	0.006***	0.842	−0.098	0.046**
	1.178	−1.105		3.510***	−1.253		2.348**	−0.748	
R&D growth	0.609	0.134	0.126	1.344	0.125	0.029**	0.750	−0.021	0.080*
	1.177	0.968		2.655**	0.902		2.417**	−0.173	
Firm age	−0.241	0.084	0.170	−0.326	0.134	0.151	−0.146	0.071	0.150
	−0.899	0.894		−1.566	1.174		−1.015	1.075	
SG&A/employees	0.500	−0.129	0.089*	1.529	−0.181	0.003***	0.978	−0.125	0.010***
	1.826*	−1.318		3.789***	−1.548		2.652**	−1.110	
Adjusted *R*-square	29.68%	33.52%		56.25%	36.87%		39.47%	14.29%	

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additional influences on first-day ending market value and on first-day returns (in the case of SG&A/number of employees.) The market reaction to R&D variables or human capital quality on the first day is material and significant. These variables are insignificant for non-biotech IPOs.

Conversely, positive profit margin seems to have at least a marginally significant impact on non-biotech firms on the first day of market value but not on biotech firms. Again, this points to nonchalance by investors about previous biotech profits along with an underestimation by underwriters of profit's significance for non-biotech IPOs. Positive profit margin is not significantly related to first-day return, which suggests that underwriters recognize most of the impact of profit margin when they estimate the offer value.

Other interesting patterns involve the fraction of shares offered in the IPO, the risk warning, attached warrants, venture capital backing, the market rate of return, post-offer institutional holdings, and the offer price relative to the filing price range midpoint.

In the case of shares offered, both biotech and non-biotech firm first-day returns (and closing prices) are strongly and negatively influenced by firms offering a larger percentage of their existing shares to the public. This is not surprising since it represents a rather obvious negative signal. What is surprising, however, is that underwriters do not seem to take adequate account of this predictable reaction, a reaction that is much larger for biotech firms than for non-biotech firms.

The risk warning likewise affects first-day market value negatively, but in this instance the impact is larger for non-biotech firms and it is significant only for them. This suggests that investors consider all biotech firms highly risky, so they are not put off by a mere warning. The exact same pattern obtains for IPOs with warrants; again, the implied negative signal is virtually ignored for biotech firms. These two variables are not significantly related to the first-day returns of either biotech or non-biotech firms indicating that underwriters take them into account when they estimate offer value. Venture capital backing (market return) is negatively (positively) associated with first-day market value for biotech firms only. There is no significant association for non-biotech firms or for either category of firms with offer value. Again, underwriters appear to be under-emphasizing the importance that the market evidently places on venture capital backing and market rate of return for biotech IPOs.

When the offer price is above the midpoint of the filing price range, the percentage of shares offered is lower, and post-offer institutional holdings are higher, all firms have significantly higher first day returns, but the impact is larger for biotech IPOs (in the case of offer price vs. filing price and percentage of shares offered). This implies that underwriters still learned while allocating the better biotech IPOs to their favored customers. When the IPO proceeds are higher, all firms have higher first-day closing prices, but insignificantly lower first-day returns. Again, a question arises about underwriter pricing.

3.5. Underwriter mispricing?

There appear to be several differences between biotech and non-biotech IPOs, but perhaps the most intriguing aspect of Table 7 is how R&D/Revenue and R&D growth fail to affect the offer value. Instead, they show up strongly in the second and third regressions that measure prices on an IPO's first day of trading. On the other hand, SG&A/employees

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Table 8
Out of sample results

This table reports regressions of total offer value (scaled by total assets), scaled first-day closing market value, and first-day returns of 105 biotech and non-biotech IPOs that went public from January 1, 2001 to December 31, 2004. The non-biotech IPOs are matching firms that went public within three days of the biotech's IPO date, had comparable total offer value, revenue growth, and revenue divided by gross costs (revenue minus EBITDA) in its most recent fiscal year. White's heteroscedasticity-adjusted *t*-statistic is shown under each coefficient. *P* (Diff) is the *p*-value from a *t*-test for the difference between corresponding coefficients of biotech and non-biotech firms. *** Indicates statistical significance at the 1% level. ** Indicates statistical significance at the 5% level. * Indicates statistical significance at the 10% level.

Explanatory variable	Ln[offer value/total assets]			Ln[1st-day closing market value/total assets]			First-day return		
	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)
Revenue growth	1.160	0.011	0.070*	0.991	0.045	0.032**	0.333	0.020	0.272
	1.849*	0.029		1.827*	0.128		1.456	0.035	
Positive	0.311	0.973	0.073*	0.599	2.316	0.048**	0.109	0.587	0.201
Profit margin	0.321	1.971*		0.534	2.272**		0.148	1.495	
Negative	−0.417	−0.084	0.201	−0.019	−0.045	0.462	0.332	0.024	0.137
Profit margin	−0.265	−0.352		−0.078	−0.190		0.159	0.161	
% of shares offered	−0.551	−0.123	0.011***	−0.641	−0.349	0.002***	−0.110	−0.147	0.011***
	−1.898*	−1.956*		−3.275***	−2.366**		−1.962*	−2.704**	
Offer vs. filing price	0.448	0.454	0.022**	0.717	1.059	0.015**	0.423	0.469	0.014**
	1.783*	2.441**		2.610**	1.972*		1.881*	2.280**	
Ln(proceeds)	1.233	0.406	0.042**	0.726	0.427	0.012***	−0.296	−0.141	0.116
	1.978*	1.914*		2.235**	2.770***		−0.935	−1.002	
Underwriter ranking	0.537	0.234	0.155	0.237	0.130	0.152	−0.470	−0.275	0.232
	1.708	1.668		1.066	1.004		−1.750*	−1.222	
Venture capital backing	−1.843	−0.044	0.052*	−3.031	−0.216	0.009***	−0.327	−0.199	0.161
	−2.369**	−0.114		−2.316**	−1.412		−0.986	−1.772*	
Market return	0.592	0.128	0.266	1.797	0.376	0.286	1.063	0.097	0.206
	0.528	0.368		1.463	0.844		1.037	0.376	

Table 8 (*continued*)

Explanatory variable	Ln[offer value/total assets]			Ln[1st-day closing market value/total assets]			First-day return		
	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)
Risk warning	−0.321	−0.477	0.097*	−0.496	−0.493	0.056*	−0.203	−0.044	0.127
	−1.015	−2.160**		−1.421	−2.601**		−1.304	−1.008	
Warrant	−0.065	−0.377	0.038**	−0.741	−0.572	0.077*	−0.582	−0.083	0.163
	−0.545	−2.416**		−0.225	−2.189**		−0.435	−0.989	
Institutional	0.793	0.351	0.013***	1.335	0.502	0.046**	0.266	0.127	0.007***
Holdings	1.880*	2.118**		2.020**	2.876***		2.014**	2.096**	
Cancer product	1.263			2.177			0.945		
	1.816*			2.351**			1.848*		
R&D/revenue	0.900	−0.248	0.009***	1.313	−0.320	0.008***	0.167	−0.074	0.113
	2.724**	−0.745		2.673**	−1.612		0.718	−0.902	
R&D growth	0.600	0.137	0.052**	1.079	0.209	0.005***	0.311	0.017	0.121
	2.356**	0.444		2.762***	0.531		1.665	0.142	
Firm age	−0.225	0.052	0.131	−0.327	0.070	0.151	−0.162	0.008	0.194
	−0.761	0.887		−1.228	1.139		−0.516	0.014	
SG&A/employees	1.540	−0.215	0.003***	1.354	−0.191	0.001***	0.421	−0.085	0.083*
	3.053***	−0.986		4.329***	−1.075		1.887*	−0.814	
Adjusted *R*-square	53.55%	37.96%		47.85%	43.27%		24.63%	20.58%	

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or human quality weakly predicts the offer price level, showing that underwriters did take account of this variable to some extent in 1980-2000. Presumably, what we see here is a partial adjustment by underwriters to this variable (see Hanley, 1993), just as we see a partial adjustment in Table 7 to other variables that are also known to affect first-day performance (% of shares offered, offer vs. filing price and institutional holdings). Overall, this suggests that underwriters were not appreciating R&D factors when they priced an offer during the 1980–2000 period. It is worth considering whether the same phenomenon could persist today for other nascent industries.

3.6. Recent IPOs

A more recent sample[10] of biotech and non-biotech matching IPOs was collected initially with the intention of performing some robustness checks. But when the striking results in Table 7, which appear to represent vivid evidence of underwriter mispricing, were noted, the supplementary sample promised to provide an even more interesting perspective about whether underwriters have learned over time. As Table 8 reveals, they have. This conclusion is based on the fact that many of the significant variables in the first-day return regressions of Table 7 have become insignificant in Table 8 while they have become significant in the offer value regressions.

Comparing Tables 8 and 7, among biotech firms, there are seven variables significant at the 5% level in the first-day return regression of Table 7, which covers 1980-2000, while there is only one (at 5%) in Table 8, which covers 2001-2004. In contrast the biotech offer value regressions in Table 7 had six variables with a 10% significance level or higher while Table 8 has ten. This shows that significance level decreases in first-day returns cannot be attributed simply to a smaller sample size during 2001–2004.

In several noteworthy instances, particularly the R&D variables, cancer product information, and the human capital quality variable (SG&A/number of employees), the strong significance on first-day returns during 1980–2000 has been replaced by strong significance on the offer value in 2001–2004. Underwriters have indeed learned that the market considers these variables highly important for biotech firms.

But underwriters are still not fully educated about the market's preferences. For biotechs, human capital quality is still marginally significant for first-day returns in the later period and the difference between biotechs and non-biotechs is also marginally significant. For both biotechs and non-biotechs, the percentage of shares offered, the offer vs. filing price midpoint, and post-offer institutional holdings are all still highly significant in the first-day return regressions. These variables are actually more significant for non-biotechs in the later period (in the case of offer price vs. filing price and percentage of shares offered); they were less significant for non-biotechs in the earlier period as reported in Table 7. Such variables, significant for both biotech and non-biotech firms, suggest systemic mispricing in all IPOs. Perhaps this can be explained by information asymmetry or other factors.

The 2001–2004 period was somewhat special. Notwithstanding the additional results reported in Table 9, I divided the total 1980–2004 sample into five sub-periods (1980–1985, 1986–1990, 1991–1995, 1996–2000, and 2001–2004) and then looked for any discernible trends. The results (Fig. 2) show that the coefficients of R&D/revenue, R&D growth, and

[10]The available sample is composed of 105 biotech firms and 105 matching firms from 2001–2004 inclusive.

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Table 9
Evidence of underwriter learning about biotech value drivers

This table reports regressions of total offer value (scaled by total assets), scaled first-day closing market value, and first-day returns of 447 biotech and non-biotech IPOs that went public from January 1, 1980 through December 31, 2004. The non-biotech IPOs are matching firms that went public within three days of the biotech's IPO date, had comparable total offer value, revenue growth, and revenue divided by gross costs (revenue minus EBITDA) in its most recent fiscal year. The model is

$$Y_{j,t} = a + \sum_{k=1}^{M} \left[b_{0,k} X_{k,j,t} + b_{1,k} \left[(j-1)/N \right] X_{k,j,t} \right],$$

where $Y_{j,t}$ is the dependent variable (e.g., scaled offer value) for IPO j issued in year t, $X_{k,j,t}$ is the kth explanatory variable ($k = 1,\ldots,M$) for IPO j issued in year t. Since the sequence indicator is $(j-1)/N$ where j is the jth IPO out of $N+1$, it varies from zero for first IPO to 1 for 447th IPO over the 447 biotech IPOs in the sample. Assume that $J = (j-1)/N$. Panel A reports the results of all IPO samples. Panels B and C reports separate results for IPOs with high- and low-ranking underwriters. White's heteroscedasticity-adjusted t-statistic is shown under each coefficient. P(Diff) is the p-value from a t-test for the difference between corresponding coefficients of biotech and non-biotech firms. Panel D tests the effectiveness of learning for high- and low-ranked underwriters; it reports t-statistics of the null hypothesis $b_0 + b_1 = 0$ for key scientific variables. ***Indicates statistical significance at the 1% level. **Indicates statistical significance at the 5% level. *Indicates statistical significance at the 10% level.

Explanatory variable	Ln (offer value/total assets)			Ln (1st day closing market value/total assets)			First-day return		
	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)
Panel A: All IPOs									
Revenue growth	0.488	0.018	0.079*	1.002	0.032	0.057*	0.490	0.050	0.174
	2.003**	0.101		2.623**	0.044		1.465	0.029	
(Revenue growth)*J	1.242	0.059	0.031**	1.220	0.033	0.069*	−0.571	−0.029	0.175
	3.111***	0.059		2.805***	0.051		−1.170	−0.061	
Positive gross profit	0.309	0.850	0.064*	0.339	1.238	0.034**	0.059	0.641	0.171
	0.311	2.284**		0.568	3.476***		0.471	1.553	
(Positive gross profit)*J	0.051	1.712	0.082*	0.045	1.628	0.064*	−0.039	−0.557	0.198
	0.958	2.581**		0.399	2.265**		−0.465	−0.447	
Negative gross profit	−0.342	−0.071	0.336	−0.009	−0.017	0.256	0.353	0.031	0.202
	−0.218	−0.618		−0.203	−0.215		0.093	0.272	
(Negative gross profit)*J	−0.106	−0.030	0.286	−0.328	−0.099	0.107	−0.390	−0.059	0.251
	−0.139	−0.657		−0.145	−0.233		−0.145	−0.371	
Shares offered (%)	−0.716	−0.170	0.014***	−0.809	−0.361	0.005***	−0.246	−0.152	0.031**
	−1.921*	−1.920*		−1.776*	−2.554**		−1.884*	−1.941*	
[Shares offered (%)]*J	−0.872	−0.137	0.006***	−0.903	−0.304	0.005***	−0.215	−0.142	0.250
	−2.639**	−1.881*		−2.761***	−3.391***		−0.665	−0.244	
Offer vs. filing price	0.336	0.579	0.005***	0.804	0.778	0.007***	0.448	0.301	0.009***
	2.744**	2.432**		2.123**	2.014**		1.757*	2.372**	

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Panel A: All IPOs

(Offer vs. filing price)*J	1.123	2.389	0.003***	1.586	2.717	0.005***	0.441	0.392	0.127
	2.084**	2.155**		2.332**	2.638**		0.459	0.830	
Ln(proceeds)	1.152	0.904	0.006***	0.466	0.411	0.023**	−0.453	−0.550	0.249
	1.998*	2.097**		1.736	1.829*		−1.430	−1.367	
Ln(proceeds)*J	0.883	1.085	0.027**	1.466	1.641	0.033**	0.394	0.398	0.310
	1.814*	3.000***		1.792*	2.722**		0.562	0.715	
Underwriter ranking	0.834	0.386	0.255	0.233	0.169	0.236	−0.530	−0.114	0.200
	1.597	1.068		1.570	1.442		−1.279	−0.027	
(Underwriter ranking)*J	0.202	0.361	0.166	0.716	0.452	0.177	0.453	0.185	0.194
	1.125	0.937		1.353	0.842		0.283	0.010	
VC backing	−0.335	−0.064	0.148	−1.985	−0.222	0.090*	−1.298	−0.172	0.145
	−1.499	−0.153		−1.896*	−0.821		−1.383	−0.851	
(VC backing)*J	−1.029	−0.155	0.074*	−0.349	−0.057	0.092*	0.821	0.097	0.318
	−2.246**	−0.169		−2.049**	−1.478		0.173	0.133	
Market return	0.714	0.096	0.142	1.380	0.277	0.108	0.467	0.127	0.404
	1.435	0.747		1.406	1.162		1.059	0.274	
(Market return)*J	1.331	0.389	0.272	0.940	0.219	0.406	−0.374	−0.363	0.201
	0.528	1.322		1.460	1.257		−0.024	−0.046	
Risk warning	−0.159	−0.387	0.067*	−0.306	−0.442	0.001***	−0.121	−0.112	0.320
	−0.776	−3.26***		−1.160	−4.271***		−0.767	−0.843	
(Risk warning)*J	−0.765	−0.544	0.006***	−0.523	−0.537	0.004***	0.290	0.287	0.198
	−0.653	−2.726**		−1.485	−4.683***		0.094	0.136	
Warrant	−0.138	−0.233	0.056*	−0.881	−1.052	0.075*	−0.821	−0.713	0.240
	−0.185	−2.312**		−0.769	−1.771*		−0.680	−0.476	
Warrant*J	−0.624	−0.735	0.031**	−0.176	−0.435	0.039**	0.899	0.405	0.189
	−0.590	−2.270**		−1.238	−2.305**		0.174	0.118	
Institutional holdings	0.391	0.366	0.016**	1.017	0.986	0.025**	0.368	0.643	0.007***
	1.881*	2.199**		2.372**	2.136**		1.976*	2.009**	
(Institutional holdings)*J	0.678	0.97	0.036**	1.252	1.546	0.023**	0.186	0.354	0.244
	1.952*	2.484**		2.110**	2.719**		0.674	0.733	
Cancer product	0.373			1.065			0.835		
	0.960			2.417**			2.759***		
(Cancer product)*J	1.140			0.504			−0.356		
	2.192**			1.771*			−1.599		
R&D/revenue	0.183	−0.138	0.171	0.790	−0.424	0.049**	0.425	−0.229	0.076*
	1.362	−0.813		3.235***	−1.153		3.299***	−1.361	
(R&D/revenue)*J	1.010	−0.487	0.064*	0.533	−0.182	0.063*	−0.644	0.233	0.080*
	2.893***	−1.187		4.493***	−1.029		−2.011**	0.888	

Table 9 (*continued*)

Explanatory variable	Ln (offer value/total assets)			Ln (1st day closing market value/total assets)			First-day return		
	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)
R&D growth	0.629	0.114	0.277	1.402	0.110	0.009***	0.558	−0.030	0.054**
	1.522	0.319		3.180***	1.005		3.414***	−0.149	
(R&D growth)*J	1.253	0.165	0.100*	1.029	0.189	0.098*	−0.476	0.018	0.076*
	1.871*	1.336		1.778*	0.398		−2.470**	0.175	
Age at IPO	−0.260	0.150	0.161	−0.317	0.461	0.275	−0.061	0.322	0.159
	−0.130	0.533		−1.088	1.014		−1.207	0.198	
(Age at IPO)*J	−0.435	0.181	0.149	−0.282	0.120	0.093*	0.205	−0.094	0.175
	−0.632	1.150		−2.116**	1.513		0.057	−0.045	
SG&A/employees	1.199	−0.147	0.085*	1.607	−0.642	0.082*	0.770	−0.219	0.085*
	1.817*	−1.302		1.953*	−1.482		2.298**	−0.909	
(SG&A/employees)*J	1.714	−0.511	0.011***	1.529	−0.266	0.098*	−0.559	0.199	0.300
	4.303***	−1.431		2.004**	−0.981		−1.132	0.988	
Adj. *R*-square	52.07%	49.11%		65.97%	38.89%		31.14%	15.57%	
Panel B: IPOs with High- Ranking Underwriters									
Revenue growth	0.389	0.020	0.077*	0.735	0.022	0.067*	0.303	0.044	0.326
	2.152**	0.089		2.751***	0.055		1.254	0.033	
(Revenue growth)*J	1.121	0.062	0.067*	0.887	0.028	0.067*	−0.275	−0.023	0.182
	2.321**	0.048		2.905***	0.052		−1.371	−0.067	
Positive gross profit	0.402	0.858	0.080*	0.284	1.645	0.041**	−0.045	0.784	0.283
	0.255	2.429**		0.601	2.804***		−0.365	1.476	
(Positive gross profit)*J	0.209	2.557	0.099*	0.258	1.789	0.069*	0.037	−0.692	0.228
	0.754	1.933*		0.400	2.629**		0.515	−0.424	
Negative gross profit	−0.247	−0.066	0.479	−0.012	−0.014	0.291	0.319	0.060	0.181
	−0.181	−0.629		−0.211	−0.190		0.092	0.295	
(Negative gross profit)*J	−0.127	−0.033	0.313	−0.272	−0.086	0.114	−0.242	−0.047	0.265
	−0.146	−0.578		−0.171	−0.210		−0.242	−0.423	
Shares offered (%)	−0.665	−0.175	0.010***	−0.817	−0.345	0.002***	−0.299	−0.176	0.009
	−2.751***	−2.117**		−1.861*	−2.319**		−2.202**	−1.757*	
[Shares offered (%)]*J	−0.649	−0.177	0.001***	−0.871	−0.323	0.001***	−0.084	−0.102	0.201
	−2.680**	−1.984*		−3.172***	−2.594**		−0.630	−0.273	
Offer vs. filing price	0.335	0.735	0.002***	1.168	0.890	0.006***	0.813	0.262	0.004***
	3.365***	2.542**		2.798***	2.209**		2.325**	3.428***	

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(Offer vs. filing price)*J	0.815	2.466	0.009***	1.807	3.164	0.001***	0.741	0.166	0.073*
	2.983***	2.403**		2.689**	3.045***		1.869*	1.912*	
Ln(proceeds)	0.782	0.548	0.007***	0.541	0.503	0.009***	−0.355	−0.197	0.240
	2.276**	2.065**		1.846*	2.333**		−0.958	−1.284	
Ln(proceeds)*J	0.473	0.778	0.005***	0.754	0.846	0.009***	0.407	0.211	0.305
	2.613**	2.962***		2.029**	2.953***		0.433	0.576	
Underwriter ranking	0.514	0.289	0.211	0.152	0.172	0.199	0.309	0.162	0.135
	1.570	1.390		1.401	1.160		−0.991	−0.029	
(Underwriter ranking)*J	0.688	0.508	0.151	0.287	0.334	0.105	−0.276	−0.180	0.231
	0.893	0.642		1.493	1.080		0.325	0.009	
VC backing	−0.865	−0.059	0.157	−1.372	−0.188	0.098*	−0.764	−0.159	0.186
	−1.610	−0.154		−1.823*	−1.064		−1.226	−0.893	
(VC backing)*J	−1.097	−0.162	0.091*	−0.279	−0.059	0.084*	0.752	0.117	0.237
	−1.788*	−0.257		−1.859*	−1.214		0.202	0.092	
Market return	0.550	0.130	0.189	1.939	0.304	0.147	0.851	0.648	0.435
	1.380	0.771		1.521	0.873		1.201	0.356	
(Market return)*J	1.098	0.264	0.243	1.026	0.210	0.497	−0.654	−0.467	0.194
	0.481	1.445		1.257	1.052		−0.021	−0.042	
Risk warning	−0.199	−0.451	0.057*	−0.352	−0.471	0.012***	−0.485	−0.275	0.205
	−0.602	−3.49***		−0.898	−3.810***		−0.916	−0.802	
(Risk warning)*J	−0.691	−0.808	0.083*	−0.543	−0.541	0.012***	0.396	0.257	0.129
	−0.804	−2.264**		−1.026	−2.890***		0.086	0.128	
Warrant	−0.155	−0.205	0.089*	−1.102	−1.165	0.083*	−0.844	−0.623	0.236
	−0.191	−1.751*		−0.700	−2.104**		−0.544	−0.581	
Warrant*J	−0.794	−0.854	0.082*	−0.192	−0.455	0.095*	0.694	0.506	0.187
	−0.658	−2.646**		−1.602	−1.973*		0.265	0.152	
Institutional holdings	0.250	0.361	0.018**	0.566	0.572	0.008***	0.320	0.143	0.077*
	1.810*	2.338**		2.036**	2.455**		1.987*	1.873*	
(Institutional holdings)*J	0.452	0.931	0.016**	0.782	1.087	0.007***	0.319	0.146	0.092*
	1.759*	2.239**		2.943***	2.603**		1.760*	1.955*	
Cancer product	0.358			0.838			0.314		
	0.945			2.502**			2.577**		
(Cancer product)*J	0.994			0.739			−0.375		
	1.940*			2.719**			−1.651		
R&D/revenue	0.172	−0.105	0.156	0.793	−0.398	0.034**	0.455	−0.249	0.041
	1.188	−0.662		3.368***	−1.053		3.062***	−1.648	
(R&D/revenue)*J	1.228	−0.354	0.026**	0.626	−0.138	0.024**	−0.589	0.177	0.115
	3.504***	−1.059		2.038**	−1.068		−1.527	0.714	

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Table 9 (*continued*)

Explanatory variable	Ln (offer value/total assets)			Ln (1st day closing market value/total assets)			First-day return		
	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)
Panel B: IPOs with High- Ranking Underwriters									
R&D growth	0.569	0.085	0.286	1.122	0.096	0.042**	0.676	0.031	0.037**
	1.118	0.279		3.503***	0.867		3.731***	0.157	
(R&D growth)*J	1.630	0.304	0.072*	1.037	0.162	0.093*	−0.674	−0.136	0.143
	2.405**	1.106		2.012**	0.526		−1.558	0.166	
Age at IPO	−0.236	0.100	0.138	−0.422	0.395	0.174	−0.459	0.390	0.174
	−0.133	0.445		−1.127	1.000		−1.314	0.173	
(Age at IPO)*J	−0.584	0.221	0.144	−0.379	0.139	0.407	0.318	−0.280	0.123
	−0.738	0.870		−0.421	1.248		0.076	−0.043	
SG&A/employees	0.784	−0.158	0.094	1.162	−0.465	0.062*	0.726	−0.276	0.053**
	1.790*	−0.829		2.612**	−1.537		2.164**	−1.057	
(SG&A/employees)*J	2.040	−0.415	0.056*	0.894	−0.204	0.080*	−0.635	0.266	0.127
	2.571**	−1.724		2.364**	−0.951		−1.574	0.974	
Adj. *R*-square	45.91%	37.90%		58.95%	43.01%		33.67%	17.92%	
Panel C: IPOs with low- ranking underwriters									
Revenue growth	0.348	0.019	0.107	0.849	0.028	0.078*	0.495	0.060	0.332
	1.953*	0.078		2.406**	0.059		1.184	0.028	
(Revenue growth)*J	0.881	0.036	0.080*	0.673	0.037	0.081*	−0.270	−0.020	0.107
	2.416**	0.050		2.463**	0.048		−1.224	−0.075	
Positive gross profit	0.427	0.778	0.079*	0.360	1.156	0.049**	−0.149	0.505	0.424
	0.308	3.133***		0.630	3.049***		−0.429	1.721	
(Positive gross profit)*J	0.033	1.700	0.094*	0.039	1.497	0.082*	0.039	−0.434	0.197
	0.852	1.885*		0.415	1.828*		0.412	−0.467	
Negative gross profit	−0.195	−0.082	0.438	−0.010	−0.016	0.225	0.259	0.095	0.232
	−0.192	−0.679		−0.243	−0.192		0.084	0.268	
(Negative gross profit)*J	−0.193	−0.039	0.317	−0.219	−0.092	0.196	−0.413	−0.045	0.179
	−0.186	−0.409		−0.183	−0.245		−0.195	−0.477	
Shares offered (%)	−0.652	−0.210	0.050**	−0.979	−0.391	0.001***	−0.944	−0.188	0.010***
	−1.818*	−1.769*		−1.865*	−2.784***		−1.937*	−1.858*	
[Shares offered (%)]*J	−0.911	−0.191	0.001***	−1.518	−0.266	0.005***	−0.408	−0.133	0.266
	−3.16***	−2.239**		−2.481**	−2.696**		−1.666	−1.492	
Offer vs. filing price	0.346	0.770	0.006***	1.079	0.871	0.006***	0.891	0.457	0.007***
	2.799***	2.919***		2.646**	1.867*		2.269**	2.625**	

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(Offer vs. filing price)*J	0.855	1.321	0.002***	0.874	1.715	0.002***	0.091	0.215	0.091*
	3.636***	2.517**		3.714***	2.822***		1.034	1.836*	
Ln(proceeds)	0.575	1.066	0.008***	0.551	0.455	0.009***	−0.302	−0.286	0.240
	2.654**	2.491**		2.003**	2.007**		−0.840	−1.848*	
Ln(proceeds)*J	0.473	1.054	0.006***	0.751	1.213	0.006***	0.361	0.153	0.255
	2.173**	2.941***		2.101**	3.356***		0.428	0.700	
Underwriter ranking	1.290	0.339	0.143	0.198	0.150	0.246	−0.564	−0.014	0.160
	1.495	0.971		1.328	0.951		−0.867	−0.032	
(Underwriter ranking)*J	0.237	0.260	0.152	0.474	0.474	0.106	0.348	0.017	0.208
	1.067	0.840		1.754*	1.206		0.226	0.010	
VC backing	−0.386	−0.063	0.174	−1.527	−0.226	0.086	−1.212	−0.201	0.148
	−1.622	−0.189		−1.871*	−1.087		−0.945	−1.177	
(VC backing)*J	−1.133	−0.170	0.073*	−0.579	−0.131	0.091*	0.934	0.120	0.137
	−2.015**	−0.318		−1.797*	−1.470		1.648	0.106	
Market return	0.548	0.141	0.238	1.681	0.320	0.122	0.838	0.491	0.365
	0.931	0.742		1.429	0.875		0.888	0.535	
(Market return)*J	1.248	0.254	0.095*	1.146	0.210	0.447	−0.736	−0.312	0.207
	0.400	1.866*		0.926	1.235		−0.025	−0.039	
Risk warning	−0.182	−0.390	0.018**	−0.350	−0.384	0.001***	−0.227	0.105	0.347
	−0.464	−3.82***		−0.909	−2.869***		−0.977	0.925	
(Risk warning)*J	−0.876	−0.553	0.038**	−0.794	−0.755	0.033**	0.021	−0.173	0.264
	−0.816	−2.872***		−0.746	−2.657**		0.078	−0.142	
Warrant	−0.172	−0.170	0.083*	−1.375	−1.202	0.095*	−0.925	−0.618	0.242
	−0.222	−2.274**		−0.642	−1.837*		−0.525	−0.441	
Warrant*J	−0.588	−0.875	0.074*	−0.231	−0.498	0.036**	1.270	0.537	0.179
	−0.410	−2.178**		−1.264	−2.039**		0.173	0.115	
Institutional holdings	0.403	0.494	0.008***	0.554	1.250	0.007***	0.295	0.328	0.032**
	2.176**	2.301**		2.627**	2.402**		1.889*	2.035**	
(Institutional holdings)*J	0.591	0.688	0.016**	0.618	1.138	0.025**	0.221	0.136	0.174
	1.753*	2.015**		1.848*	2.662**		1.159	1.636	
Cancer product	0.369			1.039			0.296		
	0.993			2.971***			2.308**		
(Cancer product)*J	0.860			0.579			−0.385		
	2.519**			2.433**			−2.011**		
R&D/revenue	0.194	−0.120	0.116	0.771	−0.308	0.057*	0.419	−0.176	0.013**
	0.897	−0.574		2.609**	−1.276		3.079***	−1.152	
(R&D/revenue)*J	0.857	−0.492	0.048**	0.639	−0.131	0.022**	−0.651	0.446	0.055*
	2.529**	−0.971		3.688***	−1.035		−2.86***	0.808	

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Table 9 (*continued*)

Explanatory variable	Ln (offer value/total assets)			Ln (1st day closing market value/total assets)			First-day return		
	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)	Biotech	Non bio	*P*(Diff)
Panel C: IPOs with low- ranking underwriters									
R&D growth	0.751	0.084	0.263	1.265	0.088	0.018**	0.658	0.032	0.017**
	1.202	0.294		3.089***	1.002		3.954***	0.199	
(R&D growth)*J	1.733	0.373	0.066*	0.839	0.229	0.066*	−0.747	−0.211	0.046**
	2.075**	1.016		2.393**	0.576		−2.616**	−0.129	
Age at IPO	−0.177	0.084	0.125	−0.358	0.316	0.190	−0.365	0.315	0.144
	−0.099	0.314		−1.207	1.148		−1.473	0.183	
(Age at IPO)*J	−0.416	0.205	0.114	−0.388	0.123	0.290	0.226	−0.209	0.120
	−0.733	1.038		−1.608	1.158		0.061	−0.053	
SG&A/employees	0.244	−0.132	0.089*	1.144	−0.431	0.062*	0.813	−0.276	0.078*
	1.782*	−1.125		2.360**	−1.336		2.442**	−1.166	
(SG&A/employees)*J	1.472	−0.436	0.075*	0.959	−0.252	0.064*	−0.447	0.108	0.092*
	2.075**	−1.387		2.217**	−1.117		−1.823*	1.079	
Adj. R-square	46.76%	52.88%		58.11%	55.11%		46.55%	21.74%	

Panel D: Tests for complete underwriter learning over time

If underwriters fully learn about the key variables that were associated with higher first-day returns in earlier IPOs, the time varying learning coefficient, b_1, should be equal to the initial coefficient, b_0, and opposite in sign, so the two coefficients should sum to zero. The t-statistics in this panel test whether this coefficient sum differs significantly from zero for key scientific variables. ** Indicates statistical significance at the 5% level. * Indicates statistical significance at the 10% level.

H_0: $b_0 + b_1 = 0$	Underwriters	
	High-ranking	Low-ranking
Cancer product	−1.11	−2.16**
R&D/revenue	−1.01	−2.03**
R&D growth	1.19	−1.90*
SG&A/employee	1.69	1.98*

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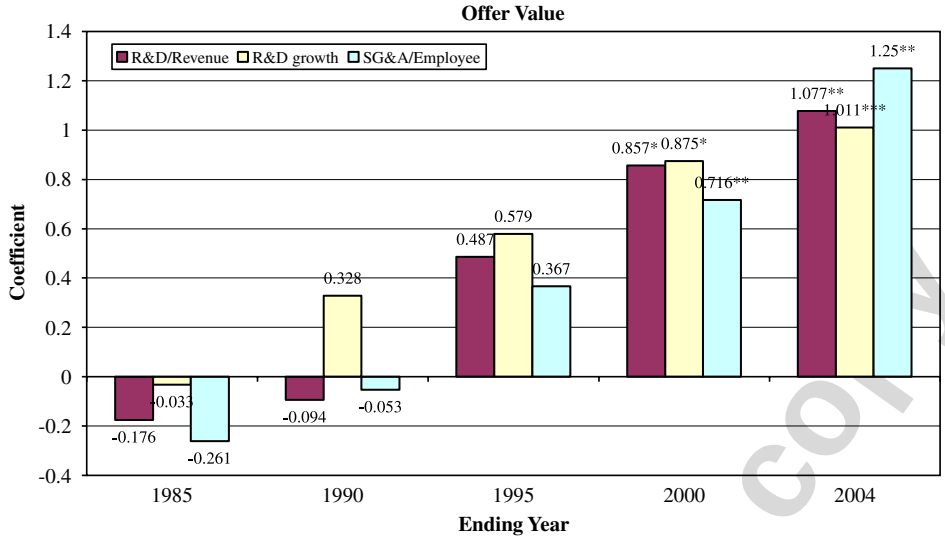

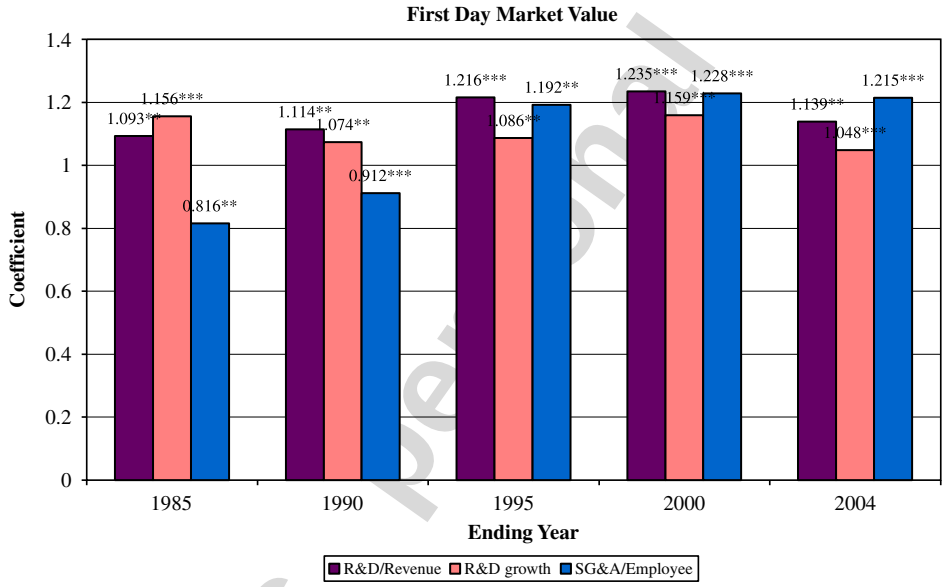

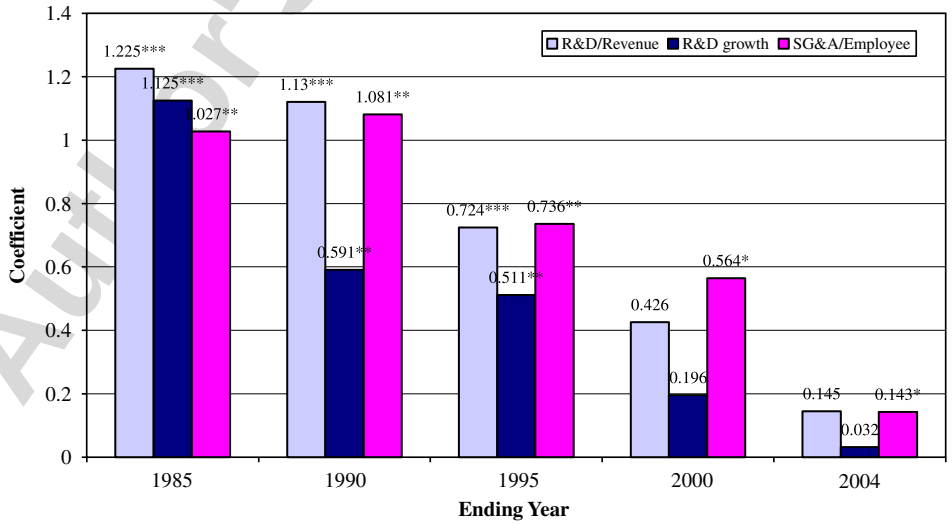

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SG&A/number of employees (HC) in the total offer value regressions increase over time (they also become statistically significant) thus indicating that they were increasingly considered by underwriters in establishing IPO offer prices. The coefficients of these same variables in the first day ending market value regressions are quite stable over time, indicating that the market took them into account in both early and later IPOs. Lastly, the coefficients of these variables in the first-day return regressions decrease over time. Indeed, the patterns clearly conform to the progression: Case #2 followed by Case #3 followed by Case #4. Underwriters appear to have learned what the market considers important drivers of IPO value for biotech firms.

3.7. Evidence of Underwriter Education (while Doing)

The overall pattern indicates that for IPOs in the new and unfamiliar biotech industry, underwriters learned about market values over time. To provide a final piece of evidence about this learning, Table 9 report regressions with coefficients for all variables that are allowed to depend on the IPO's sequence in time. Panel A reports results for all IPOs. To ascertain whether some underwriters learn more rapidly than others, Panels B and C report results for IPOs with high and low-ranking underwriters, respectively.

To understand this table, consider the schematic model

$$y_{j,t} = a_j + b_{j,t}x_{j,t}, \tag{1}$$

where j is the jth IPO issued and t is a time index; $y_{j,t}$ is the dependent variable (e.g., scaled offer value) for IPO j issued in year t and $x_{j,t}$ is an explanatory variable for IPO j issued in year t.

To allow for the notion that underwriters learn from each successive IPO, the slope coefficient in this model will be allowed to depend on IPO j's sequence within the history of all IPOs and, for simplicity, I assume it is linear in the IPO sequence; i.e., if $N+1$ is the total number of IPOs in the sample, and IPO j is the jth to appear, the slope coefficient in (1) will be modeled as

$$b_{j,t} = b_0 + b_1[(j-1)/N]. \tag{2}$$

Hence, the slope coefficient varies between b_0 for the first IPO to b_0+b_1 for the last IPO and the fitted model is

$$y_{j,t} = a_j + b_0x_{j,t} + b_1[(j-1)/N]x_{j,t}. \tag{3}$$

In Table 9, each explanatory variable is entered directly, to estimate its corresponding b_0, and is also multiplied by the IPO sequence number, to estimate its corresponding b_1. Since the sequence indicator is $(j-1)/N$ where j is the jth IPO out of $N+1$, it varies from zero for the first IPO to 1 for 447th IPO over the 447 biotech IPOs in the sample.

Fig. 2. These figures plot the coefficients of R&D/Revenue, R&D growth, and SG&A/number of employees (HC) from the regressions of total offer value, first-day market value, and first-day returns for five sub-periods (1980–1985, 1986–1990, 1991–1995, 1996–2000, and 2001–2004) controlling for size by using ln(total offer value). The number on each bar of the graphs is the coefficient of each variable. There are a total of 447 biotech IPOs issued from January 1, 1980 through December 31, 2004. Descriptions of all variables are in the appendix. *** Indicates statistical significance at the 1% level. ** Indicates statistical significance at the 5% level. * Indicates statistical significance at the 10% level.

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Table 10

Variables	Item #	Compustat quarterly data items
Panel A: Income statement variables (in $ millions or %)		
Revenue	2	Net revenue
Growth of revenue		100[(Revenue–Revenue lagged four quarters)/total assets]
R&D expense	4	Research and development expense; zero if missing. R&D includes write-offs of purchased in-process R&D. Quarterly R&D is only available beginning 1989 first quarter. Annual Compustat reports annual R&D expense under Statement of Financial Accounting Standards No. 2 starting in 1974.
Timing of R&D		R&D divided by net revenue (REV)
Growth of R&D		100[R&D/(R&D lagged four quarters)-1]
SG&A expense	1	Selling, general & administrative expense; Compustat includes R&D in SG&A, thus SG&A in this study excludes R&D
Cost of revenue	30	Cost of revenue; item 30 is total operating expense if SG&A is missing
Total operating cost		Cost of revenue + SG&A when SG&A is not missing. If cost of revenue-R&D is less than zero, Cost of revenue is set equal to zero.
EBITDA	21	Operating income before interest, tax, depreciation and amortization = net revenue−cost of revenue−SG&A
Gross profits		Revenue−Cost of revenue
Positive gross profit		Max[Gross profits,0]
Negative gross profit		Min[Gross profits,0]
Net income	69	Net income or loss
Quality of human capital		SG&A/(number of employees)
Panel B: Balance sheet variables (in $ millions or number)		
First-day market value of equity	14	First-day closing price * number of total shares outstanding
Total assets	44	Total assets
Long-term debt	51	Long-term debt
Number of employees	29	Fiscal year-end number of employees

Panel C: IPO and biotech variables

	Source	Definition
Underwriter ranking		Loughran and Ritter (2004)'s adjusted Carter–Manaster underwriter reputation ranking
Total offer value	SDC	Total shares outstanding multiplied by offer price, ($ millions)
First-day return	SDC	100[(closing price on the IPO date−offer price)/offer price]

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Table 10 (*continued*)

Panel C: IPO and biotech variables	Source	Definition
Proceeds	SDC	The money raised, after fees and expenses or shares offered in IPO multiplied by offer price after fees and expenses, ($ millions)
VC backing dummy	SDC	1.0 if the firm is backed by venture capital at the time of the IPO
Percentage of shares offered	SDC	Percentage of shares outstanding offered in the IPO
Offer vs. filing price	SDC	100[(offer price−filing price)/filing price]; filing price is mid-point of filing price range
Market return	CRSP	Value-weighted NYES-NASDAQ-AMEX market return for two weeks before the IPO
Risk dummy	Prospectus	1.0 if IPO has high risk warnings on page one of the prospectuses
Warrant dummy	Prospectus	1.0 if IPO includes components such as warrants
Firm age	SDC	Number of years before the IPO the firm was founded
Post-offer percentage of institutional holdings	Thompson financial	The number of shares owned by institutions divided by the estimated public float. Number of shares owned by each institution is available on 13F institutional holdings and is collected at least one month after the IPO.
Cancer dummy	Prospectus	1.0 if firm has a cancer or cancer-related product

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Any variable for which underwriters initially did not understand market pricing but fully learned by the sample's end should be characterized by a b_0 and b_1 of opposite signs and roughly equal sizes in the first-day return regressions. In the offer value regressions, such a variable should have an estimated b_0 near zero and a b_1 highly significant. Finally, there are intermediate cases where the underwriters took the attribute partially but not completely into account in the offer price; in such case, both b_0 and b_1 should be significant and have the same sign.

In most cases, the results in Table 9 support the view that underwriters did learn about market pricing as more and more biotech IPOs were issued. For example, recall from Table 7 that the R&D variables (R&D growth and R&D/revenue) and the Cancer product dummy were highly significant determinants of the first-day return in the overall sample and had no significant impact on the offer value. In the first-day return regressions of all Panels in Table 9, the initial coefficient (i.e., b_0) is positive and significant and the learning rate coefficient, b_1, is negative and often marginally significant. Moreover, the two coefficients are similar in absolute size. The absolute sizes of the coefficient are closer for IPOs with high-ranking underwriters, which suggests faster and/or more complete learning. In the offer value regressions, b_1 is highly significant and positive. Together, these results indicate that underwriters were initially unaware of the importance of R&D and Cancer products for biotechs, but as time progressed they learned about their importance

for pricing and by the end of the sample fully incorporated their impact in the offer prices they established for IPOs.

Another interesting variable is SG&A per capita, a measure of the quality of human capital. On average during the sample, Table 6 Panel A shows that underwriters did know something about its importance and used it in establishing the offer price, but this variable still had a significant influence on first-day returns. In other words, underwriters only partially incorporated its impact in earlier biotech IPOs. Table 9 Panel A shows this pattern of initial underestimation plus learning because the offer value regressions have both b_0 and b_1 positive and significant for SG&A/employees. At the beginning of the sample, this variable's estimated impact in scaled offer value was 1.199 while at the sample's end the impact was $1.199 + 1.714 = 2.913$; i.e., the impact more than doubled over the sample. In the first-day return regressions of Table 9 Panel A, the coefficient of SG&A/employees is significant only for the initial coefficient, but negatively insignificant for the learning rate coefficient. This result shows that underwriters learned something about the importance of SG&A per employees over time but they did not fully incorporate its impact in the offer prices of IPO. For non-biotech IPOs, underwriters successfully incorporated the importance of risk warning and warrant in the offer prices over time as their first-day returns are not affected by these two variables.

In addition, the percentage of shares offered, the offer vs. filing price, and post-offer institutional holdings have an interesting pattern in Table 9, Panel A. These three variables are significantly related to total offer value and first day market value for both biotech and non-biotech IPOs. Moreover, the signs of the initial coefficients (b_0) are the same as the signs of the time-varying coefficients (b_1), which reveals that their impact was actually getting stronger during the sample.[11] Whatever the explanation might be for the significance of these particular variables, it seems clearly unrelated to initial ignorance about pricing. Experience and learning have only strengthened their impacts.[12]

Finally, there is a different pattern of learning between high- and low-ranking underwriters. In the offer value regression of Table 9, Panel B and Panel C, the initial coefficients, b_0, of high- and low-ranking IPOs are roughly the same for Cancer Product, the R&D variables and human capital quality, (SG&A/employee.) However, the learning coefficient, b_1, is larger for higher-ranking underwriters than for low-ranking underwriters. This suggests that better quality underwriters have adjusted more completely by the sample's end.

In the first-day return regressions of Table 9, Panels B and C, the sums of the two coefficients, $b_0 + b_1$, for these same variables are for high- (low-) ranking underwriters as follows: −0.061 (−0.089), −0.134 (−0.232), 0.002 (−0.089), and 0.091, (0.366), respectively. In each instance, the sum is closer to zero in absolute value for high-ranking underwriters. Table 9 Panel D reports t-statistics for this coefficient sum. If underwriters learn fully from their experience during the sample, the coefficient sums should be insignificantly different from zero. For the pertinent variables, the variables that originally revealed a lack of complete understanding, these results reveal that the sums are not

[11]However, in the First-Day Return regressions, the signs of the time-varying coefficients are insignificant.

[12]The same analysis was repeated without IPOs that were issued in 2001–2004 period (the post-bubble bust period) and the results are altered slightly. The sums of $b0$ and $b1$ of first-day return regression for each variable are not as close to zero as when IPOs from the 2001–2004 period are included. This is consistent with underwriters' learning during the post-bubble bust period.

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significantly different from zero for high- ranking underwriters but are significantly non-zero for low-ranking underwriters in two cases (Cancer Product and R&D per revenue) and marginally significant for the other two variables. Evidently, higher ranking underwriters are quicker to learn about drivers of value in a new industry.

4. Discussion and conclusions

This paper studies the ability of underwriters to properly value unfamiliar firms prior to IPOs. I use the history of biotechnology IPOs as an empirical laboratory to study how successful underwriters were in pricing IPOs of a nascent industry. I examine whether underwriters were aware of important value drivers from the very beginning or learned from market experience.

Using a 25-year history, 1980–2004 inclusive, I study the characteristics of biotech IPOs and distinguish them from non-biotech IPOs. At the IPO, biotech firms have higher revenue growth, issue a smaller fraction of their shares to investors, are more likely to be financed by venture capitalists, are issued when market returns are higher, have higher total offer value and first-day market value, and are underwritten by high-ranking investment bankers. Non-biotech firms have higher gross profits, are less likely to have risk warnings on their prospectus, and more often issue non-bundled equities.

The offer value scaled by total assets is higher for biotech firms that have higher revenue growth and better human capital quality. These variables do not influence scaled offer values of non-biotech firms. The percentage of filing price adjustment, post-offer institutional holdings, and the IPO size, however, positively affect offer values for both types of firms whereas the percentage of shares offered in the IPO negatively affects offer values of both type of firms. Risk warnings and attached warrants are all negatively associated with scaled offer values for non-biotech firms. Interestingly, these negative signals are not statistically significant for biotech firms, which probably indicates that the market already knows how risky they really are.

In the early period of the entire sample, several variables are not associated with offer values but are significantly associated with returns on the first day of trading and with the market value at the first-day close. In the later period of the entire sample, these variables are significantly associated with offer value and with market value at the first day's close but are not significantly associated with the returns on the first day of trading. This suggests that underwriters did not place much importance on these factors and did not rely on them when establishing the offer price in the beginning; however, they learned over time. Some variables, such as the fraction of shares offered, the percentage of filing price adjustment in the IPO, and post-offer institutional holdings are significant drivers of first-day returns for both biotechs and non-biotechs. But more variables are significant for biotech IPOs, R&D/revenue, R&D growth, human capital quality, and having a cancer drug.

For non-biotech IPO's, (positive profit margin), risk warnings and attached warrants are associated with (higher) lower offer values and market values but do not affect first-day returns, thereby implying that these characteristics are adequately taken into account by the underwriters.

When biotechs first appeared on the market, underwriters were quite understandably not familiar with at least some market value drivers such as R&D and the quality of human capital. Pooling all IPOs into a single cross-sectional regression essentially

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combines earlier issues, when underwriters were still learning about the industry, and later issues, when the particular features of the industry had become more familiar. If underwriters were becoming knowledgeable about biotechs over time, money left on the table in early issues should be much reduced in later issues. According to my results, underwriters de-emphasized R&D attributes when establishing offer prices for early biotech IPOs; however, they learned the importance of these attributes over time and learned completely at the end of our sample period.

In fact, there is strong evidence that underwriters learned quite well from the sequence of biotech IPOs during the 20+ sample years. R&D, human capital quality, and having a cancer drug significantly affected offer values for later IPOs and the same variables ceased influencing first-day returns. There is some evidence that high-ranking underwriters learned better than low-ranking ones.

The founders, venture capitalists and other existing investors in the firm (who presumably have much more to lose from underpricing) also have something to do with the pricing decision. However, these individuals have less experience than underwriters with drivers of value. Underwriters deal with many IPOs and play a key role in IPO pricing. Indeed, this is one of the main reasons underwriters are hired and explains why this study focuses on underwriters' learning. One caveat of my analysis is that I probably measure allocation here with some noise. While I find strong evidence that institutional investors own the best IPOs, perhaps a more accurate measure of allocation could affect the significance of the R&D and HC variables to some extent. Yet it is hard to understand why the observed patterns over time in the significance of R&D and human quality would be eliminated by a better allocation measure. It seems unlikely that the pattern of significance, the observed progression from Case #2 to Case #3 and then to Case #4 (p. 17), would be completely eliminated by including a less error-ridden allocation variable.

In conclusion, it is worth contemplating whether a similar educational process, rather lengthy in elapsed time, is possible when new industries with uncertain odds of success emerge in the future.

Appendix. Variable Definitions are given in Table 10

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