The Changing Rewards to Science: The Case of Biotechnology

Paula E. Stephan
Stephen S. Everhart

ABSTRACT. Little is known about the form and or magnitude of compensation provided university-based scientists working on firm R&D. This is unfortunate, given the important role that university-based scientists play in R&D, and the growing literature concerning compensation and innovation. This paper sheds some light on these issues by examining the compensation of university-based scientists involved with 52 biotech firms that made an initial public offering between March of 1990 and November of 1992. Although the stock holdings of the university scientists are of particular interest, additional forms of compensation received by the scientists are also examined.

We find that approximately 10 percent of the university-based scientists affiliated with these companies hold sufficient options or stock to require disclosure at the time of the public offering. A far larger proportion has an equity position in the firm. In many instances the scientists also receive consulting fees or salary from the firm and enter into licensing agreements with the firm. In addition to providing information concerning the compensation of university-based scientists, the empirical work suggests that the rewards to science can be significantly greater than previous work would suggest.

1. Introduction

Recent work suggests that small firms are often more innovative than large firms (Acs and Audretsch, 1988; Audretsch, 1995; Holmstrom, 1989; Kleinknecht, 1989; Rothwell, 1989) and that many of their innovative inputs are supplied by agents working outside the firm. One source for such external knowledge inputs are scientists working at universities. Firms often rely on university-based scientists and engineers to perform and or guide much of their R&D. This is arguably most efficient when intellectual inputs dominate the innovation process (Aghion and Tirole, 1994). Little is known, however, about the form and or magnitude of compensation offered to these university-based scientists and engineers. This is unfortunate, given the important role that university-based scientists play, and the growing literature concerning compensation and innovation (Holmstrom, 1989; Jensen, 1993; Aghion and Tirole, 1994). Here we examine the compensation of university-based scientists involved with 52 biotech firms that made an initial public offering between March of 1990 and November of 1992. We are particularly interested in the stock holdings of the university scientists, but we also examine additional forms of compensation received by the scientists.

We find that approximately 10 percent of the university-based scientists affiliated with these companies hold sufficient options or stock to require disclosure at the time of the public offering. A far larger proportion has an equity position in the firm. In many instances the scientists also receive consulting fees or salary from the firm and enter into licensing agreements with the firm. In addition to providing information concerning the compensation of university-based scientists, the empirical work also suggests that the rewards to science can be significantly greater than previous work would suggest. For example, one university-based scientist in the sample realized a profit of over $11 million, another realized a profit of $1.9 million. We conclude that while the lure of the puzzle and an interest in priority are undoubtedly important motivators of

Final version accepted on

Paula E. Stephan
Department of Economics and
Policy Research Center
Georgia State University
Atlanta, GA 30303

and

Stephen S. Everhart
Economic Forecasting Center
Georgia State University
Atlanta, GA 30303

Small Business Economics **10**: 141–151, 1998.
© 1998 *Kluwer Academic Publishers. Printed in the Netherlands.*

scientific effort (as sociologists of science, such as Merton (1957) and Hagstrom (1965) argue), monetary rewards should not be minimized.

The plan of the paper is as follows. In Section 2 we provide background information concerning the various roles university-based scientists play in biotechnology firms. Section 3 describes the database and methodology used. Findings with regard to stock and option holdings are summarized in Section 4. Other forms of compensation are briefly discussed in Section 5. Discussion and conclusions follow in Section 6.

2. The role of university-based scientists in biotechnology firms

Biotechnology is a new industry that is knowledge based and predominantly composed of new small firms having close ties with university-based scientists (Audretsch and Stephan, 1996). Knowledge transfer between scientists and firms occurs, for example, when university-based scientists found firms with the explicit goal of developing knowledge created in their university lab. University scientists who serve as scientific advisors or consultants to the firm also facilitate knowledge transfer by providing links with other researchers doing work in the area. Along with founders, they also provide the possibility of outsourcing research into university laboratories staffed by graduate students and postdocs. The more formalized concept of a Scientific Advisory Board (SAB), most of whose members are university-based, allows the firm the possibility of having its research evaluated by key players doing research in the firm's area.

In addition to providing knowledge to newly formed biotechnology companies, university-based scientists also provide a signal of firm quality to the scientific and financial communities. An effective way to recruit young scientists is to have an SAB composed of leaders in the field. George B. Rathmann, former president and CEO of Amgen, attributes much of the company's success to an SAB of "great credibility" whose "members were willing to share the task of interviewing the candidates for scientific positions." Rathmann goes on to say that the young scientists that Amgen recruited would not have come "without the knowledge that an outstanding scientific advisory board took Amgen seriously" (Burrill, 1987, p. 77).

In the early stages of development biotechnology firms also miss no opportunity to signal the abilities of their scientists as well as the science they are undertaking to the investment community. It is not uncommon for prospectuses to read like proposals to the National Institutes of Health, both in terms of the projects they describe and the accomplishments of the scientists. In other work, Stephan (1994) has shown the importance of scientific reputation at the time a biotechnology company goes public. Based on a sample of 45 firms, Stephan found that the more substantial the reputation of the university-based scientific affiliates, the greater the proceeds raised from the initial public offering.

3. Database and methodology used

Data for this study come from the prospectuses of biotechnology companies that prepared an initial public offering in the United States during the period March 1990 to November 1992. All told, 52 firms affiliated with 420 university-based scientists meet this criterion.[1] By carefully reading these prospectuses, we are able to determine the names of university-based scientists affiliated with each firm and the role they play in the firm. The Securities and Exchange Commission (SEC) requires that the names and positions of insiders having substantial holdings in the company be listed in the prospectuses. In addition, the SEC records the market activity of insiders. These transactions are available through the Investnet/CDA database and we have used this to monitor the transactions of all insiders in the 52 firms from the period that the companies went public through early January, 1994. Thus, we know the initial position of the university-based scientists as well as transactions they have engaged in subsequent to the offering.[2]

4. Findings

Four hundred and twenty university-based scientists (UBSs) were affiliated with the 52 firms in the study. Thirty-seven of these had sufficient holdings and close enough ties with the company to warrant disclosure of their holdings at the time

of the initial public offering. Three additional university-based scientists appeared in the CDA data base as "insiders" but were not required to disclose their individual position at the time the offering was planned.[3] Thus, approximately 10 percent of the university-based scientists affiliated with a company can be classified as "insiders." The majority (55%) of the 40 university-based insiders were founders of the company. A handful of others were directors, but not founders, while still others served as chairs or members of the scientific advisory board.

The transaction activity of the 40 is summarized in Table I. We see that 14 of the 40 had activity that generated a profit; details of these transactions are recorded in the Appendix. The typical profit-generating transaction was the exercise of a stock option with the sale of a portion of the stock on the same day. Although this was the extent of the activity for six of the scientists, the other eight traded on more than one day and one engaged in a total of 11 profit-generating trades during the period of observation. The minimum cumulative profit realized by one of the 14 traders was $34,285. The maximum was $11,760,000 (in this instance the scientist, in an "off exchange" transaction, exercised an option to buy 352,000 shares of stock on one day at a price of $11.00 and sold 199,334 of them the same day for $70.00 per share). The median was approximately $250,000, the mean $1,237,598. In one instance a scientist traded but we could not identify the acquisition price and thus could not compute the profit realized. In another instance the scientist registered and then, as the value of the stock declined, made repeated purchases on the open market. Six of the 40 scientists exercised options to buy and then did not make a sale within our window of observation. In all six instances, the option exercise price was substantially less than the market-price of the stock at the date of exercise. In four additional cases, university-based scientists disposed of a portion of their stock by gift. Since we could not determine the value of the acquisition, we could not determine the net value of the gift from the perspective of the scientist. For seven of the remaining scientists, the only activity was the registration of stock. For the other seven we could find no record of activity in the CDA.

TABLE I
Summary of activity of 40 university-based scientists having a recorded beneficial position

Number	Activity
14	Exercised Options and then made a sale(s) which realized a profit.
6	Exercised options to buy; no recorded sales.
4	Registered and disposed of a portion by gift.
1	Sold but no basis could be determined.
1	Registered and made repeated open-market purchases, as the price of the stock fell.
7	Only activity was to register stock.
7	No recorded activity in CDA data base.

The twenty university-based scientists who exercised options (the first two categories in Table I) were slightly more likely to hold an M.D. degree than a Ph.D. Not surprisingly, they are a distinguished group. One is the recipient of a Nobel prize and in 1991 was cited over 850 times in the scientific literature.[4] Many of the others are also heavily cited; over half have more than one hundred citations to their work in the year the initial public offering was issued. Five of the insiders who had recorded activity are on the faculty at the University of California, San Francisco. Four of these realized substantial profits. Four are at Stanford University, two at Duke University, two at Yale University.

Another way of examining the rewards university-based scientists experience as a result of involvement with new companies is to estimate the gross value of the beneficial portfolio held by the scientist at the time of the initial public offering. This is done by multiplying the number of shares or potential shares through option exercise held at the time of the offering by the share price at the close of day one.[5] This is clearly an upper bound of the value of the portfolio at this time for a variety of reasons. First, it must be stressed that in the initial days of trading, the ability of insiders to trade is restricted. Second, the market for these stocks is thin; the knowledge by the market of an insider making a large sale could have significant negative effects. Third, in many instances the scientists must exercise an option before a sale can be made. In some

instances the option price is minuscule ($0.001); in other instances it is substantial ($11.00). Finally, some of the stock is not held by the scientists but instead is in trust either for relatives or for a non-profit institution. Despite these caveats, the value of the scientist's portfolio at day one can provide the base for borrowing from financial institutions and certainly must have some impact on the scientist's perception of net worth.

Table II summarizes the portfolio value of beneficial shares held at the close of day one for the forty. The values are impressive, with the median falling in the $3–4 million category. Only five are less than $500,000 and in one case a husband and wife (both of whom are university-based scientists) had a portfolio valued at over $25 million at the close of day one.[6] That these are not necessarily "fictional" values is underscored by the fact that the portfolio value of the scientist who made the $11,760,000 profit (and still retained a substantial number of shares) was worth a mere $7,729,375 at the close of day one; the portfolio value of the scientist who traded for a profit of $1,908,070 (and still retained a substantial number of shares) was $5,000,000.

Dasgupta and David (1987) argue that the rewards awarded scientists by industry provide an incentive for scientists to engage in research. Early in their careers, scientists build reputations which are then used to signal ability to industry. This line of argument suggests testing to see if the value of the beneficial portfolio at the close of day one is related to career characteristics of the scientists.

TABLE II
Portfolio value of beneficial shares, close of day one

< $100,000	0
100,001– 500,000	5
500,001–1,000,000	6
1,000,001–2,000,000	2
2,000,001–3,000,000	4
3,000,001–4,000,000	5
4,000,001–5,000,000	6
5,000,001–6,000,000	2
6,000,001–7,000,000	0
7,000,001–8,000,000	3
8,000,001–9,000,000	3
> 9,000,001	4

We investigate this hypothesis by estimating a Tobit equation of portfolio value at the close of day one. Career characteristics included are age, the number of citations in 1992 to first-authored articles, and a dummy variable for receipt of the Nobel Prize. These were determined by looking in standard reference works such as *American Men and Women of Science* and could be found for 330 of the 422 scientists.

The results for the 330 are presented in Table III. The variables are also defined in the table. The excluded category is university-based scientists who are neither founders nor chairs of scientific advisory boards nor Nobel laureates. Consistent with Dasgupta and David's theory, we find that the portfolio value of scientists is an increasing function of age, reaching a peak value at 55. We also find, not surprisingly, that the portfolio value

TABLE III
Tobit results: Dependent variable: day one portfolio (value in millions)

Variable	Coefficient	Standard error	Definition of variable
Intercept	–66.174	23.423	
Age	2.143*	0.839	Age
Agesq	–0.019*	0.007	Age squared
Cite	–0.020†	–0.011	Number of citations in 1992
Citesq	+0.000024†	0.000013	Number of citations in 1992 squared
Nobel	0.138	4.482	Dummy variable = 1 if Nobel laureate; zero otherwise
Founder	8.122**	1.814	Dummy variable = 1 if founder; zero otherwise
SABch	7.304**	1.999	Dummy variable = 1 if chain of SAB; zero otherwise
Log likelihood ratio test (8,76.902) **			

† Significant at the 0.10 level.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

of founders and chairs is significantly greater than that of the other university-based scientists involved with these firms. There is also evidence that the portfolio value is related to the scientist's reputation. The citation variables are significant at the 10 percent level, but not in the way predicted. Indeed, what we find is that the portfolio value decreases at a decreasing rate with the number of citations, reaching a minimum at about 400 and then beginning to increase. This result may not be as counter intuitive as appears at first blush. Scientists who are chosen to signal "quality" often have a large number of citations. While they may hold options (see below), compared to founders and chairs their role in the firm is fairly minimal. Consequently, their inside position is not declared in the prospectus and as a result they are attributed a portfolio value of zero in our analysis. Furthermore, while the value of their position is relatively small compared to that of founders and chairs, the fact that some of these scientists are on the SABs of more than one firm means that they have multiple chances of enhancing their net worth and hence cashing in.[7]

We investigate this issue by examining the prospectuses to see just how common it is to compensate members of SABs by offering them the option to purchase stock. We find that 67 percent of the companies that had SABs for which the form of compensation could be determined offered stock options to the members.[8] These 31 SABs contained an additional 242 university-based scientists. While we cannot determine the degree of their financial involvement because their position does not require disclosure, it is clearly less than that of founders and directors listed specifically in the prospectuses. If we add the 242 to the 40 reported above, we conclude that in 282 of the 420 cases the scientist holds an equity position in the firm.

5. Other forms of compensation

In addition to receiving stock and options for their services, university-based scientists also receive a third form of compensation in the form of consulting fees or salary. Because in many instances these payments are not fully disclosed in the prospectus,[9] we are unable to examine quantitatively the degree to which such forms of payment supplement equity compensation. Careful reading of the prospectuses, however, permits us to make certain generalizations. First, university-based founders who had a sufficient equity position to require disclosure always received some form of cash compensation from the firm. Sometimes these were substantial and were in the form of salary. For example, one founder who serves on the clinical faculty of a medical school, received an annual salary of $144,856 as vice president of medical research for the company, another received $114,000 for a similar position. Four others (of the 22 university-based founders who had sufficient equity positions to require disclosure) received annual compensation of $100,000 or more from the firm. Others of the scientific founders holding strong equity positions in the firm received consulting fees in lieu of salary. In most instances the existence of these fees is noted, but the magnitude is not specified.[10]

Second, in addition to receiving equity, members of scientific advisory boards almost always receive a cash payment as well. Indeed, only four of the 31 firms providing equity to the members of the SABs made no cash payments to their scientific advisory boards. These cash payments are usually made on a per meeting basis and are in the range of $500 to $2500 per meeting. In addition, many of the members of the SAB serve as consultants to the firm and receive additional compensation for these services.

Third, scientists rarely receive cash compensation for their role as director. Many who serve as directors, however, also are retained as consultants and earn fees in this way. For example, one director with a strong equity position received $68,500 in consulting fees in one year from the firm; another received around $5,000.

University-based scientists have other incentives for becoming involved with these firms. In many instances, university-based scientists may obtain funding for their labs as a result of the alliance and sometimes write joint-authored articles with scientists employed by the firm (Zucker et al., 1994). Consulting arrangements with firms also help in the placement of graduate students as well as the generation of future research ideas (Mansfield, 1995). A number of these scientists will also realize payments from the firm if and when the firm begins to sell a product

since it is not uncommon for UBSs to have entered into a licensing agreement with the firm.

6. Discussion and conclusion

Sociologists generally argue that the motivating factors for doing science are an interest in establishing priority as well as the psychic awards generated by solving the puzzle (Merton 1957, Hagstrom, 1965). Economists (Diamond, 1986; Levin and Stephan 1991; Levy, 1990; Stephan and Levin, 1992; Stephan, 1996) have assumed that scientists, like most economic agents, are interested in money as well. Anecdotal evidence supports this assumption. When Henry Rosovosky (1990, p. 242), the former dean of the Faculty of Arts and Sciences at Harvard, asked one of Harvard's most eminent scientists the source of his scientific inspiration, the reply ("which came without the slightest hesitation") was "Money and flattery." The scientist Stephen Jay Gould, in an interview with Wolpert and Richards (1988, p. 146) said that scientists want "status, wealth and power, like everyone else."

Economists have related the earnings of university-based scientists to their scholarly activity. Work by Tuckman (1976), Tuckman and Leahy (1975), and Diamond (1986) support the assumption that salary is positively related to publications and citations. The returns, however, are somewhat modest. The Diamond estimates, for example, suggest that the present value of publishing another article for a 35-year old mathematician is (in 1994 dollars) about $6,750; the present value of an additional citation to a 35-year old physicist's work is about $2,225.[11] Other forms of compensation, of course, have existed for the successful scientist. For example, it is not uncommon for scientists to consult or collect speaking fees. And, the most successful can dream of collecting a prize with a substantial purse. The Nobel, for example, has a cash award of approximately $1 million; the Bower (the richest American prize) has a purse of $250,000. These, however, are out of the reach of all but a handful of scientists.

In recent years a new opportunity for financial gain has arisen in science as a result of the development of a number of start-up firms that have strong ties with university-based scientists. While it has long been known that in a few instances the scientists involved as founders made substantial profits (Kenney, 1986), this is the first study, to the best of our knowledge, that estimates the incidence of stock ownership among university-based scientists as well as the first study to give some indication of the magnitude of the sums involved.

We find that approximately 10 percent of the UBSs have sufficient holdings to be classified as insiders by the SEC. An additional 242 have stock options as a result of membership on an SAB. Using these figures as a basis for extrapolation, we estimate that there are approximately 1,404 linkages between university-based scientists and biotech firms which result in the scientist holding equity in a firm that is publicly traded in the United States.[12]

Although only a small number of our scientists traded, those who did trade realized large profits. We also find that the value of the beneficial portfolio of the UBSs at the close of day one is substantial. In over half the instances, for example, the value of the beneficial portfolio far exceeds the present value of the scientist's university salary, assuming that the scientist earns $125,000 per year and is in mid-career.

The number of university-based scientists holding equity positions in these firms, as well as the sizeable profits realized and the potential profits in the offing, raise several questions. One is the question of how such financial ties affect the open communication pattern that has characterized university-based science in the past. Stephan and Levin (1996) argue that secrecy and a decreased willingness to share information can result when university-based scientists form alliances with start-up companies. Blumenthal et al. (1996) find that many pharmaceutical and biotechnology companies require that university-based scientists engaged in R&D activities with firms are required to keep research results secret for several months while the companies attempt to commercialize the work. A second question is whether the lure of large payoffs biases the type of knowledge that is generated by the scientific community. Does the prospect of substantial profit that this note documents encourage scientists to follow research agendas with quicker payoffs, ignoring other research areas which have the possibility of

opening new frontiers but require longer horizons and provide meager financial return?

A third question is how the possibility of capital gains motivates scientists to innovate. A growing literature exists on the relationship of compensation to innovation (Holmstrom, 1989; Jensen, 1993; Aghion and Tirole, 1994). Future research should examine the structure of compensation offered to the university-based scientists and the role the scientist plays in transferring innovative knowledge to the firm. To do so, however, requires more information than can be gleaned from the prospectuses of initial public offerings.

Acknowledgements

The authors would like to thank two anonymous referees and Diane Primont for helpful comments; John Krisulewicz for his assistance with the CDA database; and Richard Hawkins and Meghan Crimmins for their help in constructing the initial public offering database.

Notes

[1] Firms that prepared an offering and then pulled it are not included in the study unless the offering was reinstated in time to be included in the search for trades. (See discussion to follow.) In almost all cases the scientist was employed full-time by the university. In several instances, however, the individual held an adjunct position with a university or was a member of a scientific institute.

[2] Note that insider activity is censored from the right because the firms went public over a period of time, but data collection ended for all firms at approximately the same time. Thus, insiders with firms that went public early in the period had a longer time to engage in trades than did insiders with firms that went public later in the period.

[3] In all three instances their positions were disclosed jointly with other directors and officers.

[4] Citation counts are for first author only.

[5] The Black and Scholes (1973) procedure for evaluating options is not appropriate given that on day one no history of trading exists, and hence no standard deviation can be estimated.

[6] In this instance where the portfolio was jointly held by a husband and wife, the value was split in two to construct Table II.

[7] In the original data base for the 54 firms that prepared an initial public offering during this period, 393 university-based scientists had a contact with only one firm; twenty-one had a contact with two firms and three had a contact with three firms.

[8] Fifty of the 52 firms had SABs. We could determine the form of compensation for 46 of these; 67% (31) of the 46 offered stock options to the members.

[9] For example, in some prospectuses it will simply state that the founder has entered into a consulting agreement with the firm without specifying the terms. In other prospectuses it stipulates that scientific advisors receive compensation, but it does not spell out the amount. In still other instances, the total amount paid to all advisors is listed.

[10] There are also a number of university founders whose equity position is too small to require disclosure at the time the firm makes an initial public offering. Specifically, 15 of the 37 university-based founders in this database did not have a disclosed equity position at the time of the initial public offering.

[11] These calculations assume that the rewards are incorporated into the base salary.

[12] On average there are 8.25 UBSs per firm. By the end of 1992 there were approximately 265 publicly traded biotech firms (Lee and Burrill, 1995). The estimates assume that 96 percent of these firms have SABs and that 67 percent of these firms offer stock options to members of their scientific advisory boards. Note that this does not mean that there are 1404 unique scientists holding such a position. It is not uncommon, as noted above, for scientists to be involved with more than one firm.

Appendix

Company	Agent	Insider position	Date of initial activity	Date of closing transaction (if any)	Length of holding period[1]	Option exercise price / # shares purchased	Market price on date of exercise / # shares sold	Realized profit	Cumulative realized profit	Paper profit[2]	Realized profit plus paper profit[3]
Firm 1	Agent 1	Director/SAB	12-16-93			$0.30 / 15,000	$7.50 / 0			$108,000	
Firm 1	Agent 2	Director/SAB	01-05-93			$0.30 / 33,000	$14.75 / 0			$476,850	
Firm 2	Agent 1	Director/SAB	06-21-93			$0.21 / 11,466	$6.75 / 0			$74,988	
Firm 2	Agent 1	Director/SAB	06-21-93			$0.16 / 25,600	$6.75 / 0			$168,704	
Firm 3	Agent 1	Director/SAB Founder	07-08-92			$0.33 / 128,485	$7.25 / 0			$889,116	
Firm 4	Agent 1	Director/SAB	11-13-91	11-20-91	7 days	$0.10 / 20,000	$16.00 / 10,000	$159,000	$159,000	$159,000	$318,000
Firm 4	Agent 1	Director/SAB	01-03-94			$0.10 / 76,000	$15.75 / 0		$159,000	$1,189,400	
Firm 4	Agent 1	Director/SAB	01-03-94			$0.15 / 218,622	$15.75 / 0		$159,000	$3,410,503	
Firm 4	Agent 1	Director/SAB	01-03-94			$1.20 / 23,735	$15.75 / 0		$159,000	$345,344	
Firm 5	Agent 1	Director/SAB Founder	07-01-88	01-02-92	42 months	$0.10 / 176,000	$14.50 / 30,000	$432,000	$432,000	$2,102,400	$2,534,400
Firm 5	Agent 1	Director/SAB Founder	07-01-88	06-29-92	48 months	$0.10 / 176,000	$11.00 / 20,000	$218,000	$650,000	$1,373,400	$1,591,400
Firm 5	Agent 2	Director/SAB Founder	07-01-88	01-02-92	42 months	$0.10 / 176,000	$14.75 / 30,000	$439,500	$439,500	$2,138,900	$2,578,400
Firm 5	Agent 2	Director/SAB Founder	07-01-88	04-27-93	58 months	$0.10 / 176,000	$11.00 / 10,000	$109,000	$548,500	$1,482,400	$1,591,400
Firm 5	Agent 2	Director/SAB Founder	07-01-88	05-24-93	59 months	$0.10 / 176,000	$13.00 / 7,000	$90,300	$638,800	$1,664,100	$1,754,400
Firm 5	Agent 2	Director/SAB Founder	07-01-88	01-04-94	66 months	$0.10 / 176,000	$15.00 / 10,000	$149,000	$1,040,800	$1,475,100	$1,624,100
Firm 6	Agent 1	Director/SAB Founder	07-01-87	07-27-92	60 months	$0.01 / 125,000	$9.28 / 10,000	$92,700	$92,700	$1,066,050	$1,158,750
Firm 7	Agent 1	Director/SAB Founder	01-02-90	12-17-91	24 months	$4.08 / 818,611	$9.88 / 10,000	$58,000	$58,000	$4,689,944	$4,747,944
Firm 7	Agent 1	Director/SAB Founder	01-02-90	01-14-92	24.5 months	$4.08 / 818,611	$10.00 / 10,000	$59,200	$117,200	$4,727,777	$4,786,977
Firm 7	Agent 1	Director/SAB Founder	01-02-90	01-15-92	24.5 months	$4.08 / 818,611	$10.63 / 10,000	$65,500	$182,700	$5,165,402	$5,230,902

Firm 8	Agent 1	Director/ Founder	03-29-89	05-08-92	37 months	$2.38 / 21,874	$7.00 / 7,421	$34,285	$34,285	$66,772	$101,058
Firm 9	Agent 1	Director/ Founder	03-01-87	07-01-88	16 months	$0.001 / 750,000	$0.80 / 250,000	$199,975	$199,975	$399,500	$599,475
Firm 9	Agent 1	Director/ Founder	03-01-87	11-22-91	56 months	$0.001 / 750,000	$19.00 / 11,900	$226,088	$426,063	$9,273,412	$9,500,000
Firm 9	Agent 1	Director/ Founder	03-01-87	11-22-91	56 months	$0.001 / 750,000	$19.25 / 1,100	$21,174	$447,237	$9,374,263	$9,395,437
Firm 9	Agent 1	Director/ Founder	03-01-87	11-22-91	56 months	$0.001 / 750,000	$19.50 / 2,000	$38,998	$486,235	$9,457,015	$9,496,013
Firm 9	Agent 1	Director/ Founder	03-01-87	04-30-92	62 months	$0.001 / 750,000	$11.25 / 5,0005	$56,245	$542,480	$5,399,520	$5,455,76
Firm 9	Agent 1	Director/ Founder	03-01-87	08-05-92	64 months	$0.001 / 750,000	$12.25 / 3,000	$36,747	$579,227	$5,842,773	$5,879,520
Firm 9	Agent 1	Director/ Founder	03-01-87	08-05-92	64 months	$0.001 / 750,000	$12.375 / 2,000	$24,748	$603,975	$5,877,650	$5,902,398
Firm 9	Agent 1	Director/ Founder	03-01-87	11-03-92	67 months	$0.001 / 750,000	$10.25 / 1,000	$10,249	$614,224	$4,858,026	$4,868,275
Firm 9	Agent 1	Director/ Founder	03-01-87	03-13-93	71.5 months	$0.001 / 750,000	$8.375 / 150,000	$1,256,100	$1,870,324	$2,713,176	$3,969,276
Firm 9	Agent 1	Director/ Founder	03-01-87	07-08-93	75 months	$0.001 / 750,000	$9.50 / 3,000	$28,497	$1,898,821	$3,049,179	$3,077,676
Firm 9	Agent 1	Director/ Founder	03-01-87	07-08-93	75 months	$0.001 / 750,000	$9.25 / 1,000	$9,249	$1,908,070	$2,959,680	$2,968,929
Firm 10	Agent 1	Director	06-30-88	10-15-92	51.5 months	$1.00 / 320,000	$1.13 / 55,000	$7,150	$7,150	$34,450	$41,600
Firm 10	Agent 1	Director	06-30-88	10-27-92	52 months	$1.00 / 320,000	$1.50 / 50,000	$25,000	$32,150	$107,000	$132,500
Firm 10	Agent 1	Director	06-30-88	10-28-92	52 months	$1.00 / 320,000	$1.63 / 40,000	$25,200	$57,350	$110,250	$135,450
Firm 10	Agent 1	Director	06-30-88	10-29-92	52 months	$1.00 / 320,000	$1.56 / 15,000	$8,400	$65,750	$89,600	$98,000
Firm 10	Agent 1	Director	06-30-88	11-04-92	52 months	$1.00 / 320,000	$1.56 / 15,000	$8,400	$74,150	$81,200	$89,600
Firm 10	Agent 1	Director	06-30-88	11-06-92	52 months	$1.00 / 320,000	$1.44 / 10,000	$4,400	$78,550	$59,400	$63,800
Firm 10	Agent 1	Director	06-30-88	11-09-92	52 months	$1.00 / 320,000	$1.41 / 25,000	$10,250	$88,800	$45,100	$55,350
Firm 10	Agent 1	Director	06-30-88	11-11-92	52.5 months	$1.00 / 320,000	$1.50 / 10,000	$5,000	$93,800	$50,000	$55,000
Firm 10	Agent 1	Director	06-30-88	11-12-92	52.5 months	$1.00 / 320,000	$1.76 / 100,000	$76,000	$169,800	$0	$76,000
Firm 11	Agent 1	Director	01-01-92	11-16-93	22.5 months	$7.70 / 25,000	$21.00 / 5,000	$66,500	$66,500	$266,000	$332,500
Firm 11	Agent 1	Director	01-01-92	11-18-93	22.5 months	$7.70 / 25,000	$23.125/ 5,000	$77,125	$143,625	$231,375	$308,500
Firm 11	Agent 1	Director	01-01-92	11-19-93	22.5 months	$7.70 / 25,000	$24.50 / 5,000	$84,000	$227,625	$245,000	$329,000

APPENDIX *(Continued)*

Company	Agent	Insider position	Date of initial activity	Date of closing transaction (if any)	Length of holding period[1]	Option exercise price / # shares purchased	Market price on date of exercise / # shares sold	Realized profit	Cumulative realized profit	Paper profit[2]	Realized profit plus paper profit[3]
Firm 12	Agent 1	SAB	12-31-90	10-09-91	9 months	$12.00 / 102,750	$15.75 / 8,000	$30,000	$30,000	$355,313	$385,313
Firm 12	Agent 1	SAB	12-31-90	11-01-91	10 months	$12.00 / 102,750	$18.00 / 2,000	$12,000	$42,000	$556,500	$568,500
Firm 12	Agent 1	SAB	12-31-90	01-02-92	12 months	$12.00 / 102,750	$18.00 / 2,000	$12,000	$54,000	$544,500	$556,500
Firm 13	Agent 1	Director/SAB	11-01-91	11-17-92	12 months	$3.00 / 595,506	$14.375 / 32,000	$364,000	$364,000	$6,409,881	$6,773,881
Firm 13	Agent 2	Director/SAB	11-01-91	09-14-93	22.5 months	$3.00 / 19,520	$18.25 / 19,520	$297,680	$297,680	$0	$297,680
Firm 14	Agent 1	Director	03-24-94			$.40 / 12,500	$8.00 / 0			$95,000	
Firm 15	Agent 1	Director/SAB Founder	01-01-88	11-25-92	59 months	$.01 / 448,071	$7.75 / 5,000	$38,700	$38,700	$3,429,370	$3,468,070
Firm 15	Agent 1	Director/SAB Founder	01-01-88	12-03-92	59 months	$.01 / 448,071	$7.50 / 5,000	$37,450	$76,150	$3,281,152	$3,318,602
Firm 15	Agent 1	Director/SAB Founder	01-01-88	12-04-92	59 months	$.01 / 448,071	$7.50 / 5,000	$37,450	$113,600	$3,243,702	$3,281,152
Firm 15	Agent 1	Director/SAB Founder	01-01-88	12-07-92	59 months	$.01 / 448,071	$7.50 / 10,000	$74,900	$188,500	$3,168,802	$3,243,702
Firm 15	Agent 1	Director/SAB Founder	01-01-88	08-13-93	67.5 months	$.01 / 448,071	$2.63 / 25,000	$65,500	$254,000	$1,042,946	$1,108,446
Firm 15	Agent 1	Director/SAB Founder	01-01-88	08-16-93	67.5 months	$.01 / 448,071	$2.63 / 50,000	$131,000	$385,000	$911,946	$1,042,946
Firm 16	Agent 1	Director	08-01-88			$11.00 / 23,420	$18.00 / 0			$163,940	
Firm 16	Agent 2	Director/SAB Founder	08-01-88	02-19-92	42.5 months	$11.00 / 352,500	$70.00 / 199,334	$11,760,706	$11,760,706	$9,036,794	$20,797,500

[1] Holding period is determined to be either the date the options were granted or the date of the exercise if grant date is unavailable.
[2] Paper profit is determined to be remaining shares held x (market price-exercise price).
[3] This includes realized profit as of transaction date only, not cumulative profit.

References

Acs, Zoltan J. and David B. Audretsch, 1988, 'Innovation in Large and Small Firms: An Empirical Analysis', *American Economic Review* **78**(4), 678–690.

Aghion, Philippe and Jean Tirole, 1994, 'The Management of Innovation', *Quarterly Journal of Economics* **109**(4), 1185–1209.

American Men and Women of Science, 1992, 18th ed., New York: Bowker.

Audretsch, David B., 1995, *Innovation and Industry Evolution*, Cambridge: MIT Press

Audretsch, David B. and Paula Stephan, 1994, 'Company-Scientist Locational Links: The Case of Biotechnology,' *American Economic Review* **86**(3), 641–652.

Black, Fischer and Myron Scholes, 1973, 'The Pricing of Options and Corporate Liabilities,' *Journal of Political Economy* **81**(3), 637–654.

Blumenthal, David, Nancyanne Causino, Eric Campbell, and Karen Seashore Louis, 'Relationships Between Academic Institutions and Industry in the Life Sciences – An Industry Survey', *The New England Journal of Medicine* **334**(6), 368–373.

Burrill, G. Steven, 1987, *Biotech 88: Into the Marketplace*, San Francisco, Ca: The Arthur Young High Technology Group.

Dasgupta, Partha and Paul A. David, 1987, 'Information Disclosure and the Economics of Science and Technology', in George R. Feiwel (ed.), *Arrow and the Ascent of Modern Economic Theory*, New York: New York University. Press, pp. 519–542.

Diamond, Arthur, 1990, 'What is a Citation Worth?' *Journal of Human Resources* **21**(2), 200–215.

Hagstrom, Warren, 1965, *The Scientific Community*, New York: Basic Books.

Holmstrom, Bengt, 1989, 'Agency Costs and Innovation', *Journal of Economic Behavior and Organization* **12**, 305–327.

Jensen, Michael C., 1993, 'The Modern Industrial Revolution, Exit, and the Failure of Internal Control Systems', *The Journal of Finance* **48**(3), 831–880.

Kenney, Martin 1986, *Biotechnology: The University Industrial Complex*, New Haven: Yale University Press.

Kleinknecht, Alfred, 1989, 'Firm Size and Innovation: Observations in Dutch Manufacturing Industries', *Small Business Economics* **1**(3), 315–222.

Lee, Kenneth B. and G. Steven Burrill, 1994, *Biotech 95: Reform, Restructure, Renewal*, Palo Alto, Ca: Ernst & Young.

Levin, Sharon G. and Paula E. Stephan 1991, 'Research Productivity Over the Life Cycle: Evidence for Academic Scientists', *American Economic Review* **81**(1), 114–32.

Levy, David, 1988, 'The Market for Fame and Fortune', *History of Political Economy* **20**(4), 615–625.

Mansfield, Edwin, 1995, 'Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing', *Review of Economics and Statistics* **77**(1), 55–65.

Merton, Robert, 1957, 'Priorities in Scientific Discovery: A Chapter in the Sociology of Science', *American Sociological Review* **22**(6), 635–659.

Rothwell, Roy, 1989, 'Small Firms, Innovation and Industrial Change', *Small Business Economics* **1**(1), 51–64.

Rosovsky, Henry, 1990, *The University: An Owner's Manual*, New York: W.W. Norton.

Stephan, Paula E., 1994, 'Differences in the Post-entry Value of Biotech Firms: The Role of Human Capital', Paper presented at a Conference on the Post-entry Performance of Firms, Lisbon, May 27–28, 1994.

Stephan, Paula E., 1996, 'The Economics of Science', *Journal of Economic Literature* **34**(3), September.

Stephan, Paula E. and Sharon G. Levin, 1992, *Striking the Mother Lode in Science: The Importance of Age, Place and Time*, New York: Oxford University Press.

Stephan, Paula E. and Sharon G. Levin, 1996, 'Property Rights and Entrepreneurship in Science', *Small Business Economic* **8**(3), 177–188.

Tuckman, Howard, 1976, *Publication, Teaching and the Academic Reward Structure*, Lexington, Ma: Lexington Books.

Tuckman, Howard and Jack Leahey, 1975, 'What is an Article Worth?', *Journal of Political Economy* **83**(5), 951–967.

Wolpert, Lewis and Alison Richards, 1988, *A Passion for Science*, New York: Oxford University Press.

Zucker, Lynne G., Michael R. Darby and Jeff Armstrong, 1994, 'Intellectual Capital and the Firm: The Technology of Geographically Localized Knowledge Spillovers', Cambridge, Ma: National Bureau of Economic Research, working paper no. 4946.

Copyright of Small Business Economics is the property of Springer Science & Business Media B.V.. The copyright in an individual article may be maintained by the author in certain cases. Content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.