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The Organizational Study of the High-Technology Firm: Theory and Empirics on Biotechnology

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Abstract: Recent literature suggests that the new, biotechnology firms have an organizational structure different from that of traditional pharmaceutical research firms. However, little of this is formally documented or examined theoretically. This paper presents a model of a manager monitoring the R&D process in order to devise an incentive system for researchers. It is hypothesized that under the newer, biotech R&D methods, monitoring of researcher efforts is more important. The model predicts that biotechs will have managers with more residual income claimancy to increase their incentives to monitor the R&D process accurately. This generally implies smaller, owner-managed R&D firms. The empirical evidence, based on a sample of pharmaceutical research firms, is consistent with the theoretical predictions.

1. Introduction

The previous literature[2] has extensively discussed the modern theory of a firm in respect to the question of monitoring and monitoring costs. This paper treats the problem of monitoring the biotechnology or other pharmaceutical firm by a manager of this firm or establishment. The nature of monitoring in the advanced technological environment of biotechs is quite different from that of a traditional pharmaceutical research. The latter emphasizes routine procedures that are easy to monitor while in the former, monitoring effort is more difficult but important. Because of this difference, our model predicts stark differences in the residual income claimancy of managers and in other aspects of organization for innovative R&D firms like biotechs.

Anecdotal evidence supports this. Much of biotechnology research apparently is done by small, independent start-ups with contractual ties to various other firms in the pharmaceutical industry (Burrill, 1989 and 1989). This change in the organization of pharmaceutical research made away from “in-house” R&D occurred simultaneously with the change in the technology of drug research. This paper discusses the theories linking the two phenomena.

Much of traditional pharmaceutical research was (and is) performed "in-house" by pharmaceutical manufacturers (Gambardella, 1995). The typical process was extensive chemical modification of basic compounds that generated large volumes of chemical molecules that were then tested in clinical trails for effectiveness in treating various ailments and conditions. In this process, pharmaceuticals developed a predictable, but low, chance of success on any given path. The recent development of genetic engineering techniques and rapid advancements in molecular biology has changed many of the methods of innovation and the form of pharmaceutical research.

With the new technology, scientists began to gain fundamental understanding of disorders and their relationships to drugs. Moreover, it also motivated changes in the structure of the industry (Teece, 1988). The traditional large-scale in-house research in mammoth pharmaceutical firms apparently is no longer the dominant mode in the industry. Small research oriented biotechnology firms have emerged as significant players in the development of new drugs. The outputs of many biotechs are intermediate goods designed for the major pharmaceutical firms that produce and market the final product to consumers. To produce a final marketable product, the researcher's inputs are as important as the manufacturer's. As with the development of many new products, continued collaboration of both parties is needed.[3] Usually, the biotechs focus on the research side and the large pharmaceuticals are the manufacturers. However, there is some vertical integration of

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[2] See Alchian and Demestes (1972) and Jensen and Meckling (1976).

[3] See Pisano (1991), Arora and Gambardella (1990), Bower and Whittaker (1993), Smith and Fleck (1988), and Deeds and Hill (1996).

biotechs into manufacturing and of the large pharmaceuticals into biotechnology research. More typical are contractual arrangements between the biotech firms and manufacturers.[1]

This paper focuses on the internal organization problems of biotechnology firms as compared to more traditional pharmaceutical firms. The latter's emphasis on routine screening and testing procedures makes monitoring of scientists a non-issue. The opposite is true of the biotechnology firms, where the research requires intangibles such as new ideas and creative thinking. This makes monitoring inherently difficult though especially important for the owner/manager to develop a monitoring and compensation system to motivate hard work. Hence, organization structures are expected to be different. We focus on three aspects of organizational structure: managerial ownership, ownership by experts in research, and firm size.[2]

Section 2 of the paper presents the model. The focus is on the assignment of residual income claimancy to motivate managers to monitor and establish an effective incentive system for researchers. We find out that the more important the monitoring of researchers is, the greater the residual income claimancy of the R&D manager appears to be. Other predictions regarding firm size and ownership by experts are also developed. Section 3 presents an overview of the data on the pharmaceutical research industry and tests the hypotheses of the model. The data are from BioScan (1992 version), a survey of nearly 900 firms involved in biotechnology, ranging from very small firms to the giant pharmaceuticals such as NEC. As predicted, we find systematic evidence that firms more focused on the newer, biotechnology research tend to be management-owned, have more experts in the field as owner-managers, and are smaller in size. Section 4 of the paper summarizes and concludes the obtained results.

2. The Model[3]

In an R&D intensive industry, a model with three groups is considered: a manufacturing manager, an R&D manager, and research scientists/employees. Managers also may be owners in the sense of holding residual income claimancy. Assume that both managers are risk neutral and scientists/employees are risk averse. The R&D manager's job is to monitor the scientists/employees and to set compensation to induce scientist's effort. The manufacturing manager's job is assumed to be analogous, but is not modeled. The research effort of the R&D unit is combined with inputs from the manufacturer to produce a final product. But, one may ask, what are the incentives to each manager?

The manufacturing division does not simply acquire or buy the R&D and put it to use. Both the manufacturing side and the R&D side must provide ongoing effort to assure that the finished product is produced. Both sides require incentives to induce effort. Because of the cooperative nature of the efforts taken to produce the final product, it is difficult to determine the contribution of each side, so it is assumed to be noncontractable between the two managers. Therefore, the managers contract on the division of residual income claimancy on the joint output. This has its trade-offs: Greater residual income claimancy for the R&D (manufacturing) side creates more incentive for the R&D (manufacturing) manager, but less for the manufacturing (R&D) manager.

Greater residual income claimancy for the manufacturing side is interpreted as being closer to in-house R&D. Greater residual income claimancy for the R&D side is interpreted as being closer to an independent R&D firm. If the R&D unit owns one-hundred percent of residual income claimancy, then the research unit is an independent firm that receives one-hundred percent royalties from the innovation.[4] It is desirable to award residual income claimancy to maximize the value of the joint enterprise. We intend to see under what conditions the R&D unit will be the ma-

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[1] For examples of discussions of contractual relationships in the biotech industry, see Sharp (1985), Cooper (1987), Greis, Dibner and Bean (1995), and Powell et. al. (1996).

[2] Another unique feature of this industry is the extensive network of contractual ties among firms, but this is outside the scope of this paper. See Chang (1998) and Mayer and Nickerson (1998) for economic analyses of these contracts. Also, for a treatment of vertical integration and control rights to an innovation, see Aghion and Tirole (1994).

[3] Much of this section is drawn from Chang (1998).

[4] This case is not considered vertical integration by the R&D division because the manufacturer may produce or purchase many other components that the R&D unit has nothing to do with.

jor residual income claimant, as it apparently has become more features in common with biotech firms.

The model considers three layers of the incentives. The first is the contractual stage where managers determine how residual income of the joint product is divided among themselves, i.e., whether R&D is more like an "in-house" or an independent firm with royalties. At the second stage, the R&D manager, based on his/her incentives, decides how carefully to monitor scientists and how to set their pay. Finally, the scientists/employees decide how hard to work according to the incentive structure established by the R&D manager.

To solve the model, backward induction is employed. Given a pay structure, scientists decide how much effort to put forth. Given scientist behavior and residual income claimancy, the R&D manager decides how to monitor and set pay. Given manager's behavior, the decision on how to allocate residual income is made.

A. The Scientist's Problem[1]

Consider a researcher/scientist who is risk averse and produces R, useful research output. Suppose R is generated by $R = e + \varepsilon_1$, where e is an effort by the researcher and ε_1 is a random component with $\varepsilon_1 \sim N(0, \sigma_1^2)$. The manager observes R and, by monitoring, another signal on scientist effort, S, where $S = e + \varepsilon_2$ and $\varepsilon_2 \sim N(0, \sigma_2^2)$. With linear wages function, $W = b_0 + b_1R + b_2S$, where b_0 is a constant, and b_1 and b_2 are the values associated with research output and the observed signal of effort, respectively, the scientist's utility function is assumed to be $U = -\frac{1}{\rho}\exp\{-\rho(W - C(e))\}$, where C(e) is utility cost of effort and expected utility is

$$E(U) = -\frac{1}{\rho}\exp\{-\rho(b_0 + (b_1 + b_2)e - \frac{1}{2}Ke^2 - \frac{1}{2}\rho(b_1^2\sigma_1^2 + b_2\sigma_2^2))\} \quad (1)$$

where ½ Ke^2=C(e). By further simplifying the formula, one obtains the expected wage function

$$E(W) = \tau + \frac{(b_1 + b_2)^2}{2K} + \frac{1}{2}\rho(b_1^2\sigma_1^2 + b_2^2\sigma_2^2), \quad (2)$$

where τ is a constant related to the reservation utility level given by $\tau = -(\ln(-\rho\overline{U}))/\rho$.

The term σ_2^2 plays a critical role in our analysis. This is one way I distinguish the newer biotech research from traditional pharmaceutical research. Conventionally, pharmaceutical firms emphasize incremental research, such as creating new drugs by changing standardized chemical compound structures or conducting routine development procedures to meet FDA regulations. This somewhat routinized work makes the signal of an effort, S, observed by the manager quite accurately and additional managerial monitoring does little to improve it. In contrast to this, in the new biotech research scientists need to be creative and may generate new, fundamental knowledge in their fields. This process of idea creation is difficult for a manager to monitor, implying that σ_2^2 is relatively large and in additional monitoring of the effort is necessary to reduce σ_2^2.

B. The R&D Manager's Problem

i. Choosing the pay structure

Given the scientist's effort function, reservation utility, the manager's residual income share, and signal accuracy, the R&D manager's problem is to decide on a pay structure. Let the

[1] This and the following stage of the model are similar to Holmstrom and Milgrom (1991).

expected value of output, q, be a function of the useful research output, R, and manufacturing input, M. For simplicity, let the expected value of output be $E[q(R, M)] = a_1e + a_2M$. [1] Suppose the manager is risk neutral and gets a share α of net income q(R, M) - E(W). The manager chooses the compensation method (b_1 and b_2) to maximize his/her share of net income given by

$$B = \alpha\left(a_1 e + a_2 M - E(W)\right). \tag{3}$$

Substituting into (3) for e (not shown) and E(W) from (2), after some maximization and comparative static analysis, one obtains that net income is lower as the variances are higher. This occurs because it is costlier to motivate risk-averse workers when $\sigma_1^2$and σ_2^2 are greater, reducing net income.

ii. Choosing Monitoring Intensity

Given the optimal pay structure and manager's residual income share, the manager decides his/her monitoring intensity. Suppose the manager engages in monitoring effort, m. Increases in m make the signal, S, more accurate. Let $\sigma_2^2 = t(m)$, $t' < 0$. Assume this function is linear so that $t= C_0-C_1m$. Manager utility is $U=\alpha(a_1e+a_2M-E(W))-H(m) = B(\sigma_1^2, \sigma_2^2, a_1) - H(m)$, where H(m) is the cost of monitoring effort. Note that the manager bears the full cost of monitoring, H(m). The manager chooses m to maximize utility and finds the impact of the R&D manager's share of residual income (α) on monitoring effort to be as follows:

$$\frac{\partial m}{\partial \alpha} = \frac{-5\rho b_2^2 C_1}{D} > 0\,, \tag{4}$$

where D<0 is the second order condition. This result is quite intuitive. As the R&D manager's share of net income increases, s/he reaps more of the benefits of monitoring and so monitoring effort increases.

It is straightforward to show that the manager's choice of m tends to increase with both of these parameters. A greater value of C_1 raises the marginal benefit of monitoring. A higher value of a_1 makes b_2 larger. This, too, raises the marginal benefit of monitoring.

C. Determining Residual Income Claimancy

Given all of the above information, residual income claimancy is determined. It is assumed that the R&D and manufacturing managers contract over α (the R&D manager's share) to maximize expected joint returns, V, given by:

$$V = a_1 e^* + a_2 M^* - H\left(m^*\right) - G\left(M^*\right), \tag{5}$$

where G(M) is the manufacturing manager's cost. The above equation can be rewritten as:

$$V = N^*\left(m\left(\alpha, a_1, C_1\right)\right) + a_2 M - H(m) - G(M), \tag{6}$$

where $N^* = a_1e(b_1(m(\alpha, a_1, C_1)),b_2(m(\alpha, a_1, C_1)))$.

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[1] Let M be determined by the actions of the production manager.

The overall problem is to choose α to maximize joint returns, recognizing that it raises the R&D division's incentives but lowers the manufacturing division's ones.[1] The first order condition will show that the marginal benefit of α is positively associated with $\partial m/\partial\alpha$ as seen from the previous subsection, $\partial m/\partial\alpha$ is larger if a_1 or C_1 are larger. The marginal benefit of α is also higher in case $\partial N^*/\partial m$ is greater. This is given by:

$$\frac{\partial N^*}{\partial m} = 5\rho b_2{}^2 C_1 . \tag{7}$$

This, too, grows with a_1 and C_1 increasing.

Recall that the distinction between the newer, biotech research and traditional pharmaceutical research is that the former is characterized by higher values of a_1 and C_1.

Prediction: for firms that emphasize the newer, biotech research, the R&D manager holds more residual income claimancy and so the R&D unit is more like an independent firm.

D. Other Implications

i. Employment[2]

In this section, the amount of employment of the R&D unit is incorporated into this model. Let's modify the expected output level, q, as previously discussed, in the following way: $q = a_1eL + a_2M$, where L is the number of scientists/employees of the R&D unit. The manager chooses monitoring effort and employment, m and L, to maximize utility, now given by $U = \alpha (a_1e(b_1,b_2)L+a_2M - E(WL)) - H(m)$, where m and H(m) are total monitoring effort and its cost. Now, the monitoring effort is spread over L workers. Thus, it is less effective. To capture this, assume that $\sigma_2{}^2 = t(m,L)$, with $t_m < 0$, $t_L > 0$, and $t_{mL} > 0$. A greater number of workers worsen the accuracy of the signal of the effort for a given m and it reduces the marginal effectiveness of m in improving the signal. Doing the first order condition for the above maximization, one will find that it is straightforward to show that m increases with α and the effect of α on employment is negative assuming that the marginal cost effect of L dominates the effect of monitoring precision on E(W).

Prediction: the biotech firm tends to have less employment assuming that the marginal cost effect of L dominates the effect of monitoring precision on E(W).

ii. The Character of Managers

The R&D manager's primary tasks are to monitor and establish the employee pay system. Suppose that managers differ in monitoring their talents. Recall that $\sigma_2{}^2 = t = C_0 - C_1m$, where C_1 depends on the type of research. Let C_0 be an inverse measure of the manager's monitoring capability. A higher C_0 implies greater monitoring noise and less talent in monitoring.

To consider how V is affected by C_0, differentiate (11) with respected to C_0:

$$\frac{\partial V}{\partial C_0} = \frac{-a_1{}^2 K\rho\sigma_1{}^4}{(\sigma_1{}^2 + \sigma_2{}^2 + K\sigma_1{}^2\sigma_2{}^2)^2 K^2} < 0 . \tag{8}$$

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[1] The manufacturing manager will choose M to maximize $(1-\alpha)$ $(N^* + a_2M)$ $-G(M)$. The first order condition is $\frac{\partial}{\partial M} = (1-\alpha)a_2 - G' = 0$, indicating that M decreases in α.

[2] In a different approach, Holmstrom (1989) models employment in an R&D firm based on the assignment of tasks to employees.

The negative value of $\partial V/\partial C_0$ implies that a greater joint return is achieved by reduced monitoring noise. In short, a better manager raises value. The magnitude of this effect is larger with a being larger; the value of biotech firms is mostly increased by a better manager. Thus, we expect biotechs to outbid the traditional pharmaceutical firms for better monitors.[1]

It is plausible that a scientist/manager has a lower C_0 because the scientist/manager is more knowledgeable about the research than a non-scientist/manager. The manager will be able to monitor more effectively and understand who is providing an effort.

Prediction: scientists are more likely to manage firms that indulge in biotech research.

3. Empirical Evidence

This section presents the empirical results regarding the ownership, employment, and the character of managers for biotechs and other pharmaceutical research firms. Cross-sectional data for firms from the 1992 BioScan[2] are employed as the primary data source. The other data source is Compact D/SEC, used for its detailed information on the ownership of firms. More than 12,000 public held corporations are on this data set. Information provided in Compact D/SEC is from SEC filings.

A. Variables

The BioScan data are used to determine the focus of the firm. From the information on the firm's activities, three main categories are created – "new" R&D, manufacturing and marketing. The R&D is considered "new" if it involves advanced medicinal applications, such as Mabs, r-DNA techniques, protein syntheses, vaccine development, anti-viral and cancer treatment, or gene therapy. Other R&D activities are considered traditional R&D. Most companies listed in BioScan have some biotech R&D, but not all. Based on this classification of R&D and other activities, seven mutually exclusive dummy variables are generated as the main independent variables in this study. They are:

- R&D only – the firm only with "new" R&D activity, only,
- Manufacturing only – the firm only with manufacturing activity, only,
- Marketing only – the firm with marketing activity, only,
- RD&Mfg – the firm with both R&D and manufacturing activities, but with no marketing,
- RD&Mkt – the firm with both R&D and marketing, but with no manufacturing,
- Mfg&Mkt – the firm with both manufacturing and marketing, but with no R&D, and
- Conglomerate – the firm with all three activities.

The meanings of these variables, along with others discussed below, are shown in Table 1.[3] The R&D variable is our indicator of a firm with the newer type of research activities. Firms with only this focus are predicted to have more management ownership, less employment, and more scientist/managers than firms with less focus on R&D.

To test the residual income claimancy, information on the ownership of the firms is collected. They are the following variables.

- Private – a dummy variable equal to 1 if the firm is privately held, zero otherwise,

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[1] This can occur via a lump-sum transfer between the two parties.

[2] Biotechnology as well as pharmaceutical, chemical, and other major companies that have in-house biotechnology research groups or agreements with biotechnology companies are included in the data. There is a wide range of firms in the data, from small firms with as few as five employees to large firms such as NEC with more than 100,000 employees.

[3] Not all firms in BioScan are used because very limited information is provided for some firms. Specifically, if more than two major fields in the main entry section (the major fields include the agreements, employees, business strategies, research and development, and facilities) are missing from BioScan, the companies are excluded. Pure agricultural-oriented firms are also excluded from the data set, since this study focuses on pharmaceuticals. The majority of the foreign (non-US) firms are excluded, too, unless they are listed with Securities and Exchange Commission. The total number of remaining usable firms is 336.

- Diffused Owner – a dummy variable equal to 1 if it is a publicly traded firm with no owner having more than a 10% share of ownership, zero otherwise,
- Block Holder – a dummy variable equal to 1 for the publicly traded firm with the owner(s) having between 10% and 50% of ownership share, zero otherwise, and
- Subsidiary – a dummy variable equal to 1 for the publicly traded firm more than 50% owned by another firm, zero otherwise.

Table 1

Summary Statistics

	BioScan			Compact / DSEC		
Variable	Obs.	Mean	SD	Obs	Mean	SD
Focus of the Firm						
R&D	336	.789	.388	164	.78	.40
Mfg	336	.568	.495	164	.66	.47
Mkt	336	.592	.492	164	.65	.48
Categories of Firm						
R&D only	336	.253	.435	164	.201	.402
Manufacturing only	336	.027	.161	164	.030	.172
Marketing only	336	.018	.132	164	.006	.078
RD & Mfg	336	.128	.335	164	.116	.321
RD & Mkt	336	.155	.362	164	.128	.335
Mfg & Mkt	336	.140	.347	164	.159	.366
Conglomerate	336	.280	.449	164	.360	.481
Type of Ownership						
Private	336	.387	.488	164	.15	.366
Diffused Owner	336	.321	.469	164	.59	.493
Block Holder	336	.098	.302	164	.15	.360
Subsidiary	336	.179	.359	164	.09	.289
				164	.15	
Ownership Concentration						
Insider Share				150	18.28	21.21
5% Owner Share				153	30.84	31.246
Individual Owner				146	19.67	21.53
CEO Share				155	4.03	9.52
Employment	296	3625.93	13597.8	144	6545.19	18450
Scientist	185	49.88	321.02	68	112.87	520.3
Key scientists	269	3.03	2.31	132	3.37	2.56

A privately-held firm most likely indicates ownership highly concentrated with management, while diffused ownership is the opposite. The firm with block holder owners has higher concentration than the one with diffused ownership, but lower than that of the privately-held firm. The ownership concentration of a subsidiary is not clear because it depends on the ownership of the parent firm.

Because the above measures of ownership concentration are somewhat crude, we obtain more accurate measures of ownership by management from Compact D/SEC, including[1]:

[1] Other related variables are available but are not used, including:

- 5% owner Share – the percent of stock held by the owners who own more than five percent of the firm's stock,
- Insider Share – the percent of stock held by firm insiders,
- CEO Share – the percent of stock held by the CEO, and
- Share of Individual owners – the percent of stock held by non-institutional 5% owners plus the percent held by insiders.

Observations are lost with these data because Compact D/SEC includes only publicly traded firms and so has fewer biotech firms than BioScan.

Several other variables from BioScan are also used. Employment is the total number of employees of the firm. Scientist is the total number of PhDs, MDs, and PharmDs, sometimes denoted directly as scientists of the firm. The key scientists' variable is the above mentioned scientists that appear in the key personnel field in BioScan.

B. Results

i. Ownership Structure of Biotech Firms

To get a general idea of the ownership structure of the industry, Table 2 shows the percent of ownership type for each firm focus. Column 1 shows that 71.76 percent of the firms with only R&D activities are privately held. This kind of firm is likely to have the most concentrated ownership. In contrast, the firm least likely to be privately held is the conglomerate; only 13.83% are privately held. Related conclusions are evident from Column 3 – the firms most likely to have diffused ownership are the conglomerates (47.87%) and the R&D only firms are the least likely to exist (14.12%). These summary data are consistent with the theoretical prediction that firms more focused on non-traditional R&D are more likely to be management-owned.

Table 2

Percent of Ownership Type for Each Firm Focus

Variable	(1) Private	(2) Block Holder	(3) Diffused Owner	(4) Subsidiary
R&D only	71.76	7.06	14.12	3.53
Manufacturing only	22.22	33.33	33.33	11.11
Marketing only	50.00	0.00	16.67	33.33
RD & Manufacturing	41.86	6.98	32.56	18.60
RD & Marketing	46.15	12.54	25.00	17.30
Manufacturing & Marketing	19.15	17.02	44.68	17.02
Conglomerate	13.83	8.51	47.87	27.65
Observations	336	336	336	336

Source: BioScan 1992

Note: Variables as defined in Table 1.

To obtain more robust tests of the model, probit and ordered-probit analyses are employed. Table 3 presents the results of the probit model.[1] The dependent variables are the four types of ownership listed in the previous section. The independent variables are the seven mutually exclusive activity categories (conglomerate is the omitted category). Also, employment is held constant to control the possibility of the firm size to influence the financial structure of the firm. The findings of Table 3 are consistent with Table 1. The R&D only variable has a positive and

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Share of major owners – total percent of stock held by both institutional and individual owners,
Share of Institutional Owners -- total percent of stock held by other institutions,
Number of Insiders per Employee – number of inside owners divided by total employment, and
Number of 5% owners -- number of owners who own more than five percent divided by total employment.
In the empirical work, use of these variables yields similar findings to those reported.

[1] Some missing observations occur because not all firms report employment.

significant effect on the probability of the firm's being privately held and is the largest in magnitude of all the firm categories. The coefficients on RD & Mfg and RD & Mkt are positive, significant, and large in magnitude, although the Marketing only coefficient is larger. These findings generally indicate that the greater the focus of the firm on R&D is, the more likely it is to be privately held. This is reinforced by the results of column 3. The R&D only firms are least likely to have diffused ownership. These findings are with employment held constant, which has a negative effect on the probability of the firm being privately held and a positive effect on the likelihood of diffused ownership. Thus, our results do not arise simply because R&D firms are smaller on average.

Table 3

Probit Estimates of Likelihood of Ownership Structure[a]
(z-scores are in the parentheses)

Variable	(1) Private	(2) Block Holder	(3) Diffused Owner	(4) Subsidiary
R&D only	1.16	-.22	-.79	-1.40
	(4.46)	(.75)	(3.25)	(4.03)
Manufacturing only	.18	1.04	-.24	.00
	(.30)	(2.01)	(.45)	(.00)
Marketing Only	.75	.00	-.49	-.29
	(1.26)	(.00)	(.74)	(.44)
RD & Mfg	.44	-.23	-.21	-.30
	(1.53)	(.66)	(.79)	(1.08)
RD & Marketing	.61	.018	-.46	-.43
	(2.16)	(.06)	(1.71)	(1.51)
Manufacturing & Marketing	.11	.42	-.24	-.26
	(.33)	(.32)	(.89)	(.91)
Employment[b]	-.2.67	-.06	.10	-.04
	(3.25)	(.98)	(2.34)	(1.78)
Constant	-.33	-1.21	-.36	-.55
	(1.47)	(5.65)	(2.19)	(3.28)
Observations	296	296	296	296
Pseudo R^2	.27	.07	.19	.10

Source: BioScan 1992
Notes: [a]Variables as defined in Table 1.
[b]Employment in 1000s.

For the ordered probit, the independent variable is arranged for the degree of management ownership. A positive coefficient indicates that the variable raises the concentration of managerial ownership. Among the four types of ownership – private, block holder, diffused owner, and subsidiary, the privately held firms have the most concentrated ownership and are given the highest number in order. The next highest is the block holder-firm. The diffused owner-firms have lower ownership concentration. Since the ordering of the subsidiary-firm is unclear, these observations are first excluded from the probit and then included with experimentation with the orderings.[1] The results are presented in Table 4.

[1] Thus, some observations are lost in column 1 because of the exclusion of the subsidiary firms.

Table 4

Ordered Probit Estimates of Ownership Type[a]
(z-statistics in parentheses)

Variable	(1)[b]	(2)[c]	(3)[d]
R&D only	1.28	1.21	1.45
	(5.26)	(5.87)	(7.36)
Manufacturing only	.39	.38	.79
	(.85)	(.87)	(1.85)
Marketing only	1.05	.74	.80
	(1.54)	(1.36)	(1.50)
RD & Manufacturing	.56	.41	.56
	(2.02)	(1.81)	(2.56)
RD & Marketing	.80	.64	.77
	(2.91)	(2.81)	(3.56)
Manufacturing & Marketing	.45	.26	.27
	(1.53)	(1.13)	(1.30)
Employment	-.0002	-.0001	-.0000
	(2.46)	(2.51)	(.37)
Observations	247	296	296
Pseudo-R^2	.21	.14	.09

Source: BioScan 1992.

Notes: [a]Variables as defined in Table 1.

[b]The dependent variable equals 0 if the firm is categorized as diffused owner, 1 if the firm has block owners, and 2 if the firm is privately held.

[c]The dependent variable equals 0 if the firm is categorized diffused owner, 1 if the firm is a subsidiary, 2 if the firm has block owners, and 3 if the firm is privately held.

[d]The dependent variable equals 0 if the firm is a subsidiary, 1 if the firm is categorized as diffused owner, 2 if the firm has block owners, and 3 if the firm is privately held.

Throughout the table, the R&D only coefficient is positive, significant and of the largest magnitude of all the firm focus categories. Also, the RD & MFG and RD & Mkt coefficients are positive and significant. The results are, again, consistent with the basic prediction that the firm with greater R&D focus has more concentrated managerial ownership.

Relying on the Compact D/SEC data, Table 5 reports on estimates of the determinants of the more precise measures of ownership concentration. These measures are treated as dependent variables in several OLS regression models with the firm-focus variables and employment as regressors. The marketing only and manufacturing only types of firms are excluded so only five types of firms remain. The reason for doing so is that there is only one marketing only firm and three manufacturing only firms in the smaller Compact D/SEC sample.

From Table 5, it is clear across all columns that firm size has a negative impact on ownership concentration. The R&D only firm is estimated to have the highest ownership concentration by all measures with the exception of the CEO's share, which is second highest. With holding firm size constant at 1000 employees, column 1 shows that, on the average, 23.74% of the firm's stock is held by insiders of the R&D firm, while column 2 indicates that 46.63% is held by 5% owners.[1] Column 3 shows that CEO's of the R&D only firms hold 5.6% of the firm's stock and column 4 indicates that individual owners hold 33.23%. With the exception of the CEO's share, these are

[1] These figures are arrived at by adding the constant term, representing the excluded conglomerate category, to the coefficient on the variable at hand.

higher magnitudes than any other firm type. Other results in Table 5 show that firms with R&D activity (RD&Mkt and RD&Mfg) generally have the second highest ownership concentration, while firms without "new" R&D activity (conglomerate and Mfg&Mkt) have the lowest level ownership concentration.

Table 5

Determinants of Ownership Concentration[a]
(t-statistics in parentheses)

Variable	Insider share (1)	5% Owner Shares (2)	CEO Share (3)	Share of Individual Owners (4)
R&D	5.42	18.14	3.28	16.55
	(1.04)	(2.50)	(1.90)	(3.25)
RD & Mfg	2.37	13.14	4.45	14.19
	(.37)	(1.44)	(2.14)	(2.36)
RD & Mkt	8.40	-1.95	1.86	10.52
	(1.34)	(.22)	(.89)	(1.71)
Mfg & Mkt	2.65	11.42	-.44	.96
	(.47)	(1.46)	(.23)	(.18)
Employment[b]	-.03	-.04	-.04	-.03
	(2.72)	(2.96)	(1.20)	(2.75)
Constant	18.32	28.49	2.68	16.68
	(5.94)	(6.57)	(2.58)	(5.57)
R^2	.09	.14	.08	.21
Observations	131	131	127	126

Source: Compact D/SEC and BioScan 1992
Note: [a] Variables as defined in Table 1. The dependent variables are in percentage.
[b] Employment is in 1000s.

In conclusion, firms with greater R&D focus have higher concentration of ownership of 5% owners, inside owners, CEO ownership, and individual owners. This supports the theoretical hypothesis that the research firm needs more ownership concentration among managers to motivate monitoring effort.

ii. Firm Size

To study the relationship between firm size and R&D, the number of employees is used as the measure of firm size and treated as the dependent variable in an OLS regression. The independent variables are the seven firm-focus dummies used before, with conglomerate being the excluded category. Table 6 presents the results. The conglomerate firm is the largest with an average 9,351 employees.[1] The others, except for Manufacturing & Marketing firms, have an average of over 9,000 fewer employees than conglomerates do. The smallest are the Marketing only firm and the pure R&D firm with the average employment of 62.20 and 64.76, respectively. Next smallest are the RD & Marketing firm and the RD & Manufacturing firm with average employment of 106.7 and 196.44. The Manufacturing only firms, with an average of 315.29, and the Manufacturing & Marketing firms, with employment of 7338.15, are substantially larger.

[1] The conglomerate effect is estimated by the constant term. The coefficients on the other dummies show the difference from the conglomerate effect.

Table 6

Determinants of Employment
(t-statistics in parentheses)

Variable	Employment
R&D only	-9286.46
	(4.52)
Manufacturing only	-9035.93
	(1.76)
Marketing only	-9289.02
	(1.55)
RD & Manufacturing	-9154.78
	(3.67)
RD & Marketing	-9244.52
	(3.76)
Manufacturing & Marketing	-2013.07
	(.79)
Constant	9351.22
	(6.49)
Observations	296
R^2	.10

Source: BioScan 1992
Note: Variables as defined in Table 1.

All in all, the results show that firms with a greater focus on R&D activities tend to be smaller. This is consistent with the idea that the marginal cost of monitoring additional workers is larger in this environment, inducing lower employment.

iii. The Character of Managers

In this section, the character of owners/managers and the concentration of scientists of the firm are examined. The number of key scientists reported by the firm is used as the measure of scientists who are owner/managers because being in a key position indicates managerial capacity and probably residual income claimancy. Table 7 gives an overview of the number of scientists and key scientists in our data. The share of total scientists and key scientists per 100 employees is shown for all types of firms.[1] (Marketing only firms are dropped because only six of this type of firm had valid responses for these variables.)

The pure R&D firm has the biggest number of scientists per 100 employees and the conglomerate has the least. This is not surprising as the nature of R&D is to utilize scientists. The R&D only firm also has the most key scientists per 100 employees at 12.18. The other firm-types with R&D activity also tend to have more scientists per employee in both total number and in key positions.

[1] Sample sizes are reduced in Table 7 due to missing values on the scientist data.

Table 7

Means of Total Scientists and Key Scientists Per 100 Employees

Variable	(1) Total scientists	(2) Key scientists
R&D only	28.58	12.18
	(17.02)	(10.4)
Manufacturing only	20.00	3.37
	(1.53)	(.76)
RD & Mfg	19.35	8.81
	(7.61)	(5.13)
RD & Mkt	22.69	10.02
	(9.64)	(6.01)
Mfg & Mkt	13.05	3.84
	(4.22)	(2.13)
Conglomerate	15.60	3.61
	(7.71)	(2.95)
Observations	184	244

Source: BioScan 1992
Note: Variables as defined in Table 1.

Table 8

Determinants of Number of Key Scientists[a]
(t-statistics in parentheses)

Variable	(1) Ratio[b]	(2) Key scientists
R&D only	15.54	6.77
	(2.34)	(3.86)
Manufacturing only	-2.04	-1.75
	(.11)	(.38)
RD & Mfg	13.25	3.43
	(1.67)	(1.59)
RD & Marketing	9.02	4.58
	(1.12)	(2.17)
Mfg & Mkt	6.50	-1.03
	(.77)	(.48)
Total scientists	--	-.01
		(2.25)
Constant	29.06	5.65
	(6.27)	(4.17)
Observations	243	244
R^2	.027	.134

Source: BioScan 1992
Note: [a] Variables as defined in Table 1.
[b] Ratio is the key scientists to total scientists ratio.

Our model predicts that the R&D firms have more scientists in managerial positions, i.e., more key scientists. Table 7 shows that this is the case, but an issue that arises is that R&D firms may have more key scientists per employee simply because they have more scientists. Even if promotion to key positions is random, having more scientists implies having more key scientists. To address this issue, the determinants of the number of key scientists are estimated holding the total scientists constant.[1] Again, the firm-focus dummies are the regressors with conglomerate being the excluded category. Table 8 presents the results[2]. In Column 1, the ratio of key scientists to total scientists is used as the dependent variable. It shows that nearly half of the scientists (about 45%) in the R&D only firm are in key positions.[3] The firm with the second highest key scientists to total scientists ratio is the RD&Mfg firm (about 42.3%). A little less than one-third of the scientists in conglomerates are in key positions. Column 2 presents the results with the number of key scientists being the dependent variable and the total number of scientists held constant. It also indicates comparable results. The R&D only firm has the most key scientists, followed by the RD & Marketing and the RD & Manufacturing firm-types. To sum it up, both sets of estimates indicate that firms with a greater R&D focus have a disproportionate number of scientists in managerial positions. This is expected from our model.

4. Conclusion

This study focuses on determination of the incentives of a manager to monitor the R&D process. We argue that monitoring is quite different for the newer, biotechnology research than for traditional pharmaceutical research in that it is more difficult but more important. In our model of managerial incentives, this implies important differences between the firms that emphasize the new, biotech research and other traditional, pharmaceutical companies. Our model predicts the following. First, residual income claimancy tends to be concentrated in the hands of the owners/managers for R&D intensive firms. Second, to facilitate monitoring accuracy, firm size tends to be small. Third, owners/managers are disproportionately likely to be scientists in the R&D oriented firms since they improve monitoring accuracy. The empirical work tests these hypotheses.

In general, the results are consistent with the theoretical predictions. Firms with greater focus on the newer, biotech R&D are more likely to be privately held and have more ownership by the CEO, insiders, and large block holders. This holds even for a given level of employment. The number of employees is, on average, lower for R&D only firms. Additionally, they have more scientists in key, managerial positions per scientist/employee.

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[1] Because some observations with the key scientists variable have missing values for total scientists, values for total scientists are predicted from a tobit model with the independent variables including categories of firm, types of ownership, and other BioScan information.

[2] The one fewer observation in Column 1 is due to one firm with zero total scientists.

[3] This figure is arrived at by adding the constant term, representing the excluded conglomerate category, to the coefficient on the R&D only variable.

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