Bargaining in technology markets: An empirical study of biotechnology alliances

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September 7, 2009

Abstract

The division of innovative labor between biotechnology and pharmaceutical companies has become essential in pharmaceutical research since the first successful biotechnology products reached the market in the early 1990s. A well-functioning market of knowledge assets is now indispensable for health care innovation. However, if either sellers or buyers of biotechnologies have too large bargaining power, the efficiency of the technology market could decrease. When sellers have too large bargaining power, it could cause the "anti-commons." If buyers have too large bargaining power and thus strong control rights in the research project, it could cause inefficiency in research performance.

We empirically analyze the distribution of bargaining power at biotechnology markets between sellers (mainly biotechnology companies) and buyers (mainly pharmaceutical companies) by estimating the price increase and decrease due to bargaining by sellers and buyers. The data is taken from RDNA database of Deloitte Recap, a company specializing in the biotechnology industry since 1988. Using the data of contract price and technological characteristics (fields and stages of traded technologies) of 1516 alliance agreements from January 1990 to September 2008, we first estimate the two-tier stochastic frontier model proposed by Polachek and Yoon (1987). Then, using estimated parameters and the equations

derived by Kumbhakar and Permeter (2008), we calculate the conditional expectations of the price increase and decrease due to bargaining by the seller and buyer for individual alliance agreements.

We also examine the factors that could be related to sellers and buyers' bargaining power: the characteristics of each individual alliance agreement and the parties. For the characteristics of the alliance agreement, we use RDNA's twenty-six types of alliances. For characteristics of each party, we include sellers and buyers' (i) regions (US, Europe, Japan, others), (ii) types (pharmaceutical, biotechnology, others), and (iii) whether public or not. We also include year dummies. The relationship between these factors and the estimated conditional expectations of the price increase and decrease due to bargaining are analyzed using OLS.

The results show that on average, the decrease of price due to buyer's bargaining power is larger than the increase of price due to seller's bargaining power, although the latter has been increasing since 1990, after controlling types of alliances and each party's characteristics. It is conjectured that pharmaceutical companies' bargaining power has been larger than biotechnology companies but that biotechnology companies' bargaining power over pharmaceutical companies has been improving over the past decades.

For the relationship between the effects of bargaining on contract price and each party's characteristics, we found that US sellers, which are mostly biotechnology companies, tend to increase the contract price larger than other regions' sellers do. It is conjectured that US biotechnology companies may have less financial constraints possibly because US stock markets are better suited for high-tech industries compared to other country's markets.

1. Introduction

The division of innovative labor between biotechnology and pharmaceutical companies has become essential in pharmaceutical research since the first successful biotechnology products reached the market in the early 1990s.[1] A well-functioning market for knowledge assets, where biotechnology and pharmaceutical companies trade technologies in various types of alliance agreements, is now indispensable for health care innovation.

This paper examines how the knowledge market in the biopharmaceutical industry has been working by empirically analyzing the distribution of bargaining power of sellers (mainly biotechnology companies) and buyers (mainly large pharmaceutical companies) of the knowledge assets. Both sellers and buyers of biotechnologies can have large bargaining power in an alliance contract, and unevenly distributed bargaining power to either side can negatively affect research performance and thus health care innovation.

For the sellers, strong patent rights can give large bargaining power to biotechnology companies and cause the "anti-commons" (Heller and Eisenberg (1998)). If the price of research input is too high, many pharmaceutical companies could be discouraged to use them, resulting in the delay of new drugs.

For the buyers, financial constraints to biotechnology companies can give large bargaining power to pharmaceutical companies (Lerner et al. (2003)). Biotechnology products usually take many years of R&D and large amount of money for it. Moreover, because of considerable information asymmetries in biotechnology research, it is often difficult for investors to assess the progress of the research. Many research-intensive biotechnology companies have financed themselves through both public equity issues and alliances with pharmaceutical companies. However, because of the characteristics of biotechnology research, the amount of capital raised from the public market has been highly variable.[2] Thus, when it is difficult for a biotechnology company to finance their R&D project, pharmaceutical companies can have large bargaining power as the investor. This could cause inefficiency in the research project if the financing

[1] For a history of the development of the biotechnology industry, see Audretsch (2001).
[2] See Lerner et al. (2003), Figure 2 (page 418).

company has a larger part of the control right in the research project.[3]

We analyze bargaining on biotechnology alliances applying an empirical framework proposed by Kumbhakar and Permeter (2008). Although their framework does not identify each party's bargaining power itself, it does estimate the surplus extracted by each party in the individual alliances, which depends on the bargaining power. By using their framework, it can be analyzed what kind of factors are related to the results of bargaining on each alliance.

The organization of the paper is as follows. Section 2 explains the empirical framework proposed by Kumbhakar and Permeter (2008). Section 3 describes our dataset. Section 4 explains results. The final section discusses the results and concludes the paper.

2. Empirical framework

Both a seller and buyer extract surplus from an alliance agreement, but how the surplus is divided between the seller and buyer depends on their bargaining power. In this paper, we apply the empirical framework of Kumbhakar and Parmeter (2008), which is explained below, to examine the effect of bargaining on alliance agreements.[4]

Let contract price of an alliance agreement, a seller's reservation price, and a buyer's maximum offer be p, $\underline{p}$, and $\overline{p}$, respectively. Then, the contract price can be decomposed as follows:

$$p = \underline{p} + \eta\left(\overline{p} - \underline{p}\right), \tag{1}$$

where $0 \leq \eta \leq 1$ is the bargaining power of seller. Moreover, let $\mu(x) = E(v \mid x)$ denote the expected value of technologies traded in an alliance agreement conditional on characteristics of the technologies, where v is the unobservable expected value of traded technologies and x is a vector of characteristics of the technologies. By construction, $\underline{p} \leq \mu(x) \leq \overline{p}$. Then, the equation (1) is re-written as

$$p = \mu(x) + \eta\left(\overline{p} - \mu(x)\right) - (1-\eta)\left(\mu(x) - \underline{p}\right). \tag{2}$$

[3] See Lerner et al. (2003) for a survey of the theoretical literature on the relationship between external finance and R&D firm's performance.

[4] Kumbhakar and Parmeter (2008) applied the framework to examine the relationship between wage dispersion in labor markets and bargaining power in each job match.

The terms $\left(\overline{p}-\mu(x)\right)$ and $\left(\mu(x)-\underline{p}\right)$ in the equation (2) are a buyer's and a seller's expected surplus from the transaction, respectively. In the equation (2), the difference between the actual contract price and $\mu(x)$ is determined by each party's bargaining power and surplus. The seller can increase the price by extracting the buyer's surplus $\left(\overline{p}-\mu(x)\right)$ depending on the bargaining power η. Similarly, the buyer can decrease the price by extracting the seller's surplus $\left(\mu(x)-\underline{p}\right)$ depending on the bargaining power $(1-\eta)$. Although η cannot be identified, the surplus extracted by the seller and buyer, $\eta\left(\overline{p}-\mu(x)\right)$ and $(1-\eta)\left(\mu(x)-\underline{p}\right)$, can be interpreted as the result of each party's bargaining on the contract price. Then, based on the equation (2), the following regression equation is formulated:

$$p = x'\delta + w - u + v, \tag{3}$$

where $x'\delta = \mu(x)$, δ is a vector of parameters for the covariates x, $w = \eta\left(\overline{p}-\mu(x)\right) \geq 0$, $u = (1-\eta)\left(\mu(x)-\underline{p}\right) \geq 0$, and v is the usual error term.

To identify *w*, *u*, and *v*, the following assumptions are imposed: *w* follows an exponential distribution with mean σ_w, *u* follows an exponential distribution with mean σ_u, and *v* follows a normal distribution with zero mean and variance σ_v^2. This speciation of the two-tier stochastic frontier model is proposed by Polachek and Yoon (1987). Then, the parameters δ, σ_w, σ_u, and σ_v can be estimated by the maximum likelihood method.

Using the estimated parameters, we further calculate the observation-specific expectation of *w* and *u* conditional on the total residual $\varepsilon \equiv w - u + v$, which are driven by Kumbhakar and Permeter (2008). Having the estimate for $E[w \mid \varepsilon]$ and $E[u \mid \varepsilon]$, we examine the relationship between each of them and the characteristics of alliances and each party by using OLS.

3. Data

All the data for the empirical analysis is taken from RDNA database of Deloitte Recap, a company specializing in the biotechnology industry since 1988. For the contract price of alliance agreements (the dependent variable of the equation (3)), we use log of *SIZE* in RDNA, where *SIZE* is deflated by using US GDP deflator. The *SIZE* variable is the deal size of an alliance agreement including twenty-six types of alliances such as acquisition, joint venture, and license.

For the technological characteristics of an alliance agreements (the control variables of the equation (3)), we use the types and the development stages of traded technologies in the alliance agreement. RDNA classifies technologies into more than fifty categories. Then, we integrated them into twelve categories. For the development stages, we use nine stages in RDNA. One alliance agreement can have several technologies, and thus also can have several development stages. We include all technology dummies in such cases. For development stages, we use the latest stage among them and thus one stage dummy for an alliance agreement.

Having estimated coefficients of equation (3), we calculate $E[w \mid \varepsilon]$ and $E[u \mid \varepsilon]$ of individual alliance agreements, that is, the increase and decrease in contract price due to bargaining by the seller and buyer in each alliance agreement. Since the dependent variable is in log form, w and u approximate the rate of increase and decrease in the contract price, respectively. Then, we examine the relationship between those bargaining effects and alliance agreement's and each party's characteristics. For alliance agreement's characteristics, we use the twenty-six alliance types of RDNA.[5] Moreover, since changes in macro economy (e.g., stock market) and government policy (e.g., patent policy) can affect bargaining power, we capture them by year dummies. For seller/buyer's characteristics, we use (i) dummy variables for company's type (biotech, drug, others), (ii) dummy variables for company's location (US, Europe, Japan, others), and (iii) listed public company dummy.

All the data downloaded from RDNA database includes 21,452 alliance agreements from September 1973 to September 2008. The estimation of the two-tier stochastic frontier model and the regression analysis of the effects of bargaining, $E[w \mid \varepsilon]$ and $E[u \mid \varepsilon]$, are both based on the same sample that consists of alliance agreements containing the data of all the above variables. The sample, however, excludes the alliances including universities since they may have been in a different competitive position from commercial organizations. Moreover, only the sample of the alliance agreements from January 1990 is used because it is after the 1990s

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[5] In the database, there are several alliance types that are not listed in the database help file. Alliances of those unlisted types are excluded from our dataset.

that the relationship between pharmaceutical and biotechnology companies had developed involving the commercialization of biotechnology products (Audretsch (2001)). Then, the sample is confined to 1516 alliance agreements.

4. Results

4.1 The two-tier stochastic frontier model

We first show the estimation results of the two-tier stochastic frontier model (equation (3)) in table 1. Since there are alliance agreements including several technologies, we use all the technology and development dummy variables instead of including the constant term. We also include the product of technology dummies and 2000s dummy (1 for alliances since 2000 and 0 for alliances before 2000) to capture changes in the value of technologies. For the maximum likelihood estimation of the equation (3), the estimated coefficients of OLS using the same control variables are used as the initial values (the initial values of the variance parameters are all set to one).

Table 1 Estimation results of the two-tiered stochastic frontier model

The results show that development stages are dominant factors to determine the contract price. The coefficients of development dummies are all larger than technology dummies. Moreover, later stages tend to be priced higher than earlier stages, which is quite intuitive because later stage technologies are close to the market than early stages.

Although the effects of technology dummies are relatively small, there are differences among them. The estimated coefficients of technology dummies are the technological differences in 1990s, and the estimated coefficients of the products of technologies and 2000s dummies are the differences between 2000s and 1990s technology dummies' coefficients. The results of Wald test rejects the null hypothesis that changes of technology dummies in 2000s are all zero. Among the changes in technology differences, the increase in Monoclonals, Synthetics, and Diagnotics are remarkable.

The variance parameters of error terms are all statistically significant, and the parameter σ_u is more than twice larger than σ_w. Since σ_u and σ_w are equal to means of *u* and *w*, which follow exponential distributions, it can be implied that on average, buyers tend to have larger bargaining power on biotechnology alliances.

4.2 OLS analysis for the effects of bargaining

Having the estimated coefficients of equation (3), the conditional expectation of *w* and *u* are calculated using the equations of Kumbhakar and Parmeter (2008). Then, they are regressed on characteristics of alliance agreement and each party. The results are shown in Table 2 and 3. Since there is no alliance agreement classified into "merger" in the sample, alliance types in the regressions are twenty-five.

Table 2 OLS analysis for the rate of increase in contract price ($E[w \mid \varepsilon]$)

Table 3 OLS analysis for the rate of decrease in contract price ($E[u \mid \varepsilon]$)

The results show that the effects of bargaining can be different by alliance types. For sellers, the rate of increase is remarkably large in acquisition compared to other alliance types. For buyers, the rate of decrease is larger in cross-license and sub-license than in other alliance types. Although the estimated coefficients of those alliance types seem economically significant, they are all statistically insignificant.

After controlling alliance types and sellers/buyers characteristics, estimated coefficients of year dummies show that *w* is increasing and *u* is decreasing. It can be conjectured that sellers' bargaining position against buyers may have been improving.

For the characteristics of parties, whether a party is a listed or unlisted company can affect its bargaining power since unlisted company can face financial restrictions. However, the estimated parameters are economically and statistically insignificant in both regressions. This can be because the sample includes only small number of unlisted companies. Among 1516 alliances, there are only 351 unlisted sellers and 314 unlisted buyers. If those unlisted companies are mostly consist of large companies such as a subsidiary of pharmaceutical company, they could have been less financially restricted.

On the other hand, Wald tests reject hypotheses that there are no differences among sellers' regions and among both sellers' and buyers' types (table 3), which implies that these characteristics of each party may be related to their bargaining power.

Table 3 Wald tests for buyers/sellers characteristics

For the differences in sellers' regions, the effects of price increase tend to be lower for European, Japanese and other regions' companies compared to US companies, although European companies' coefficient is both economically and statistically insignificant. It can be conjectured that regions affect bargaining position for sellers located in other than US.

Finally, for the differences in company's types, drug companies as sellers tend to increase the contract price larger than biotechnology and other companies do, and biotechnology companies as buyers tend to decrease the contract price larger than drug and other companies do. Since drug companies include many established pharmaceutical companies, they can have large bargaining power as sellers too, though drug companies are mostly buyers as shown in table 4. Table 4 also shows that biotechnology companies are mostly sellers. It can be conjectured that small number of successful biotechnology companies may have exerted larger bargaining power as buyers rather than as sellers of biotechnologies.

Table 4 Number of alliances by pairs of company's types

5. Discussion

Because of the success of biotechnology, many new drugs for diseases that were previously intractable such as cancer and HIV are coming to markets.[6] It is not only patients but also investors to feel delighted to have such drugs because the markets of those drugs are quite large. For example, it is reported that the market for hepatitis C medications could reach 4 billion to 5 billion dollars by 2015.[7] For the health of both human body and the economy, division of labor between biotechnology and drug companies should be efficient.

In this paper, we investigated distribution of bargaining power between sellers and buyers of biotechnologies, though indirectly, by estimating the increase and decrease in contract price due to bargaining by the seller and buyer. It is not sellers but buyers extracting large surplus from the transactions, which implies that pharmaceutical companies' bargaining power has been larger than biotechnology companies. Then, government policies to decrease financial constraints of new biotechnology companies could improve the efficiency of biotechnology market.

However, the results show that the seller's effects of contract price increase has been increasing after controlling types of alliance agreements and sellers' characteristics, which imply that biotechnology companies bargaining position against pharmaceutical companies may have been improving since 1990. There could be several reasons for sellers' increasing bargaining power. One reason would be that success of developing biotech-based new drugs is attracting more investors and thus improving financial conditions of biotechnology companies. Another reason would be the trend of pro-patent. Pro-patent policy is often criticized for the possibility to deter innovation by causing the anti-commons problem. Based on the result of this paper, however, it can be conjectured that pro-patent policy may have been rather contributing health care innovation by reducing too large bargaining power of pharmaceutical companies against biotechnology companies.

The results also imply that sellers located in other than US might have been in weaker bargaining position compared to sellers in US. A possible reason of such differences in regions

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6 See for example an article of Businessweek, August 25, 2005 ("Cancer Drugs: Therapy for Stocks?").

7 Businessweek, April 6, 2009, the article of Gilead Science in "The Best Performers" (pp. 46-47). Businessweek rank Gilead Science, one of the world's top developers of infectious disease drugs, at the top of 13th annual ranking of the top-performing companies.

is that US investors may have superior technological knowledge compared to other regions' investors. For example, Pagano et al. (2002) argue that US exchanges tend to be suited to the needs of high-tech companies based on statistical analysis of cross-listing behavior of European and US companies in 1986-1997. Thus, US biotechnology companies may have had easier access to public market than other regions' companies not listed in US.

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Table 1 Estimation results of the two-tiered stochastic frontier model

		Coefficient	S.E.	p-value
Tech dummy	Genetics	0.209	0.184	0.258
	Bioinformatics	-0.043	0.238	0.855
	Recombinant DNA	-0.038	0.169	0.822
	Other biotechnology	-0.186	0.156	0.233
	Monoclonals	-0.325	0.176	0.065
	Drug related components	-0.274	0.180	0.129
	In-licensed products	-1.115	0.200	0.000
	Synthetics	-0.524	0.165	0.002
	Screening	0.134	0.152	0.378
	Diagnotics	-1.108	0.276	0.000
	DDS	-0.727	0.229	0.002
	Others	-0.325	0.197	0.098
Tech dummy* 2000s dummy	Genetics	-0.569	0.268	0.034
	Bioinformatics	0.325	0.366	0.374
	Recombinant DNA	0.558	0.276	0.043
	Other biotechnology	0.661	0.223	0.003
	Monoclonals	1.231	0.216	0.000
	Drug related components	0.750	0.231	0.001
	In-licensed products	-0.124	0.240	0.607
	Synthetics	1.596	0.164	0.000
	Screening	-0.158	0.210	0.454
	Diagnotics	1.386	0.771	0.072
	DDS	0.656	0.204	0.001
	Others	0.272	0.295	0.356
Stage dummy	Discovery	3.333	0.173	0.000
	Lead Molecule	3.610	0.181	0.000
	Preclinical	3.810	0.177	0.000
	Phase I	4.109	0.193	0.000
	Phase II	4.290	0.176	0.000
	Phase III	4.420	0.186	0.000
	Approved	4.550	0.197	0.000
	BLA/NDA filed	3.832	0.253	0.000
	Formulation	3.606	0.212	0.000
Error component parameter	σ_v	0.833	0.125	0.000
	σ_u	1.250	0.077	0.000
	σ_w	0.548	0.120	0.000
Tech-changes in 2000s	Wald test statistics	219.917		
	p-value	0.000		

Table 2 OLS analysis for the rate of increase in contract price ($E[w \mid \varepsilon]$)

		Coefficient	S. E.	p-value
Constant		0.345	0.033	0.000
Type	Acquisition	0.480	0.394	0.224
	Asset Purchase	0.111	0.032	0.001
	Assignment	-0.032	0.043	0.453
	Co-Development	0.040	0.021	0.052
	Collaboration	0.058	0.016	0.000
	Co-Market	0.002	0.046	0.965
	Co-Promotion	0.082	0.021	0.000
	Cross-license	0.055	0.099	0.576
	Development	0.053	0.012	0.000
	Distribution	0.020	0.029	0.481
	Equity	0.076	0.016	0.000
	Joint Venture	0.149	0.065	0.021
	Letter of Intent	0.145	0.085	0.089
	License	0.008	0.022	0.725
	Loan	0.076	0.034	0.027
	Manufacturing	-0.042	0.039	0.282
	Marketing	0.060	0.071	0.397
	Option	0.049	0.019	0.010
	Research	0.037	0.015	0.011
	Security	0.199	0.155	0.199
	Settlement	-0.046	0.031	0.131
	Sublicense	-0.005	0.046	0.906
	Supply	0.009	0.015	0.555
	Termination	0.020	0.015	0.183
	Warrant	-0.048	0.021	0.023
Year	1991	-0.035	0.024	0.154
	1992	0.007	0.030	0.808
	1993	0.029	0.037	0.439
	1994	-0.019	0.025	0.459
	1995	0.036	0.030	0.233
	1996	0.070	0.026	0.008
	1997	0.045	0.026	0.086
	1998	0.156	0.037	0.000
	1999	0.099	0.031	0.001
	2000	-0.005	0.023	0.831
	2001	0.095	0.041	0.020
	2002	0.037	0.028	0.185
	2003	0.017	0.027	0.544
	2004	0.049	0.029	0.091
	2005	0.107	0.035	0.003
	2006	0.165	0.038	0.000
	2007	0.267	0.044	0.000
	2008	0.206	0.094	0.029
Region	Europe	-0.009	0.020	0.655
	Japan	-0.071	0.028	0.013
	Others	-0.062	0.020	0.002
Public		-0.010	0.026	0.682
Party	Drug	0.124	0.039	0.002
	Others	-0.005	0.024	0.823
R-square	0.851			

Table 3 OLS analysis for the rate of decrease in contract price ($E[u \mid \varepsilon]$)

		Coefficient	S. E.	p-value
Constant		2.887	0.247	0.000
Type	Acquisition	-1.161	0.273	0.000
	Asset Purchase	-0.733	0.120	0.000
	Assignment	0.075	0.192	0.695
	Co-Development	-0.301	0.065	0.000
	Collaboration	-0.190	0.054	0.000
	Co-Market	-0.342	0.159	0.032
	Co-Promotion	-0.358	0.052	0.000
	Cross-license	0.436	0.401	0.276
	Development	-0.373	0.054	0.000
	Distribution	-0.227	0.122	0.062
	Equity	-0.248	0.049	0.000
	Joint Venture	-0.700	0.121	0.000
	Letter of Intent	-0.200	0.171	0.240
	License	-0.345	0.107	0.001
	Loan	-0.289	0.062	0.000
	Manufacturing	-0.134	0.124	0.278
	Marketing	-0.228	0.172	0.187
	Option	-0.072	0.058	0.211
	Research	-0.187	0.060	0.002
	Security	-0.811	0.154	0.000
	Settlement	-0.223	0.241	0.355
	Sublicense	0.542	0.336	0.107
	Supply	0.031	0.064	0.634
	Termination	-0.253	0.051	0.000
	Warrant	-0.033	0.102	0.746
Year	1991	-0.078	0.243	0.747
	1992	-0.022	0.242	0.928
	1993	-0.448	0.221	0.043
	1994	-0.370	0.217	0.089
	1995	-0.365	0.220	0.097
	1996	-0.542	0.215	0.012
	1997	-0.655	0.205	0.001
	1998	-0.727	0.215	0.001
	1999	-0.581	0.215	0.007
	2000	-0.461	0.216	0.033
	2001	-0.402	0.223	0.073
	2002	-0.394	0.221	0.074
	2003	-0.430	0.224	0.056
	2004	-0.552	0.216	0.011
	2005	-0.717	0.222	0.001
	2006	-0.645	0.222	0.004
	2007	-0.877	0.216	0.000
	2008	-0.901	0.231	0.000
Region	Europe	-0.029	0.063	0.648
	Japan	0.072	0.082	0.382
	Others	0.000	0.151	0.998
Public		-0.081	0.065	0.209
Party	Drug	-0.346	0.094	0.000
	Others	-0.103	0.102	0.315
R-square	0.693			

Table 3 Wald tests for buyers/sellers characteristics

	Seller		Buyer	
	Test Stat.	P-value	Test Stat.	P-value
Regions	15.164	0.002	1.597	0.660
Parties	14.290	0.001	22.511	0.000

Table 4 Number of alliances by pairs of company's types

		Buyers			
		Biotech	Drug	Others	Total
Sellers	Biotech	41	163	188	392
	Drug	26	18	92	136
	Others	77	419	492	988
	Total	144	600	772	1516