International Journal of Management Science
Vol 10, No 1, May 2004

Examining Incentives to License Technology in U.S. High-Tech Industries

YoungJun Kim*
Adjunct Professor, Department of Economics,
The George Washington University, 2201 G Street, N.W., Washington, D.C. 20052, USA.

(Received Oct. 2003; Revised Dec. 2003; Accepted Mar. 2004)

ABSTRACT

This paper empirically investigates potential factors that might affect firms' incentives to license out technology. The analysis is done with the help of a panel data set of observed licensing transactions involving U.S. public companies in high-technology industries. The important explanatory factors relate to the firm characteristics such as the company's stock of technological knowledge (patent stock), prior involvement in technology licensing, the company size, R&D intensity and capital expenditure. The results suggest that there seems to be significant inter-sectoral differences as well as similarities in determinants of the propensity to transfer technology through licensing agreements.

Keywords: Licensing incentives, Cross-industry difference

1. INTRODUCTION

A recent study by British Technology Group (1998) provides evidence that large companies in the United States, Western Europe, and Japan ignore a large fraction of their patented technologies, which could be licensed or profitably sold. This anecdotal evidence demonstrates the argument that the technology market is less efficient than most product markets and that it operates at a suboptimal level. The inefficiency of market for technology is caused by a number of impediments it faces. For instance, Arrow (1962) argues that once an idea is disclosed to a potential buyer, it is possible for that buyer to use the information without paying for it. Because of this concern, a potential licensor would be reluctant to disclose the

* Email: yjk@gwu.edu

core of technology. Nelson and Winter (1982) point that innovation is largely the outcome of organizational routines, and hence, is more effectively performed within organizations. "Cognitive" limitations in the transfer of technology to another context require extensive adaptations and costs (Arora and Gambardella, 1994). Additional difficulty arises in subdividing a given problem-solving task into subtasks. It can be difficult to partition the innovation process into independent tasks (Kline and Rosenberg, 1986; Von Hippel, 1990).

Despite of these impediments, however, there is also an evidence of the increasing use of licensing deals as inter-firm strategic alliances in technology-intensive industries. For instance, Thompson Financial's SDC database used in this paper lists more than 10,000 publicly announced licensing agreements worldwide during the 1990s.

Then what are factors that determine firms' incentives to license technology? Are there differences in licensing activities across firms and industries? How firms' operational and organizational characteristics affect business managers' decision making process involved in technology licensing. We address such questions.

This paper empirically examines potential factors that might affect firms' incentives to license technology with the help of a unique panel data set of observed licensing transactions involving publicly traded companies in the United States. Especially, we explore inter-sectoral differences and similarities in licensing activities across six technology-intensive industries: drugs and pharmaceutical, chemicals except drugs, computer and office equipment, electronics, communications, and computer and data processing services. The managers' licensing decisions are presumed to be bounded to a large extent by the operational characteristics of firms. Thus, the probability of selling technology licenses is explained by firms' characteristics such as the company size (sales amount), the company's stock of technological knowledge (patent stock), prior experience of licensing, R&D intensity, capital investment, cash flow, and net income flow.

The organization of the rest of the paper is as follows. Section 2 describes the data. The model is specified in Section 3. Section 4 discusses the main results. Section 5, finally, concludes.

2. DATA

The sample firms for this study are drawn from CompuStat by Standard & Poor (publicly traded companies in the United States) to obtain firms' financial information necessary for the analysis. This study concentrates on companies operating in high-tech industry sectors such as drugs and pharmaceutical, chemicals except drugs, computer and office equipment, electronics, communications, and computer and data processing services. Among U.S. firms operating in above industries as of year 1999, we choose companies[1] publicly traded in United States in all six years from 1994 to 1999. Table 1 shows the frequency distribution of final sample companies in each industry.

Table 1. Frequency Distribution of Sample and Licensor firms, By Sector, 1994–1999

Industry[a]	Number of sample firms	Number of licensor[b] firms among sample
Drugs and pharmaceutical	206	77
Chemicals except drugs	131	18
Computer and office equipment	122	43
Electronics	235	48
Communications	86	10
Computer and data processing services	240	80
Total	1020	275

Notes: [a] The industry definitions follow the Standard Industrial Classifications (SIC); the classification is based on the information obtained from the public sources used to collect the data.

[b] Sum of exclusive and nonexclusive licenses. It includes cross licenses.

Next, in order to obtain the licensing history of these sample firms, we use the Securities Data Company (SDC) database of Thomson Financial. SDC database records all publicly announced strategic alliances worldwide tracked down in the Security Exchange Commission filings, newswires, press, trade magazines, professional journals, and the like. SDC provides information on contract type (i.e. licensing agreement, marketing agreement, joint venture, joint development or production, etc.), description of the deal, the date of agreement, and identities of participants (i.e. company name, Standard Industrial Classification (SIC) code of primary business, nation, parent companies, etc.).

SDC database has many advantages for our analysis. First, this is the largest database on strategic alliances including licensing agreements. Second, it identifies all licensing participants and provides the detailed supplementary information on them. Finally, it provides a link to the original source of information and

[1] We drop few firms experiencing more than a 200% growth rate in independent variables. Companies who were out of business before the year 1999 are also eliminated from the sample.

date of licensing agreements. For the analysis, we read through the description of all licensing agreements to ensure that each deal was related to technology transfer or exchange of technology, licensing of new product, process technologies and designs, and to confirm the direction of technology transfer (i.e. licensor, licensee). We include few licensing deals that are also accompanied by other types of agreements such as joint ventures, joint marketing and research since this inclusion does not create any obvious biases. However, licensing deals referring to termination of licensing agreements and litigation settlements of past licensing deals are not counted.

3. MODEL SPECIFICATION

This study uses a random-effects probit model to estimate the probability that a firm will license out its technology. Since the purpose of this study is to examine cross-industry differences and similarities in determinants of licensing, the model is tested over six industry sectors separately for six years (1994-1999).

3.1 Dependent Variable

LICENSE $_{i,t}$ is coded as 1 if firm i grant one or more technology licenses to other firms at year t (t = 1994-1999), and otherwise 0.

3.2 Independent Variables

PATENT $_{i,t}$ is the firm i's patent stock at year t. That is, $PATENT_{i,t} = I_{it} + (1\text{-}\rho)\ PATENT_{i,t\text{-}1}$, where I_{it} is the number of patent granted to the firm by U.S. Patent Office in a particular year[2], $PATENT_{i,t\text{-}1}$ is a firm i's patent stock at year $t\text{-}1$, and ρ is the depreciation rate[3]. 'Patent-intensive' firms may be inclined to license out since they may have more technologies available than they can exploit internally.

[2] We calculated patent stock based on the yearly patent data from 1969 to 1999. We assume the initial patent stock is zero. The assumption over initial stock makes no practical difference due to the long period of depreciation.

[3] Depreciation rate is taken to be 15 %. Fifteen percent is frequently taken as the rule of thumb in knowledge depreciation in the empirical literature. There is little difference with higher values (20%, 30%) in our experiment. The value of the patent stock depreciates because of newer inventions by the same owner or others, developments in complementary technologies, and ultimately the expiration of legal rights.

They may also want to exploit peripheral technologies. The anticipated sign is positive.

LOGSALE $_{i,t}$ is the log of sales amount of firm i at year t. Sales amount is used as a proxy for the firm size. Large firms may license a lot because of various strategic incentives. They may license in order to influence dominant standards. They also may license a weak rival to crowd out the market and deter entry by a stronger competitor. We expect a positive sign.

(R&D/SALE)$_{i,t}$ is the R&D intensity of firm i at year t, and ***(CAPITAL/ASSET)***$_{i,t}$ is the capital investment over total invested asset of firm i at year t. These variables represent the technological capabilities and rate of implementation of innovations. The higher level of R&D and capital investment is usually associated with the higher probability of invention and/or innovation. Thus, R&D and capital intensive companies may have more technologies available to license and actively engage in technology sales through licensing agreements. The expected signs of these variables are positive.

CASHFLOW $_{i,t}$ is the cash flow of firm i at year t (millions of dollars). Companies who are under severe cash flow constraints often cannot even attempt to commercialize and market their inventions on their own. Thus, selling technologies to other firms would be the better strategy for them since they can avoid the risk of marketing their proprietary technologies on their own and still extract profits from technologies by receiving licensing fees or royalties. Thus, firms suffering from cash flow difficulty are expected to license technologies more frequently. A negative sign is anticipated.

(INCOME/ASSET)$_{i,t}$ is the net income over total invested asset of firm i at year t. The return on assets is used as a proxy for firms' profitability and performance. Once firms obtain technologies from technology holders, they are now able to produce products using licensed technologies and compete with their own licensors at the product market (Mitchell and Singh, 1992). Additional competition lowers the firms' profits and incentives to license accordingly. However, for firms that are generating higher rates of return, this dampening effect on profits would relatively be minor to them. Thus, the expected sign is positive.

EXPERIENCE $_{i,t}$ is coded as 1 if the firm i has licensed one or more technologies during the previous five years at t, and otherwise 0. This variable is used as a proxy for transaction costs of licensing. Firms' prior experiences of licensing to other firms would lower transaction costs of licensing such as costs of gathering information about prospective licensees, negotiating, writing contracts and enforcing them. Based on the transaction cost theory (Williamson, 1979), a positive sign is expected since lower transaction costs of licensing give firms more incentives to license out technology.

Year dummy variables are ***Year94, Year95, Year96, Year97*** and ***Year98***. These are included to control for potential year-specific macroeconomic effects.

Table 2 shows the descriptive statistics of variables.

Table 2. Descriptive Statistics

Variables	1 Mean Median (Std.Dev)	2 Mean Median (Std.Dev)	3 Mean Median (Std.Dev)	4 Mean Median (Std.Dev)	5 Mean Median (Std.Dev)	6 Mean Median (Std.Dev)
$LICENSE_{i,t}$	.1351 0 (.342)	.0449 0 (.2073)	.1161 0 (.3206)	.0645 0 (.2458)	.0407 0 (.1978)	.1229 0 (.3285)
$PATENT_{i,t}$	21.690 3.131 (101.660)	70.6893 8.4185 (359.524)	37.7583 0 (297.164)	70.4639 0 (607.297)	65.0778 0 (492.679)	65.8606 0 (478.679)
$LOGSALE_{i,t}$	1.3059 1.197 (1.2324)	2.5058 2.7622 (1.0497)	1.8558 1.7083 (1.1623)	1.8566 1.7836 (.9212)	2.6485 2.6053 (1.056)	1.6095 1.5772 (1.0086)
$(R\&D/SALE)_{i,t}$	5.7499 1.946 (36.8557)	.183 .0351 (2.3205)	.1853 .1551 (.5008)	.1962 .1396 (1.8682)	.0068 0 (.0388)	.2996 .1889 (1.9326)
$(CAPITAL/ASSET)_{i,t}$	.0499 .0341 (.0576)	.064 .0541 (.0504)	.050 .0394 (.0445)	.0694 .0503 (.066)	.0927 0 (.0388)	.047 .0361 (.0478)
$CASHFLOW_{i,t}$	174.9837 6.878 (728.3726)	278.3395 179.7 (772.784)	200.5302 17.916 (760.348)	126.0386 24.86 (638.475)	1086.985 651.203 (2957.37)	101.369 14.3285 (745.51)
$(INCOME/ASSET)_{i,t}$	-.3057 -.1101 (1.1616)	-.009 .056 (.3808)	-.1368 .0899 (.5153)	-.0873 .0425 (.6366)	-.0094 .0305 (.1918)	-.1889 .0147 (1.0334)
$EXPERIENCE_{i,t}$	.2913 0 (.4545)	.1391 0 (.3463)	.1803 0 (.3847)	.1702 0 (.376)	.0349 0 (.1837)	.0875 0 (.2827)

Notes: Model **1**: drugs & pharmaceutical; Model **2**: chemicals except drugs & pharmaceutical; Model **3**: computer & office equipment; Model **4**: electronics, Model **5**: communications; Model **6**: computer & data processing services.

4. RESULTS AND DISCUSSIONS

Table 3 reports the estimation results for drugs & pharmaceutical (model 1), chemicals except drugs & pharmaceutical (model 2), computer & office equipment (model 3), electronics (model 4), communications (model 5), and computer & data processing services (model 6).

The stock of technical knowledge (patent stock) does not necessarily exert a strong positive influence on licensing incentives across all sectors. While coefficient on PATENT enters positively and significantly in drugs & pharmaceutical and chemicals industry, it generates opposite signs and fails to produce statistically significant results in other industry sectors. These results are somewhat puzzling. But, the findings demonstrate anecdotal evidence that some companies ignore a large fraction of their patented technologies that could be licensed or profitably sold.

LOGSALE maintains expected positive signs even though it is statistically significant only in industries such as computer & office equipment, communications, and computer & data processing services. This confirms the fact that large firms license a lot because of strategic incentives and in order to establish and dominate a de facto standard. Also, large companies would do license since they tend to have more proprietary technologies to license than small firms do due to their better financial capability for innovations than small companies. It is, however, interesting to see that company size has no statistically significant impact on technology licensing in chemicals including drugs & pharmaceutical industry. These sectors comprise relatively large number of small firms like research labs. Small research-oriented firms often earn their profits through licensing arrangements with more established firms in commercializing a new technology since they often cannot even attempt to market their inventions without assistance from larger established companies due to their usual lack of market power (Gans and Stern, 2000). Thus, small firms are pressured to license technologies and they may grant licenses as many as larger companies do, especially in chemicals industry.

R&D/SALE and CAPITAL/ASSET enter with significant positive signs in computer & data processing services and communications, respectively, indicating that propensity to license technology rises with technological capabilities. R&D and capital intensive companies may have more technologies available than they can exploit internally and thus increasingly try to supplement income from the active management of intellectual property, frequently involving technology sales.

EXPERIENCE has a significant positive impact on the propensity to license out technology across all sectors. This suggests that transaction costs consideration is clearly a very important determinant of managers' licensing incentives.

Firms' prior involvement in licensing and the relevant experience that comes with it would lower transaction costs of licensing, giving firms the stronger incentives to license technology.

CASH FLOW, however, fails to produce statistically significant results across all industries. INCOME/ASSET does not perform well as explanatory variables for licensing incentives either.

Table 3. Random-effects probit estimates, 1994–1999

$LICENSE_{i,t}$	1	2	3	4	5	6
$PATENT_{i,t}$	.002***	.0005*	-.0001	-.0002	.00004	-.00007
	(.0007)	(.0003)	(.0003)	(.0003)	(.0003)	(.0002)
$LOGSALE_{i,t}$	.1432	.0905	.2317*	.1732	.9619***	.4286***
	(.087)	(.1784)	(.1329)	(.1681)	(.3666)	(.1133)
$(R\&D/SALE)_{i,t}$	-.008	-2.0975	.2205	.0416	-5.987	.065**
	(.0073)	(4.0459)	(.3502)	(.220)	(15.201)	(.0275)
$(CAPITAL/ASSET)_{i,t}$	-.013	-2.2213	2.0856	.9111	5.9572**	.2933
	(1.2116)	(3.5908)	(2.2549)	(1.5182)	(3.0364)	(1.404)
$CASHFLOW_{i,t}$	-.0002	.0003	.00007	.0007	-.00005	.0001
	(.0001)	(.0004)	(.0001)	(.0006)	(.00007)	(.0002)
$(INCOME/ASSET)_{i,t}$	.0341	.1918	.0969	-.092	.1461	.0189
	(.1274)	(.7759)	(.2518)	(.1753)	(2.1258)	(.1136)
$EXPERIENCE_{i,t}$	1.4853***	1.217***	1.351***	1.031***	2.185***	1.516***
	(.1593)	(.2974)	(.2848)	(.3008)	(.8078)	(.3068)
Year94	.4161**	.595	-.2619	-.444	-1.0093	.0369
	(.208)	(.4215)	(.2948)	(.2754)	(.694)	(.2121)
Year95	.4963**	.1246	.6435**	.4459	.394	-.0275
	(.2001)	(.4638)	(.2774)	(.2748)	(.7437)	(.2081)
Year96	.2238	.4154	.0154	-.0742	1.2077**	.0076
	(.2059)	(.4288)	(.3014)	(.3006)	(.6625)	(.2055)
Year97	.4135**	-.4841	.3425	.4527*	1.1473**	.3982**
	(.1994)	(.589)	(.2854)	(.2666)	(.6514)	(.1917)
Year98	.2726	.2098	.2555	.1533	1.1426**	.1278
	(.2037)	(.4311)	(.2858)	(.2776)	(.6405)	(.1968)
Constant	-2.456***	-2.78***	-2.47***	-2.91***	-6.18***	-2.79***
	(.245)	(.6159)	(.3637)	(.4224)	(1.4929)	(.287)
N	1227	684	721	1387	513	1424
Chi square	116.72	76.65	43.69	36.16	18.22	63.37

Notes: Model **1**: drugs & pharmaceutical Model **2**: chemicals except drugs & pharmaceutical, Model **3**: computer & office equipment Model **4**: electronics, Model **5**: communications, and Model **6**: computer & data processing services; ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level; Standard errors are in parentheses.

5. CONCLUDING REMARKS

This paper empirically examines the validity of potential factors that might affect firms' incentives to license out technology. The analysis is done with the help of a panel data set describing such arrangements involving publicly traded companies in the United States. Especially, we explore inter-sectoral differences and similarities in licensing activities across six technology-intensive industries: drugs and pharmaceutical, chemicals except drugs, computer and office equipment, electronics, communications, and computer and data processing services.

The results suggest that there seems to be significant cross-industry differences as well as similarities in determinants of the propensity to transfer technology through licensing agreements. The important explanatory factors that determine the firms' incentives to license out technology relate to the company's stock of technological knowledge (patent stock), prior involvement in technology licensing, the company size, R&D intensity and capital expenditure.

One of limitations of this analysis relates to the fact that it has considered only one set of factors affecting the propensity to license out technology: the characteristics of a licensor firm. Given the fact that various characteristics of the firm's primary operating industry might also influence a manager's licensing decision, a diverse set of the firm's industry characteristics need to be considered in the model as well. The next step should be to also incorporate sets of variables describing the characteristics of licensees and the relationship between licensor and licensee firms. Follow-up research should try to do more in this area.

REFERENCES

[1] Arora, A., and A. Gambardella, "The changing technology of technological change: General and abstract knowledge and the division of innovative labour," *Research Policy* 23 (1994), 523-532.

[2] Arrow, K. J., "Economic welfare and the allocation of resources for invention," In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, ed. R. R. Nelson. Princeton University Press, 1962.

[3] British Technology Group (BTG), IPR Market Benchmark Study, 1998.

[4] Gans J. S., and S. Stern, "Incumbency and R&D Incentives: Licensing the Gale of Creative Destruction," *Journal of Economics & Management Strat-*

egy 9 (Winter 2000), 485-511.

[5] Kline, S., and N. Rosenberg, "An overview of innovation," In *The Positive sum Strategy*, ed. R. Landau, and N. Rosenberg. Washington, DC: National Academy Press, 1986.

[6] Levin, R. C., A. K. Klevorick, R. R. Nelson and S. G., "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity: Microeconomics* 3 (Winter 1987), 783-820.

[7] Mitchell, W., K. Singh, "Incumbents use of pre-entry alliances before expansion into new technical subfields of an industry," *Journal of Economic Behavior & Organization* 18 (1992), 347-372.

[8] Nelson, R. R., and S. *An Evolutionary Theory of Economic Change*. Cambridge, MA: The Belknap Press of Harvard University Press, Winter 1982.

[9] Von Hippel, E., "Task partitioning: An innovation process variable," *Research Policy* 19 (1990), 407-418.

[10] Williamson, O .E., "Transaction cost economics: the governance of contractual relations," *Law Economics* 22 (1979), 233-261.