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기술시장의 존재가 기술공급자의 시장진입에 미치는 영향

The Effect of Markets for Technology on The Entry of Technology Suppliers: Evidence from the Chemical Industry

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국문요약

이 논문은 기술시장의 성장이 그 기술을 기반으로 한 기술서비스 공급자 시장을 확대시킨다는 것을 실증 분석하였다. 즉 , 라이센싱된 기술의 숫자가 증가할수록 기술 공급자의 시장 진입이 촉진된다는 것이 본 논문의 핵심 가설이다. 이 가설을 검증하기 위하여 화학 산업의 기술거래 및 엔지니어링 서비스 데이터를 대상으로 하여, 기술 라이센싱이 증가함에 따라 기술 공급자의 고정비용이 줄어들어서, 기술공급자가 시장에 진입하고자 하는 유인이 증가한다는 것을 검증하였다. 나아가 엔지니어링 서비스 시장의 수요 증가 또한 기술 공급자의 시장진입을 증가시키지만, 가변비용의 대용변수로 쓰인 일인당 임금수준은 그다지 공급자의 시장진입 결정에 영향을 미치지 않는다는 것으로 나타났다.

핵심어: 기술공급자, 화학산업, 플랜트 엔지니어링, 라이센싱, 시장진입

Abstract

This paper provides an empirical evidence that the entry of a technology supplier depends on the markets for technology. In particular, using the chemical industry dataset, we test the hypothesis that the number of specialized engineering firms (SEFs) depends on the number of licensors in the market. Moreover, the number of plant investment, which is a market demand shifter is positively related with the entry of the SEFs, while the effect of the GDP pre capita does not have a significant effect on the entry of the SEFs.

Key words: Chemical Industry, Plant Engineering, Licensing, Technology Suppliers, Entry

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Ⅰ. Introduction

Considering technology as a critical input factor for the firm, the markets for technology can be used to acquire crucial technology instead of developing it through the firms in-house R&D (Barney, 1986). Indeed, the markets for technology facilitated the wide and efficient use of existing technology, and many emerging economies have benefited from the global technology transactions, letting alone the advanced countries (Arora et al., 2001).

Regarding the rapid growth of global technology transactions, one mechanism this paper focuses on, which hasn't been clearly addressed, is the operation of the specialized technology suppliers in the vertical market being conditioned by the technology availability in the market. In particular, a key phenomenon explored by this paper is the available technologies in the market lowering the fixed cost of the specialized engineering firm using the relevant technologies.

Specifically, this paper provides empirical evidence that the entry of specialized engineering firms depends on the number of technologies licenses in the market. We develop an empirical model which explicitly considers the cost of a specialized input factor and the market for specialized input for the entry of the specialized engineering firms.

For our purpose, the plant design and engineering services in the chemical industry are chosen, because the division of inventive labor in plant design and engineering services among downstream firms and specialized input suppliers are relatively well-established phenomena (Rosenberg, 1998, Arora et al., 1999). Also, since 1970s and through 1980s, the rise of chemical industry in the emerging economies with the entry of small local chemical firms as well as the large multinationals provides a perfect environment (Arora and Gambardella, 1998) which allows us to test the hypothesis.

Section 2 provides a brief overview of the chemical industry, which provides a legitimate background and rationales for using chemical industry to empirically test the hypotheses we are interested in. Next, we present an empirical model at the industry level based on a firm's optimal entry decision in section 3. Section 4 explains the sample and the dataset being used to test the hypothesis. Finally, section 5 discusses the empirical results, followed by a brief conclusion in section 6.

II. Rise of Specialized Engineering Firms and Technology Licensing

Division of innovative labor is not a new phenomenon. In the chemical industry, the downstream chemical firms outsourced plants from specialized engineering firms (SEFs), since the second world war (Freeman, 1968; Arora et al, 1998; Rooij and Homburg, 2002). For example, from 1960 to 1966, the three quarters of new plant investment were contracted out to specialized engineering and construction firms (Freeman, 1968). Meanwhile, due to the advance in chemical engineering field as well as the accumulated experience by continuous downstream firms' outsourcing since the early 20^{th} century, independent engineering companies have had a chance to move quickly down the learning curve, which allowed independent engineering firms to grow and to be more efficient than downstream firms (Rosenberg, 1998; Arora et al., 1999).

Initially, like other industries, chemical firms did most of the process development, basic and detailed engineering procurement, and over-all management of the design and construction process, in-house (Arora and Gambardella, 1997, Rooij and Homburg, 2002). Since companies wanted to keep their knowledge secret, they were reluctant to get external suppliers involved. However, in certain areas, companies didn't have the expertise to construct the necessary installations themselves. As a result, in those areas, firms gradually outsourced to specialized independent engineering & construction firms, such as equipment firms, and followed by the building contractors increasingly focusing on sophisticated process design and on project management. Eventually, external suppliers handled the entire range of activities emerged (Rooij and Homburg, 2002).

One important issue is that building a plant was a long term investment, which did not happen frequently. Therefore, it was costly for a (small) chemical firm to maintain the whole engineering division. For example, in the Chemintell dataset, top 10 chemical firms' average new plant investment was 2.4 for ten years in the market.[1] In this regard, firms producing end product chemical outsourced the plant engineering services rather than having the full internal engineering division on its own.

For example, according to Rooij and Homburg(2002), BASF was familiar with manufacturing dyes, but not with the product of inorganic basic chemicals, such as sulfuric acid and soda. They employed an engineer with the knowledge and experience who brought along experienced workers. In the following year, BASF established its internal engineering & construction department, which enabled the company to do everything on its own. Meanwhile, companies such as Royal Dutch/Shell relied on contractors when it planned to enter new fields. For example, in 1908, Royal Dutch offered Hartmann & Benker to submit a plan and quotation for sulfuric acid plant. Hartmann & Benker supplied the process design for the plant as well as the materials to be purchased (Rooij and Homburg, 2002). They also put the installation into operation and would give instruction to the workers.

In both cases of BASF and Royal Dutch/Shell, when a firm tries to build plants internally, a firm is likely to face the cost of building a sizable internal engineering team, which is necessary in designing, engineering, and constructing plants. Plant design and engineering is a multi-disciplinary team operation which requires collective knowledge and a set of know-how. Chemical process engineers as well as mechanical and civil engineers are needed, along with electrical engineers and drafting office. Moreover, business economists, scheduling engineers, purchasing specialists, and other managerial/logistics specialists are also needed.

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[1] Here the definition of the market is by the chemical sub-sector and region. The detailed definition is provided in section 3.

〈Table 1〉 The Market for Engineering Services and Licenses in Chemicals, 80-90s by Sector

	Percentage of Plants engineered			Percentage of Licenses		
Sectors	In-house	by SEF	by other firms(*)	In-house	by SEF	by other firms(*)
Air Separation	32.4	34.1	33.5	27.2	33.7	39.0
Fertilizers	4.8	79.6	15.6	4.8	61.5	33.7
Food Processing	5.0	74.8	20.3	20.4	38.8	40.8
Gas handling	5.0	78.0	17.1	4.9	62.3	32.8
Inorganic Chemicals	14.1	66.9	18.9	24.4	29.2	46.4
Industrial Gases	21.9	60.3	17.8	12.9	36.1	51.1
Minerals & Metals	7.8	71.3	20.9	23.9	24.4	51.7
Miscellaneous	6.6	78.9	14.4	16.8	34.6	48.5
Organic Chemicals	24.3	53.8	21.9	44.2	19.4	36.4
Oil Refining	6.4	83.7	10.0	9.3	48.6	42.1
Petrochemicals	13.3	75.9	10.8	18.5	32.4	49.1
Pharmaceuticals	19.4	63.0	17.6	54.8	3.2	41.9
Plastic & Rubber	23.8	63.1	13.2	41.2	6.1	52.8
Pulp & Paper	4.0	79.0	17.0	3.8	46.2	50.0
Misc. Specialties	31.0	52.1	16.9	61.5	2.9	35.6
Textile & Fibers	7.4	72.2	20.3	17.9	52.9	29.2
Total (%)	12.7	71.6	15.6	21.5	34.6	43.9

Source: Chemintell, 1991

(*): Typical chemical firms or other downstream manufacturing firms

Table 1 shows that for the period between 80 and 90, SEFs engineered three-fourths of the total number of plants in the world. In most sectors, the percentage of plant engineered in-house is below 10 percent. Another interesting point is the sources of licenses. As can be seen in table 1, the share of licensing of the SEFs is lower than that of the plants engineered by the SEFs. This may imply that there are difficulties for SEF to finance the research projects in the new fields (Arora et al., 2001). Table 1 is also consistent with the notion that the major new break through innovation are carried out by the large oil and chemical companies, while SEFs took more incremental move, which is effectively going down the learning curve (Mansfield et al., 1977).

Moreover, chemical firms licensed its technologies to other firms, including the engineering service providers, in order to make use of the technologies under utilized for their plant investment, while producing the chemicals on their own. For example, Dow Chemicals and Exxon, are licensing Metallocene technology, a base technology for polyethylene, with other firms' complementary process technology, such as Union Carbide's gas phase process, worldwide, which became an important source of revenue. These set of licensing involving several different technology component ended up forming joint ventures which became independent engineering service providers. This is a good example of large chemical firm licensing their technologies as well as producing the chemicals based on those technologies, and the rise of engineering service providers for certain technology. Nowadays, licensing revenue takes around 15-20 percent of the R&D budget of spending in polyethylene division at Exxon (Arora et al., 2001).

Ⅲ. Entry Model of the Specialized Engineering Firms

We develop an empirical model to test whether the entry of the SEF is affected by the number of technologies available in the market. We first briefly provide an entry condition of the SEFs at the industry level. And an empirical model is constructed based on that entry condition. The entry condition an applied version of the zero-profit equilibrium constraint model used by Bresnahan and Reiss (1991).

1. Entry condition of the SEFs

To provide plant design, engineering and construction services, SEFs incur both variable and fixed costs. Variable cost may consist of labor and other capital inputs that vary with the level of production. Fixed costs (Fij) may be related with construction of facilities, acquisition of equipments, accumulation of the relevant technologies and know-how. We specify the cost function as the following:

$$C_{ij} = VC_{ij}(B_{ij}) + F_{ij}$$

where the total cost for a SEF is increasing in quantity demand (B_{ij}), and the fixed costs(F_{ij}). We do not allow fixed cost to vary across firms, arguing that the latter SEFs entering the market do not face any late entry disadvantages in acquiring the fixed cost components.

With a single SEF serving the market, the individual SEF's demand is equal to the market demand. As an additional SEF enter the market, we assume that the market demand is split equally among the SEFs. Thus, the demand for Nth SEF entering the market (sector i and region j) is $\frac{B_{ij}}{SEF}$, where SEF refers to the total number of SEFs in the market.

Therefore, assuming that all the SEFs are bounded by the zero profit constraint (Bresnahan and Reiss, 1991), for the Nth SEF in the market, the profit maximizing condition can be expressed as the following:

$$\pi_{ij}^{SEF} \equiv V_{ij} \cdot \frac{B_{ij}}{SEF} - F_{ij} = 0 \qquad \text{---(3)}$$

where V_{ij} is the price-variable cost margin, $V_{ij} = P_{ij} - VC(B_{ij})$.

Solving equation (3) with respect to SEFs,

$$SEF_{ij} = V_{ij} \cdot \frac{B_{ij}}{F_{ij}} \qquad \text{---(4)}$$

Above equation (4) indicates that the entry of SEF is a function if the market demand (B_{ij}), fixed cost (F_{ij}) and variable cost (V_{ij}). We would like to clarify the points regarding the cost components of SEFs. First, our model assumes no entry cost of SEFs in sector i and region j. Our model also assumes that the entry decision of a SEF in sector i in region j is independent.

We explore the technology sector and regional variation. Regional variation is interesting, because geographical location is crucial for firms' licensing behavior. Firms are likely to license their technology in the region where they do not operate. Technology sector variation is a key variation that separates firm investment as well as licensing.

2. Econometric specification using ordered probit model

Based on above entry condition of SEFs, we develop an empirical model in order to test the hypotheses. We use ordered probit method to estimate the model because the number of SEFs appears to be not a perfectly continuous variable. The maximum number of SEFs in the market is 8. In this case, ordered probit model is recommended to estimate the model to avoid the possible bias that can be created by using a discrete dependent variable.

Hence, using the equation (4), we can get an ordered probit model in the reduced form equation as the following:

$$SEF^* = X\beta + \varepsilon_{ij} \quad \text{--------------------------------}(5)$$

$$\begin{array}{lll} SEF = 0, & \text{if} & SEF^* < 0 \\ SEF = 1, & \text{if} & 0 < SEF^* < \mu_1 \\ SEF = 2, & \text{if} & \mu_1 < SEF^* < \mu_2 \\ \vdots & & \vdots \\ SEF = 8 & & \mu_7 < SEF^* \end{array}$$

where SEF indicates the number of SEFs in the market, and X is the vector of exogenous factors including market demand factors(B_{ij}), fixed cost factors(F_{ij}), variable cost factors(V_{ij}). And ε_{ij} is the error component with normal distribution with 0 mean and 1 standard deviation. μ_i is the estimated cut-off points representing the threshold of each number of SEFs increased in the market.

Hence the probability of the number of SEFs being equal to certain value is the following:

$$\Pr(SEF = 0) = \Phi(-X\beta),$$

$$\Pr(SEF = 1) = \Phi(\mu_1 - X\beta) - \Phi(-X\beta),$$

$$\Pr(SEF = 2) = \Phi(\mu_2 - X\beta) - \Phi(\mu_1 - X\beta)$$

$$\vdots$$

$$\Pr(SEF = 8) = 1 - \Phi(\mu_7 - X\beta)$$

Therefore, to run the ordered probit model, we specify the exogenous factors as the following:

$$SEF_{ij} = \beta_0 + \beta_1 \cdot I_{ij} + \beta_2 \cdot LIC_{ij} + \beta_3 \cdot WMFG_j + \sum_{i=1}^{5} \delta_i \cdot D_i + \varepsilon_{ij} \text{ --------------(6)}$$

where SEF_{ij} takes the value from 0 to 8, and ε_{ij} is the error component of normal distribution with mean 0 and standard deviation 1. In addition to the above specifications, technology sector dummies (D_i) are used in order to run a rough fixed effect estimation that can control for the unobserved industry characteristics. We classified 105 technology sectors into roughly 6 upper level categories: Agriculture & Fertilizing chemicals, Industrial Gases, Oil & Refinery, Petrochemicals, Plastics, Rubbers & Resins, and Minerals & Metallurgy, and others. Note that the regional dummies are not used because the average wage of the manufacturing sectors (*WMFG*) only varies by the region.[2]

Equation (6) is a linear empirical model which represents the entry condition of the SEFs. The dependent variable is the number of SEFs in sector i and region j. The number of SEFs are the plant engineering service providers, who get the contract for plant design, building, and engineering. They develop their own process technologies as well as license the available process technologies to provide engineering services.

Basically, equation (6) is saying that the number of SEFs depends upon the market demand of plant outsourcing, profit-variable cost margin factors and fixed cost factors. Obviously, the number of SEFs is expected to be increasing in the market demand, because larger market demand allows more SEFs to enter the

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[2] However, we also estimated a model without *GDPC* and with region dummy variables, and the estimation results were qualitatively the same.

market. However, since the quantity demand (B) is an endogenous variable, we let the quantity demand (B) to be a function of the total number of plant investment of the chemical firms in sector i and region j (I_{ij}). We argue that the quantity demand is shifted by the total number of plant investment (I_{ij}), because firms are likely to outsource plants based on their plant investment.

We let the number of non-SEF licensors (LIC_{ij}) to be a fixed cost (F_{ij}) factor, because there are fixed costs incurring for firms to accumulate technologies and know-how in a certain technology sector and region. Hence, if there are more firms licensing and transferring the technologies in the sector, the fixed costs (e.g. learning costs) are likely to be lower, because the competition among licensors is likely to lower the license fee and the cost of using the technology. Note that the SEF-licensors are excluded. Including the number of SEF-licensors and arguing that the fixed cost is decreasing in the number of licensors is not right, because SEF licensors already incurred fixed cost to develop the technology which they are licensing.

We also let the relevant wage in the manufacturing sectors ($WMFG_j$) to be a variable cost factor, because the relevant wage in the manufacturing sectors can be a proxy for the market wage or income of the chemical engineering and services, a variable cost factor, in the region.[3]

We would like to clearly acknowledge several limitations in this model. First, we are assuming that the entry of SEFs in a market is independent of other markets. In other words, we assume that the SEFs entering one market does not enter into other related market.

Second, we are not modeling the dynamic aspect of SEFs' entry in the market. Our empirical model is a static model in a sense that it does not deal with time variation or dynamics of firm entry, but rather incorporates the variation of technology sector and region. Although it is interesting to examine the dynamics of the firm entry and market expansion, we don't have enough information to do so.

Third, we are not considering the possibility of SEFs in-licensing from Non-SEF

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3) We also tried GDP per capita ($GDPC_j$) as a variable cost (V_{ij}) factor, because GDP per capita is typically used as a proxy for the market wage or income, a variable cost factor, in the region. However, the estimation results were qualitatively the same.

firms in the other regions. It may be difficult to geographically confine the range of technology licensing, while the technologies licensing may have technology sector constraints. However, non-SEF firms may restrict licensing in the region where they are operating in order to prevent more competition. For example, there can be a process technology which can be only used for agricultural chemical, and a firm operating in North America license to the SEFs in Southeast Asia. Meanwhile, we also tried the number of licensors just by allowing it to vary by the technology sector, assuming that the technology can be license to any region in the world. And the results were similar to that of the licensors which varies by technology sector and region.

Ⅳ. Data and Sample

To test our model, we use the database named Chemintell, a chemical industry specialized database constructed by Stanford Research Institute in the 1990-1999. This data set provides firm level plant investment data worldwide. Moreover, the data provides information about the licensors of the technology and the contractors building the plants by the process and product information.

The data set consists of 105 process technologies and 7 regions, which ideally gives us 735 "markets", where the unit of analysis is process technology and region pair. However, we only use 330 observations of technology process i and region j, because there are technology processes and regions which firms don't invest in. If there is no investment, there will be no plant engineering services being contracted out. This means that the entry of SEFs is conditioned by the market demand which create a base for the SEFs to enter the market.

In addition, we selected the technology processes with 20 and more plants in the database as major process technologies. We would like to deal with major technology sectors rather than the minor ones to test our hypothesis.4)

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4) We do not explore the yearly variation due to the nature of plant investment. Plant investment is a long-run investment decision, and the Chemintell data confirms this. There are on average around 2 plant investment between 1990 and 1999, which has a limited variation to run an empirical test on the entry of SEFs.

The number of Specialized Engineering Firms in sector i and region j (SEFij) is constructed by aggregating the number of contractors in sector i and region j. In the dataset, we are able to know the exact contractors that build the chemical plants for the downstream firms. Hence, we include all the contractor as a specialized engineering firms to be the sample for this paper.

The number of plants investment in sector i and region j (Iij) is constructed by summing the number of plants that are contracted out to external engineering and construction firms. The plants that are actually informed to be completed or commissioned are counted as plant investment in sector i and region j. We didn't include the plants that were planned, or studied or expanding, because it is not an actual new plant investment. We also included the plants which we know the construction start year, even if the plants were coded as "existing and operating plant".

〈Table 2〉 Descriptive Statistics

Variables	Obs.	Average	std. Dev.	Min.	Max.
Number of specialized engineering firms	330	3.33	2.74	0.00	8.00
Number of investment	330	4.64	5.00	1.00	36.00
Logged wage average in the manufacturing	330	7.02	0.66	5.83	7.63
Number of licensors	330	5.41	5.04	0.00	27.00
Agriculture & Fertilizers	330	0.09	0.29	0.00	1.00
Industrial Gases & Air separations	330	0.10	0.30	0.00	1.00
Oil Refining	330	0.09	0.29	0.00	1.00
Petrochemicals	330	0.25	0.43	0.00	1.00
Plastics, Rubber & Resins	330	0.28	0.45	0.00	1.00
Other Chemicals	330	0.08	0.28	0.00	1.00

The key variable is the number of non-SEF licensors (LIC_{ij}), which is a proxy variable of the fixed cost of SEFs. As the fixed cost of SEFs in sector i and region j is not observable, we make the fixed cost a function of the number of licensors in sector i and region j (LIC_{ij}). The decision to license proprietary technology depends upon the presence of competing licensors. For SEFs, there are fixed costs of accumulating relevant knowledge or technologies in order to operate in sector i and region j. The knowledge (or technologies) can either be accumulated by individual SEF's in-house efforts, or by the knowledge transfer of technology holders, which is achieved usually in the form of licensing. However, we are only counting non-SEF licensors in the market, because it is not so unreasonable to assume that SEF licensors already incurred the fixed costs for the technology they are licensing. Hence, if there are more than one licensor in the sector, the price of license is likely to be lower than the case of single licensor. Thus, the fixed cost of accumulating technology is likely to decrease when there are increasing competition among licensors. Therefore, the number of licensors is a reasonable proxy to capture the fixed costs of SEFs in sector i and region j.

Average wage in the manufacturing sectors in region j ($WMFG_j$) is used as a proxy for the variable cost factor of the SEFs in region j. We construct the average wage in the manufacturing sectors using the "occupational wage database" constructed by Freeman and Oostendorp in 2005 (http://www.nber.org/oww/).5) We classified the countries into 7 regions: Western Europe, North America, Latin & South America, Northeast Asia, Middle East, Southeast Asia, Africa. We then logged the average wage of the chemical industry ($WMFG_j$) in order to avoid the heteroschedasticity that can occur with other covariates in the model.

Finally, we construct six industry dummy variables to control for the industry specific effects. In the sample, the 330 sectors with the 105 technology processes are grouped into six chemical sub-sectors. Based on this categorization, we made as six dummy variables: Agriculture & fertilizers; Industrial Gases & Air separations; Oil Refining; Petrochemicals; Plastics, Rubber & Resins; and Others chemicals. Other chemicals is the omitted contrast.

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5) We also tried several other measures for the variable cost factors, such as GDP per capita ($GDPC$). However, the estimated results were qualitatively the same.

V. Empirical Results

In table 3, we present the empirical results of the ordered probit model. In order to cross check the different results between the empirical methods used to estimate the same dataset, we also provide ordinary least square (OLS) regression results. Note that the ordered probit model is used, as we treated the number of SEFs to be discrete dependent variable that can incur biased coefficient estimate if used in the OLS model.

〈Table 3〉 Estimated Results of the OLS and Ordered probit model

		OLS			Ordered Probit		
Variables	Param.	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.
Number of Investment	β_1	0.33	0.02	***	0.30	0.02	***
Number of Licensors	β_2	0.08	0.03	***	0.04	0.02	**
Logged avg. wage in the manuf.	β_3	-0.34	0.16	**	-0.08	0.09	
Agriculture & fertilizers	δ_1	1.20	0.45	**	0.42	0.26	
Industrial Gas & Air separations	δ_2	1.08	0.42	**	0.67	0.24	***
Oil Refining	δ_3	1.54	0.42	***	0.66	0.23	***
Petrochemicals	δ_4	0.57	0.32	*	0.21	0.18	
Plastics, Rubber & Resins	δ_5	0.01	0.32		-0.20	0.18	
		Adj. R-square=0.53 F(8, 321)=47.56			log likelihood=-543.18 LR chi(8)=300.50		

sig. level: *** 1%, ** 5%, * 10%

1. The effect of the number of licensors on the entry of SEFs

The key hypothesis related with this coefficient is that the number of SEFs increases, when the number licensors increases in the market. Hence, the effect of the number of non-SEF licensors on the entry of SEFs is expected to be positive, because the competition among licensors is likely to decrease the cost of acquiring the technologies SEFs use to provide plant design and engineering services.

The estimation result in table 3 supports our expectation with the significant effect size of 0.04 ($\beta 2$=0.04, *P-value* = 0.01). Based on this result, we can examine the marginal effect of a licensor on the probability of the entry of the SEFs.

〈Table 4〉 Marginal effect of the licensors

SEF=i	dy/dx Coef.	Std. Err.	Sig. level
SEF=0	-0.012	0.007	*
SEF=1	-0.039	0.021	*
SEF=2	-0.016	0.009	*
SEF=3	-0.003	0.003	
SEF=4	0.009	0.005	*
SEF=5	0.018	0.010	*
SEF=6	0.015	0.008	*
SEF=7	0.014	0.008	*
SEF=8	0.008	0.005	*

Sig. level: ***1%, ** 5%, * 10%

The marginal effect of the licensors on the number of SEFs in the market is interesting, because it let us estimate the level of market competition. For example, when the marginal effect of the number of licensors is positive for the probability of when the probability of entry of the SEFs equals to four, this means that the market is likely to have four SEFs in the market when there are increasing number of licensors. Meanwhile, when the licensors are increasing the markets with three or less SEFs are less likely to exist. The increase in the number of licensors are not likely to affect the markets with three SEFs. This result indicates that the number of licensors has an effect of increasing competition among the SEFs in the market.

2. The effect of total plant investment on the entry of SEFs

The market demand of SEFs is the number of plant bought by the downstream firms in the market. This market demand is endogenous, as it can be determined by the price of a SEF's service and other market conditions. Hence, in this paper, we used total number of plant investment of the downstream firms in the market as a proxy of the demand shift factors. This variable can be thought as a population of the plant, which is an exogenous shift factor of the market demand of the SEFs' service.

As shown in 〈table 3〉 the effect of the total plant investment on the number of SEFs is positive and significant ($\beta1=0.30$, *P-value* < 0.001). This confirms our expectation that the entry of SEFs is increasing in the positive market demand shift.

〈Table 5〉 Marginal effect of the plant investment

SEF=i	dy/dx Coef.	Std. Err.	Sig. level
SEF=0	-0.137	0.027	***
SEF=1	-0.432	0.048	***
SEF=2	-0.178	0.041	***
SEF=3	0.033	0.027	
SEF=4	0.099	0.027	***
SEF=5	0.200	0.041	***
SEF=6	0.163	0.036	***
SEF=7	0.159	0.033	***
SEF=8	0.092	0.024	***

Sig. level: ***1%, ** 5%, * 10%

Moreover, the marginal effect of the plant investment on the number of SEFs in the market is positive when the number of SEFs are greater than or equal to four. This indicates that the one more increase in the plant investment is also likely to have a positive effect on increasing the competition among the SEFs in the market with more than four SEFs.

3. The effect of the average wage in the manufacturing sectors on the entry of SEFs

Admitting that the measure is somewhat crude, we used the average wage of the manufacturing sectors as one of the variable cost factors. Arguing that the average wage of the manufacturing sectors represents the variable cost factors in the region, the effect of the average wage of the manufacturing sectors on the entry of SEFs is expected to be negative.

Although the estimation results in table 1 show that the effect of the average wage of the manufacturing sectors on the number of SEFs in the market is negative, it is not statistically significant ($\beta 3$=-0.08, *P-value* =0.350). Note that the OLS estimate has a negative and significant results ($\beta 3$ = -0.34, *P-value* = 0.035).

4. The effect of dummy variables for process technologies

The effect of technology sector dummy variables is used to control the sector specific characteristics. Thus, we are using the technology sector dummy variables in order to run rough fixed-effect estimate, because ideally doing technology fixed effect estimation will eliminate all the variation in the data.

The estimated results in table 3 indicates that there are some industry different in the entry of the SEFs. The industrial gas and air separation sector, and the oil refinery sector are more likely to have SEFs than other chemical sectors. One reason we can think of is the intensity or scale of the plant engineering discipline in these two fields, compared to other segments. For example, firms in the oil refinery or industrial gas segments may be more likely to build large-scale plants than other segments. And they are likely to outsource to SEFs than firms in the other chemical segments. Hence, more SEFs are likely to enter those two segments than other segements. However, we admit that this paper has a limitation of not having an accurate explanation for this industry different in the number of SEFs among the industry sectors. It'll be interesting to further investigate the reasons for more SEFs in these two field for the future study, because there can be technological or economic phenomena during that era that can be meaningful for policy makers.

Ⅵ. Conclusion

This paper provides empirical evidence that the number of a SEFs depends on the number of technology licensors in the market, which supports our hypothesis that the entry of SEFs in the market is increasing in the number of technology available in the market. Moreover, the total number of plant investment, which shifts the market demand for SEFs, has a positive effect of the entry of SEFs in the market. However, the GDPC does not have a strong enough effect on the entry of the SEFs.

The empirical results in the paper suggest that the SEFs benefited from the markets for technology in terms of acquiring strategic factors, which follows the resource-based view in the business strategy field (Barney, 1986).

Meanwhile, from the policy point of view, SEFs in the emerging markets may benefit from the markets for technology, because those firms do not need to go through a complete learning process or developing process that firms in the advanced countries already experienced. In other words, SEFs in the emerging market may just pay the marginal cost to acquire certain technologies they need, although there can be assimilating cost to some extent for the technology buyers, and strategic pricing and technology transfer scheme of the technology holder.

In conclusion, the contribution of this paper is providing an empirical evidence that links the markets for technology and the entry decision of a firm at the industry level. A complementary further research of which can be easily thought is a firm level entry decisions in the markets for technology. Moreover, it seem crucial to further explore the demand conditions, which is modeling the demand of plant engineering services and identifying the exogenous factors that affect the outsourcing decision of the firms contracting out to SEFs.

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미국 카네기멜론대학교에서 "기술혁신 관리와 정책에 대한 연구"로 박사학위를 취득하고 현재 카네기멜론대학교 하인즈정책대학원에서 박사후과정(Post-Doc)을 밟으면서 강의도 하고 있다. 연구분야는 정책분석 및 평가, 기술혁신정책, 정보통신정책, 전자정부 등이다.