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海外專利的決定因素：跨國研究

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行政院國家科學委員會專題研究計劃成果報告

海外專利的決定因素－跨國研究

The Determinants of Overseas Patenting－A Cross-National Study

中文摘要

本研究建立一個海外專利行為的理論架構, 納入出口與對外直接投資等貿易相關因素對赴海外申請專利的影響。利用 2000 年 59 個國家在美國申請專利的跨國資料, 本研究的實證結果發現：海外的專利申請數與該國的出口及至該國的直接投資存在正向顯著的關係, 支持海外專利行為授貿易相關因素影響的假說。其次, 對先進國家與開發中國家而言, 這些因素的影響效果有顯著的差異。

關鍵詞：海外專利, 出口, 對外直接投資, 研究發展

英文摘要

This project provides an theoretical framework of overseas patenting that considering the trade-related influences, including exports and outward foreign direct investment (OFDI), on a country's overseas patenting. Based on the patent applications data for 59 countries in the U.S., the empirical results find that the behavior of overseas patenting is positive associated with exports and OFDI, supporting the viewpoint that overseas patenting is mainly trade-related. Moreover, these influences vary substantially between developed and developing countries.

Key words：Overseas patenting, Export, FDI, R&D

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1. Introduction

The patent-R&D relation is widely discussed in previous empirical works that set an innovation production function with endogenous R&D flows and other exogenous variables. While only a few studies consider patenting behaviors in an international context, even though the activity of overseas patenting is emerging during past decades.[1]

Eaton and Kortum (1996) develop a model of growth and technology diffusion and fit to aggregate data from OECD countries, finding that a country's productivity growth can be spurred by patents granted to foreigners. Using application for German, European and US patent by German companies, Licht and Zoz (1998) find that as the more the exports toward foreign market, firms will apply for more patents in the targeted country. Inkmann et al (2000) construct a trade-theoretical model of overseas patenting that incorporates the sense that relative factor prices, demand conditions and transportation costs. Adopting the detailed information on the patenting behavior of German firms, their results show that trade variables as captured by relative market size and relative wage do not substantially contribute to explain the location choice of patenting.[2]

Patent law is a territorialism, that is, the protection mechanism is effective as a firm files a patent in that country. Although the cost of patenting abroad is usually higher than that in the home country, we can clearly see that many firms act aggressively on patenting abroad to preserve their international competitiveness. Despite the question that what drives firms to apply for patents abroad is interesting and emerging important, it remains little systematic evidence on the determinants of overseas patenting, suggesting the need for future works. The main concern of this study is to develop a conceptual framework that involves international economic influences on overseas patenting.

Extending Eaton and Kortum's (1996) overseas patenting model and adopting a cross-national data of patenting in the U.S., this paper investigates the role played by international economic influences, including exports and outward foreign direct investment (hereafter OFDI), on a country's overseas patenting and their potential differences between developed and developing economies. The remainder of this paper is organized as follow: Section 2 presents the theoretical concepts, empirical model and data. In Section 3, I analyze the econometric results. The possible differences on the determinants of overseas patenting are examined in section 4 and concluding

[1] According to the statistics of world intellectual property organization (WIPO), the member countries issued, on average, more patents to foreign inventors since 1989.

[2] For earlier empirical studies, please refer to Bosworth (1984) and Dosi et al (1990).

discussions are in the final section.

2. Theoretical Concept and Empirical Model

This model I use borrows heavily from Eaton and Kortum's (1996) model by introducing new trade theory (e.g. Helpman and Krugman 1985) which will help us in modeling the trade-related strategies on patenting choices.

Assume the number of patent applications from country *i* for protection in country *n*, P_{in}, is:

$$P_{in} = \varepsilon_{in}\alpha_i f_{in} e^{u_{in}} \qquad i,n=1,\ldots,N. \qquad (1)$$

where ε_{in} is technology diffusion, indicating the probability that an invention from country *i* will be adopted in country *n*. Term α_i represents *i* country's invention talents, relating to some observable characteristics, such as R&D expenditures, national productivity and so on. f_{in} denotes the fraction of diffused ideas that patenting abroad and term $e^{u_{in}}$ is a multiplicative i.i.d. error term.

Subsequently, we introduce the international economic influences as the factors of f_{in}. Let a country's R&D program be described by the vector *R*, where

$$R_i = (r_i, \cdots, r_k) \qquad (2)$$

and where the *k* elements of *R* represent the country's research resources in the *k*th technological field. Moreover, I assume the existence of two locations, *D* for domestic market and *F* for foreign country. Let country *i* has a comparative advantage of R&D on technological area *k*, enabling it plays as a monopoly to produces *k* product and the country can choose either export the product to the foreign markets or produce there (through OFDI) to gain profits. That is, the profit function can be specified as a function of exports and OFDI. In case of imitation threat, profits will be reduced if the country has decided not to file the patent. Hence, the country *i* would apply for patents in location *F* if it generates expected profits that exceed profits under non-patenting plus the patenting cost C_F:

$$\pi_{DF}^{pat}(q) - \pi_{DF}^{not}(q) \geq C_F \qquad (3)$$

Because operating profits is an increasing function of *q* that exported or produced locally via OFDI of country *i*, and therefore, the fraction of patenting abroad, f_{in}, is an increasing function of exports and OFDI.

$$f_{in} = f(EXP, OFDI) \qquad (4)$$

where $\partial f_{in} / \partial EXP > 0$ and $\partial f_{in} / \partial OFDI > 0$

Adopting the specification by indexing the U.S. as the destination country to examine bilateral patenting from the world perspective, assuming technology diffusion, ε_{in} as depending on the distance between *i* and *n* and its square to reflect possible geographical impediments to the free flow of ideas,[3]

[3] Eaton and Kortum (1996) also include the level of human capital in *n* and the level of country *n*'s imports form *i* relative to *n*'s GNP. We do not employ these two variables in this study, because we consider only two locations.

and including country-specific characteristics and trade-related variables, the empirical specification of overseas patenting is thus

$$\ln PAT_{in} = \beta_0 + \beta_1 \ln RD_i + \beta_2 PGDP_i + \beta_3 \ln EXP_i + \beta_4 \ln OFDI_n + \beta_5 \ln DIS_{in} + \beta_6 \ln DIS_{in}^2 + \varepsilon_i \quad (5)$$

where PAT_{in} represents the number of patents granted to country *i* in the U.S.

The first endowment is R&D expenditure that is the most important variable in the patent production function. The literature focus on the R&D-patent relationship has concluded that the lag structure of R&D expending is very poorly identified (Hall and Ziedonis, 2001), therefore we use only a contemporaneous level of R&D spending. Term *PGDP* is the per capita real GDP of country *i* in US dollars, representing national differences in economic development and reflecting a country's ability to innovate (Eaton and Kortum, 1996). It is also a better proxy, relative to GDP and population, to capture the notional economies of scale. Both of the variables are used to represent the invention potential of country *i*.

According to our conceptual framework, the motivation of overseas patenting should also be influenced by international economic influences, one country's exports (*EXP*) and outward foreign direct investment (*OFDI*). As the theoretical inference suggests, both exports and OFDI has a positive impact on the fraction of overseas patenting. The reasons are intuitive: as firms increase exports to foreign markets, they will seek shelters from imitation and competition at local markets, and then resulting in a higher patenting propensity. On the other hand, firms that proceed OFDI and produce abroad, they will also apply for patents in guest countries when they develop new products or processes. Moreover, previous studies have confirmed that patent flows are positive correlated to trade (Dosi et al 1990) and OFDI (Bosworth, 1984). Therefore, both coefficients of *EXP* and *OFDI* are expected to be significantly positive. Lastly, the geographic distance between the country *i* and the U.S. (*DIS*) and its square are also employed.

Because the dependent variable is a discrete variable, a classical linear model is inadequate. For count data, the linear exponential family provides a good alternative. I use Poisson-based count data models and estimation methods in this analysis. As is well known, the Poisson model has the restriction that the mean and variance are equal, while it is unlikely to hold. Therefore, I employ the type II negative binomial model (NBII) in this analysis.

The patents data I use is the U.S. patent granted to 59 foreign countries in 2000. The patents data are collected from the U.S. Patent and Trademark Office (USPTO) and the explanatory

variables are drawn from different data sources. The definitions and data sources of variables are summarized in Table 1.

[Insert Table 1 about Here]

3. Empirical Analysis

The estimates for the national determinants of overseas patenting are shown in Table 2. The coefficients shown in column (1) are estimated based on Eq. (5) and it is specified as the basic model. Because the variables ln*RD*, ln*EXP*, and ln*OFDI* are highly correlated,[4] I therefore also undertake other specifications to lower the collinearity problem. On the other hand, the likelihood ratio (LR) test for model 1 versus mode2 and model 1 versus model 3 are larger than the 5% critical value, indicating EXP and OFDI are both important determinants that can not be excluded in overseas patenting equation.

[Insert Table 2 about Here]

The estimated elasticity of patenting with respect to R&D is near 0.8 that the impact is quite similar as those obtained using firm level data in previous studies.[5] When the R&D expenditure is transformed into R&D intensity (*RDR*, measured as the ratio of R&D expenditure to gross domestic product), it reveals also a strong impact on overseas patenting due to the fact that R&D is the essential input of the patent production function. Moreover, the estimated coefficient of ln*PGDP* is positive and statistically significant at the 1% level in all specifications, revealing that a richer, more productive country potentially has a higher propensity to innovate and patenting abroad.

Does overseas patenting is spurred by exports and OFDI toward the destination? The positive and significant coefficients of ln*EXP* indicate that there is a strong association between overseas patenting and exports as expected, representing that a country has a more aggressive patenting behavior to protect its products as it increases trade flows toward the U.S. This finding is consistent with Dosi et al's (1990) argument that patent flows are correlated to trade.

The estimates in model 1 shows that the coefficient of ln*OFDI* is positive but not significant at a traditional statistical level, lending no support of our viewpoint that OFDI should associate with an aggressive patenting in the guest country. While, when remedial measures, dropping one variable or variable transformation, are employed to reduce collinearity problem, the estimates in second and fourth columns show that both the coefficient of ln*OFDI* reveals a significantly positive impact on overseas patenting, supporting my argument that a multinational enterprise

[4] The pairwise correlation among lnRD, lnEX, and lnFDI are 0.711, 0.826, and 0.756, respectively.

[5] See Crepon and Duguet (1997) for a review of firm-level evidence.

might file its patents both domestic and abroad.

Taken together, the series of estimates on ln*EXP* and ln*OFDI* suggest that the behavior of overseas patenting is essentially trade-related, while the influence of exports seems to be stronger than that for OFDI. Lastly, the sign of the coefficients of distance and its quadratic term are as expected, indicating that international technology diffusion between countries rises at a decreasing rate as the distance between them falls, while this effect seems to be less supported.

4. Economic Development and Overseas Patenting

As is well known, IPRs laws and the enforcement of existing laws differ widely across countries due to national differences in economic development and trade policy. It implies that there might be substantial differences on the determinants of overseas patenting between developed and developing countries. To further examine whether the level of economic development did affect the determinants of overseas patenting, we classify the sample countries into developed countries and developing countries by the level of economic development and then implement similar econometric technique on obtaining the estimates in Table 2. The results are shown in Table 3.[6]

[Insert Table 3 about Here]

The results in Table 3 suggest overall that the determinants of overseas patenting are quite similar that national invention potentials, measured by R&D ratio and per capita GDP, have positive and significant impacts on the number of patents granted in U.S. Moreover, the geographical distance plays a less role for international knowledge spillover on innovation at the country level. One important and interesting finding is that the international economic influences show different levels of impacts on patenting between richer and poorer countries. The coefficients of ln*EXP* and ln*OFDI* are still significant positive in estimates for developed countries, indicating that international economic influences are indeed important factors of overseas patenting, as the arguments in previous conceptual framework. While the influences of trade-related variables are quite different for developing countries that only the impact of outward direct investment is significant. Exports seem to have a less influence on patenting at destination country after controlling other variables.

Why the role of exports on overseas patenting differs between developed and developing countries and its effect is insignificant for developing countries? My interpretation is that the products exported from poorer countries to the

[6] The classification is based on the World Bank categorization of income (in U.S. dollar) per capita as follows: the countries with a high income (above $8356) are classified as developed countries, and others are developing countries.

U.S. are more labor-intensive and the technological level embodied in the products is also low, e.g. wearing apparels and plastic products. Therefore, the potential threat of imitation and competition are quite limited, and then, it is not necessary and less possible for them to apply for patents in the U.S. From the viewpoint of global market structure, the products exported from developed countries to the U.S. are competitive for local producers, while those form developing countries are complementary. As for the effect of OFDI, the possible motivations for developing countries to proceed with OFDI toward developed countries, such as the U.S., might aim to learn advanced management knowledge and acquire advanced technologies. [7] These multinational enterprises would emphasize more on innovative activities and more aggressive on applying patents for their new products or technology processes.

5. Concluding Remarks

The international patenting activity was emerging popular and important over the past decades, while it remains little systematic evidence on the determinants of overseas patenting, especially the international economic influences.

This paper provides a simple theoretical framework of overseas patenting that encompassing the international economic influences. Applying a cross-national data to fit our model, the empirical results show that the behaviors of overseas patenting are related to R&D and the level of economic development. Even more important, we find that overseas patenting is indeed trade-related that it is spurred by the amounts of exports and OFDI toward the target country, supporting our theoretical argument on the effects of international economic influences.

Moreover, we also find the possible differences on patenting between developed and developing countries. Both exports and OFDI has a significant and positive impact on overseas patenting for developed countries, while only the later performs a significant impact for developing countries. The finding lend an important implication for the international debates on the divergence for effects of strengthening IPR and it also sheds some light on the theoretical literature on IPRs and trade.

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Table 1 Variable Definitions and Data Sources

Variables	Definition and Data Source
PAT (1309.88 4591.03)	Number of US patents granted to country *i*. (Data source: US Patent Office)
RD (3380.94 6672.47)	Research and Development Expenditure of country *i*. (US$ million. Data source: Institute for Statistics, UNESCO)
PGDP (11708.82 8463.11)	Per capita real gross domestic product of importing country *i*, using 1996 as the base year. (US$ dollar, Data source: Penn World Table)
EXP (17917.64 40796.41)	The value of export from country *i* to the U.S. (US$ million, Data source: Bureau of Census, U.S.)
OFDI (3697.64 10443.50)	The value of foreign direct investment from country *i* to the U.S. (US$ thousand, Data source: Bureau of Economic Analysis, U.S. Department of Commerce)
DIS (7880.98 3505.53)	Geographic distance between country *i* and the U.S. (Km, Data source: http://www.cepii.fr)

Note: Figures in parentheses are means and standard errors, respectively.

Table 2 The Determinants of Overseas Patenting

Variable Name	(1)	(2)	(3)	(4)
Constant	-6.171	9.261	-5.426	-14.045
	(11.048)	(10.263)	(10.028)	(15.028)
ln*RD*	0.778***	0.881***	0.805***	
	(0.082)	(0.076)	(0.078)	
RDR				0.804***
				(0.208)
ln*PGDP*	0.951***	0.767***	0.891***	1.289***
	(0.222)	(0.223)	(0.203)	(0.268)
ln*EXP*	0.228***		0.219***	0.480***
	(0.083)		(0.070)	(0.116)
ln*OFDI*	0.035	0.110**		0.182***
	(0.059)	(0.055)		(0.073)
ln*DIS*	-1.811	-4.567**	-1.822	-0.772
	(2.378)	(2.325)	(2.217)	(3.287)
$(\ln DIS)^2$	0.113	0.279**	0.114	0.053
	(0.142)	(0.139)	(0.132)	(0.198)
α	0.337***	0.422***	0.337***	0.694***
	(0.083)	(0.097)	(0.079)	(0.181)
Log-likelihood	-267.485	-271.343	-279.895	-287.560

Notes: a. Figures in parentheses are heteroskedastic-consistent standard deviations.

b. ***, **, and * indicate significance at the 1%, 5%, and 10% statistical level, respectively.

Table 3 Differences in the Determinants of Patenting

Variable Name	Developed Countries		Developing Countries	
	(5)	(6)	(7)	(8)
Constant	-25.970***	-47.107***	-18.333**	61.586
	(5.693)	(15.115)	(8.850)	(75.639)
ln*RD*				
RDR	0.484***	0.423***	2.377***	2.207***
	(0.172)	(0.169)	(0.732)	(0.702)
ln*PGDP*	1.531***	1.761***	1.424*	1.374**
	(0.518)	(0.561)	(0.747)	(0.685)
ln*EXP*	0.798***	0.863***	0.072	0.091
	(0.109)	(0.115)	(0.157)	(0.174)
ln*OFDI*	0.147**	0.127*	0.359*	0.311*
	(0.068)	(0.074)	(0.190)	(0.187)
ln*DIS*	0.286	4.761	0.582	-18.033
	(0.268)	(0.297)	(0.540)	(17.703)
$(\ln DIS)^2$		-0.272		1.069
		(0.181)		(1.019)
α	0.515***	0.487***	0.671*	0.546*
	(0.128)	(0.121)	(0.362)	(0.325)
Number of obs.	33	33	26	26
Log-likelihood	-224.857	-223.808	-52.858	-52.351

Notes: a. Figures in parentheses are heteroskedastic-consistent standard deviations.

b. ***, **, and * indicate significance at the 1%, 5%, and 10% statistical level, respectively.