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Will Domestic Imitative Threats Influence High-Tech Imports? Evidence from Taiwan

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In contrast to existing empirical studies focusing on the relationship of foreign patent rights protection and exports, this paper investigates how a country's high-tech importation is influenced by domestic imitative threats. Using a panel data of four high-tech industries in 1989–2003 and the augmented gravity model, we conclude that reducing imitative threat increased Taiwan's importation of high-tech products.

Keywords: gravity model, high-tech industry, intellectual property rights, patent rights, trade

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1 Introduction

The intellectual property rights (IPRs) system has long been recognized as an effective way to protect the value of business enterprises (Lerner, 1994), preserve R&D incentives (Aoki and Prusa, 1993), and promote the economic growth and welfare of a country (Taylor, 1993 and 1994). Owing to the Uruguay Round of Trade Negotiations in 1995, the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) turned out to be a key obligation for members of the World Trade Organization. Strengthening IPRs become the focus in trade policy. In the past 20 years, the pros and cons of strengthening IPRs in developing countries has been debated in trade policy.[1] The supporters of reducing IPRs claim that additional restrictions on IPRs would adversely affect the learning-by-imitating strategies of firms, reduce legal trade in imitative products, and lower the welfare of consumers. By contrast, enthusiasts of increasing IPRs assert that reducing IPRs decreases firms' incentives for innovations and disrupts trading patterns. Although protecting patent rights (PRs) can prevent the imitation of products of a manufacturing firm by its competitors, thus securing its economic well-being, the decision made by an exporting firm in a country where its products are shipped to will certainly be distorted when national differences occur when PRs are protected.

Despite the importance of protecting PRs in trade, studies on this issue from the perspective of developing countries (low- or middle-income countries, e.g. China or Taiwan) are limited. Previous work emphasized the effects of protecting PRs on the exportation of developed countries (high-income countries, e.g., U.S. and Canada) and provided ambiguous results at the aggregate or industry level. This paper, by contrast, focuses on Taiwan, which transitioned from a middle-income country to a high-income country in the 1990s, as a case study to analyze the effects of PRs protection on patent-sensitive and high-tech imports. Taiwan is a suitable case to study because it is a typical trade-oriented and middle-income economy (the South) in the 1990s, which varies from high-income and developed countries (the North) investigated in previous studies. We hope that our case study on the PRs–imports

[1] See Maskus (2004), Diwan and Rodrik, (1991), Helpman (1993), Yang and Maskus (2001), Lai and Qiu (2003) for in-depth discussions.

nexus can help to fill the gap in the existing literature. In addition, our study focuses on the imports of four high-tech products (optical, semiconductor, communication, and information) only, which differs from existing studies, because trading high-tech products (instead of low-tech products) has long been recognized as an important channel of international knowledge spillovers.[2] When a country seeks to benefit from such spillovers, which increase the productivity of a country and consequently promote its economic growth, determining how to increase its high-tech imports from foreign states becomes a critical subject. Taiwan's PRs protection was lax in the mid-1980s. Thus, firms in developed countries with advanced technologies were reluctant to export their patent-sensitive and high-tech products to Taiwan because of the fear of potential imitative threats. However, with the progressively improved PRs protection in Taiwan, these imitative threats considerably lessened in recent years. Thus, examining the evidence to determine whether weaker domestic imitative threats in Taiwan truly affect its high-tech importation from foreign in the past two decades is an interesting endeavor.

In summary, our study differs from previous works of the PRs–trade nexus in some distinct ways. First, this work explores the issue from the perspective of the importing country in contrast to that of the exporting country, as carried out by previous studies. Although previous studies (such as Liu and Lin, 2005) focus on the effects of different IPR regimes in various destination countries on the exports of a single exporting country (Taiwan), this study provides an assessment of the possible effect of the IPR regime in a single destination country (Taiwan) on the exports of various exporting countries. Our study contributes to the literature by linking the international knowledge diffusion literature and the PRs–trade literature from the perspective of the importing country, whereas the previous studies mainly focus on the effect of the IPR regime on export-oriented growth from the viewpoint of the exporting country. Second, Plasmans and Tan (2004) were unable to resolve the endogeneity problem between trade and the explanatory variables. Thus, we consider the potential endogeneity between high-tech imports and the IPR regime and utilize the recently developed system GMM methodology in our study. Previous

[2]There are two main reasons why four high-tech industries were selected in our study. First, the trade volumes of these industries are more likely to be affected by IPRs than other industries because these industries are patent-sensitive. Second, these industries are key industries that directly contributed to the economic development of Taiwan during the 1990s.

studies only employ cross-sectional, pooled, or traditional panel data analyses (ordinary least squares with fixed or random effect). Thus, their estimations seem to be biased and less reliable than that of the System GMM method when an endogenous problem is detected. Third, we apply the concept of *PI* ratio, as suggested by Plasmans and Tan (2004), to measure the domestic imitative threat at the industry level. Using this new ratio will help us more precisely identify the true degrees of imitative threat at the industry-level rather than other widely used PRs indices, which are usually measured at the country-level. Hence, we believe our study will contribute to the empirical literature of the PRs–trade nexus.

The remainder of the paper is organized as follows: Section 2 reviews previous theoretical and empirical studies on the PRs–trade issue. Section 3 explains the empirical strategy, data, and hypotheses of our study. Section 4 discusses the empirical results and its policy implications. The paper is concluded in Section 5.

2 Literature Review

Debates on the PRs–trade nexus have occurred for a long time. Strengthening PRs can have two offsetting effects on trade from the perspective of an exporting country. On the one hand, firms are encouraged to export their products to a country with strong PRs protection because the risk of their products being imitated by competitors is considerably reduced. Thus, stronger PRs protection is expected to increase exports (the so-called "market expansion" effect). On the other hand, stronger PRs protection reduces the imitative threat and increases the market power of the exporting firm. Thus, the exporting firm may behave like a monopolist by reducing sales. With this perspective, stronger PRs protection is expected to reduce exports (the so-called "market power" effect). Similarly, stronger protection of PRs or weaker domestic imitative threat may result in two countervailing effects from the viewpoint of an importing country. First, stronger PRs protection (weaker domestic imitative threat) not only increases the cost of obtaining advanced technology but also restricts the ability of "inventing-around-patent", both resulting in the reduction of imports of developing countries from developed countries. Second, stronger protection of PRs would encourage the importation of a wider range of goods to meet domestic needs because it motivates innovators worldwide to modify their products based on the consumer preferences of the importing country, which are often different from those of the exporting country. Thus, the effect of weaker domestic imitative threat on imports is theoretically disputed (Plasmans and Tan, 2004).

The strategy of export-oriented growth is widely adopted by many countries. Thus, enhancing their exports to foreign countries with varying degrees of PRs protection is critical. Empirical studies on the relationship of foreign patent rights (FPRs) and exports began in the mid-1990s. Empirical studies on the FPRs–export relationship began in the mid-1990s. Ferrantino (1993) first examined export patterns in relation to national membership in the IPRs treaties using aggregate U.S. data and determined a weak link between the two variables. Maskus and Penubarti (1995) used an augmented version of the Helpman-Krugman model of monopolistic competition to estimate the effects of patent protection on international trade flows. The study explored the export data of the U.S. in 1984 to demonstrate the market expansion effect, which results in a positive relationship between FPRs and exports. After Maskus and Penubarti's (1995) pioneering work, several papers addressed this issue. Table 1 provides a comparison of the model setups and data sources of the existing literature.

Smith (1999) first classified the importing countries into four different categories according to the strengths of their PRs and imitative abilities. The study empirically determined that U.S. exportation increased with the improvement of FPRs when the country experiences a strong threat of imitation, i.e., the importing country has weak PRs and strong imitative ability. Meanwhile, U.S. exportation decreases with the improvement of FPRs when the country experiences a weak threat of imitation, i.e., the importing country has weak PRs and strong imitative ability. Smith (2001, 2002) assumed that the effect of market expansion (market power) will occur only when the importing country exhibits strong (weak) imitative abilities. However, the drawback of this assumption is that it disregards the fact that strong FPRs may also provide exporters with monopoly power. When an importing country exhibits both strong imitative ability and FPRs, the exporters experience the effects of market power and market expansion at the same time. Thus, the change on exports is, in fact, ambiguous. In addition, Rafiquzzaman (2002) studied the exports of 10 provinces in Canada to 76 countries in 1990 as a sample to analyze the relationship between FPRs and exports. The findings show that the exports increase with the improvement of FPRs regardless of the degree of development of the importing country.

Liu and Lin (2005) analyzed consecutively pooled data from 1989 to 2000 to investigate the relationship between FPRs and the exports of three high-tech industries at Taiwan. The empirical results indicate that the effects of both market expansion and market power effects exist in the case of Taiwan. In addition, a new hypothesis (Hypothesis 3) was proposed, which stated that the importing country may exhibit a stronger R&D ability than does the exporting country. If an importing country has a stronger R&D ability than does Taiwan, the improvement of FPRs increases Taiwan’s exports. The improvement of FPRs in an importing country increases Taiwan’s exports via the market expansion effect when an importing country has a lower R&D ability than Taiwan and the importing country exhibits a strong threat of imitation. By contrast, the improvement of FPRs in an importing country decreases Taiwan’s exports through the market power effect when the importing country exhibits a weak threat of imitation.

Plasmans and Tan (2004) estimated and compared the data of China’s bilateral trade with those of the U.S. and Japan using a three-country multiple-good trade model by measuring trade distortions related to patenting activity on the industry level. By employing the number of patent applications as an admittedly primitive proxy to the strength of IPRs protection and the ability of imitation in China, the study determined that strong protection of domestic patent rights (DPRs) enhances foreign exportation to China in high-tech and patent-sensitive industries, whereas more stringent DPRs protection initiatives adversely affect low-tech and trademark-sensitive industries when China exhibits a strong ability of imitation.

Fink and Promo Braga (2005) found a positive relationship between IPRs and international trade flows for total non-fuel trade for 89 countries in 1989. This relationship was weak between IPRs and high-tech trade. The authors argued that the market expansion effect may encourage firms to serve foreign markets though foreign direct investment (FDI) rather than by exportation. Therefore, firms in developed countries may respond to the improvement in the IPR regime in the destination country by increasing their level of FDI or licensing instead of increasing exports.

Yang and Huang (2009) used the panel data for Taiwan's exports to 51 countries in 1997–2003 and employed a longitudinal IPR index surveyed by the World Economic Forum. The authors determined that the market expansion effect prevailed over the market power effect on Taiwan's exports to developed and developing countries. Particularly, this effect was stronger for high-tech exports than that for non-high-tech exports.

By employing threshold regression under the gravity model, Falvey *et al*. (2009) investigated how IPRs affect the trade flows between 5 advanced countries and 69 developed and developing countries in the manufacturing sector in 1970–1999. The study confirmed the importance of imitative ability of importers and found some evidence on the role of market size in this relationship.

Delgado *et al*. (2013) used the difference-in-differences approach to examine the effects of TRIPs on the trade flows of knowledge-intensive goods among 158 countries in 1993–2009. The study concluded that the increase in imports by developing countries was driven by the exchange with high-income countries, which was concentrated in the information and communications technology sector. These findings suggest that the effect of TRIPS in promoting knowledge diffusion from high-income countries to developing countries varied by sector.

In a more recent paper, Boring (2015) showed that implementing TRIPs increased the exportation of pharmaceuticals of the U.S. to 108 developing countries in 1995–2010 under the gravity model. However, the effect of patent protection depends on the life expectancy of people in importing countries. The author concluded that U.S. exportation increased to countries where the demand for pharmaceutical products is similar to that in developed countries and where people live longer.

Based on the review of empirical research, we can draw the following conclusions: First, most studies noted in Table 1 estimated the PRs–trade relationship using the Gravity model, while Maskus and Penubarti (1995) and Plasmans and Tan (2004) employed the Helpman-Krugman model. Second, most studies conducted cross-sectional analysis, whereas Smith (2002) and Liu and Lin (2005) conducted pooled data analyses. Recent studies extended the research scope to the panel data. Third, the effects of FPRs on exports are ambiguous when the importing countries are classified based on strong/weak imitative abilities. A better classification involves categorizing importing countries based on their threats of imitation. Thus, we should examine the effects of domestic imitative threats on imports, instead of domestic imitative abilities. Finally, the PRs index proposed by Plasmans and Tan (2004) seems to be a more reasonable index than are widely used and country-level indices, such as the Rapp-Rozex Index or the Ginarte-Park Index, when the true degree of imitative threat is measured at the industry level.

Table 1: Comparison of Empirical Studies on PRs Protection and Trade

Authors	Sample period	Number of importing countries	Model	Exporting countries	IPRs index	Industries studied
Ferrantino (1993)	1982	77	Gravity model	U.S.	1. Number of conventions involved 2. Duration of patent protection	total exports
Maskus and Penubarti (1995)	1984	77	Helpman-Krugman model	U.S.	Rapp-Rozex Index	28 ISIC 3-digit industries
Smith (1999)	1992	95	Gravity model	U.S.	Rapp-Rozex Index	19 SIC 2–digit industries
Smith (2001)	1989	50	Gravity model	U.S.	Rapp-Rozex Index	manufacturing sector
Smith (2002)	1972, 1977, 1982, 1987, 1992	105	Gravity model	U.S.	Ginarte-Park Index	3 bio-tech industries
Rafiquzzaman (2002)	1990	76	Gravity model	Canada	Rapp-Rozex Index Ginarte-Park Index	22 SIC 2-digit industries
Plasmans and Tan (2004)	1991-2001	1 (China)	Helpman-Krugman model	U.S. and Japan	*PI* ratio as a proxy of imitative threat	22 ISIC 2-digit industries
Liu and Lin (2005)	1989-2000	54	Gravity model	Taiwan	Ginarte-Park Index	3 high-tech industries

Table 1: Comparison of Empirical Studies on PRs Protection and Trade (Continued)

Authors	Sample period	Number of importing countries	Model	Exporting countries	IPRs index	Industries studied
Fink and Primo Braga (2005)	1989	89	Gravity model	89 countries	Ginarte-Park Index	non-fuel and high-tech
Yang and Huang (2009)	1997-2003	51	Gravity model	Taiwan	World Economic Forum IPR index	high-tech and non-high-tech
Falvey *et al*. (2009)	1970-1999	69	Gravity model	5 advanced counties	Ginarte-Park Index	manufacturing sector
Delgado *et al*. (2013)	1993-2009	158	Differences-in-differe nces	158 countries	TRIPs dummy	manufacturing sector
Boring (2015)	1995-2010	108	Gravity model	U.S.	TRIPs dummy	pharmaceutical
This study	1989-2003	1 (Taiwan)	Gravity model	9 advanced countries	*PI* ratio as a proxy of imitative threat	4 high-tech industries

3 Model Setup and Data Sources

3.1 Augmented Gravity Model

The Gravity model is the most popular model in studying how a trade policy affects the volume of trade. The basic principle of the model is that the geographic distance between two trading countries and the GDP of each country may influence trade volume. Bergstrand (1985) first constructed a general equilibrium model based on the principles of utilization maximization and profit maximization, and some basic assumptions. The following are the assumptions of the study: the utility and production functions are the same across countries, each country has a monopolistic firm in its exporting industry, and both countries are small open economies, i.e., they cannot influence the world price. However, the above assumptions are exceedingly strict to meet the requirements of the real world. Thus, Bergstrand (1989) modified these assumptions by considering different utility functions across countries as long as the consumers in the same country share the same utility function and by changing the market structure of the exporting industry from monopoly to monopolistic competition. Detailed discussions of the Gravity model can be found in Anderson (1979) and Deardorff (1995).

In this paper, we utilized the commodity version of the Gravity model, which is widely applied in industrial analyses of bilateral trade to four high-tech industries:

$$m_{ijk} = \alpha_{0i} (Q_j / N_j)^{\alpha_{1i}} (POP_j)^{\alpha_{2i}} (Q_k / N_k)^{\alpha_{3i}} (POP_k)^{\alpha_{4i}} (D_{jk})^{\alpha_{5i}} (A_{ijk})^{\alpha_{6i}} \varepsilon_{ijk} , \qquad (1)$$

where m_{ijk} represents the bilateral imports of country k (Taiwan) from country j in industry i; Q_j / N_j and Q_k / N_k denote the per capita income of countries j and k; POP_j and POP_k are the populations of countries j and k; D_{jk} is the geographic distance between countries j and k; A_{ijk} represents other possible factors that may influence the bilateral imports. The Gravity model predicts that the parameters on income per capita and population are positive and the parameter on distance is negative if trade costs increase with distance between trading countries.

In this paper, we focus on the effect of PRs protection on trade. Thus, we employ the PRs protection in industry i of country k, PI_{ijk} as a candidate of A_{ijk}. We expect that stronger PRs protection should reduce domestic imitative threat and increases high-tech importation. In addition, we extend the Gravity model by considering other possible factors mentioned in Plasmans and Tan (2004), such as industrial production in the exporting country j, MO_j, domestic demand in terms of retail sales in the importing country k, RS_k, and the ratio of exports of country j to imports of country k, IE_{jk}.[3] We assume that the volume of Taiwan's imports from country j is likely higher when the scale of industrial production in country j is larger (i.e., the manufacturing sector in country j is more mature and has more surplus to export), the retail sales in Taiwan is higher (i.e., the

[3]Plasmans and Tan (2004) derived an empirical version of the Helpman-Krugman model, which includes MO_j, RS_k, IE_{jk}, and PI_{ijk}. To increase the prediction power of the Gravity model, we included the four variables in the original Gravity model to generate an augmented Gravity model for our empirical study. Please refer to Plasmans and Tan (2004) for a more detailed discussion on the derivation of the four variables.

potential demand from Taiwan for imports is stronger), or the ratio of exports of country j to the imports of Taiwan is higher (i.e., Taiwan imports more from the country with a larger volume of exports). As a result of taking the logarithm, the augmented Gravity model can be further expressed as:

$$\begin{aligned}\ln m_{ijk} &= \ln \alpha_{0i} + \alpha_{1i} \ln(Q_j / N_j) + \alpha_{2i} \ln POP_j + \alpha_{3i} \ln(Q_k / N_k) \\ &+\alpha_{4i} \ln POP_k + \alpha_{5i} \ln D_{jk} + \alpha_{6i} \ln PI_{ijk} + \alpha_{7i} \ln MO_j \\ &+\alpha_{8i} \ln RS_k + \alpha_{9i} \ln IE_{jk} + \varepsilon_{ijk}.\end{aligned} \tag{2}$$

We selected Taiwan as the only importing country in this study. Thus, Q_k / N_k and POP_k can be disregarded because these variables are the similar regardless of the exporting country we deal with. Equation (2) can be rewritten as:

$$\begin{aligned}\ln m_{ijk} &= \ln \alpha_{0i} + \alpha_{1i} \ln(Q_j / N_j) + \alpha_{2i} \ln POP_j + \alpha_{3i} \ln D_{jk} + \alpha_{4i} \ln PI_{ijk} \\ &+\alpha_{5i} \ln MO_j + \alpha_{6i} \ln RS_k + \alpha_{7i} \ln IE_{jk} + \varepsilon_{ijk},\end{aligned} \tag{3}$$

and its panel data form with the time-invariant distance variable D_{jk} can be further written as:

$$\begin{aligned}\ln m_{ijkt} &= \ln \alpha_{0i} + \alpha_{1i} \ln(Q_{jt} / N_{jt}) + \alpha_{2i} \ln POP_{jt} + \alpha_{3i} \ln D_{jk} + \alpha_{4i} \ln PI_{ijkt} \\ &+\alpha_{5i} \ln MO_{jt} + \alpha_{6i} \ln RS_{kt} + \alpha_{7i} \ln IE_{jkt} + \varepsilon_{ijkt}.\end{aligned} \tag{4}$$

3.2 Data Source

We collected the data of Taiwan's imports from country j, m_{ijkt}, in 1989–2003 in four patent–sensitive and high-tech industries, namely, optical, semiconductor, information, and communication equipment. Nine exporting counties are selected because of their substantial share of high-tech exports to Taiwan and their large amounts of high-tech patent applications in Taiwan. The nine countries are the U.S., the U.K., France, Germany, the Netherlands, Sweden, Switzerland, Japan, and Korea. However, Sweden did not have any patent applications in optical and semiconductor industries in the earlier years. Thus, we excluded the data from this country and only studied the eight other countries in the two industries. The data on the imports from country j were obtained from the Trade Database of Taiwan Customs and the Trade Statistics of Taiwan Bureau of International Trade. Both are the most reliable sources of Taiwanese trade data.

The national-level export data of the exporting countries, which are used to construct IE_{ijkt}, were collected from World Bank's World Development Indicator (WDI) database. Population, POP_{jt}, and real GDP per capita, Q_{jt} / N_{jt}, were also obtained from the WDI database. Industrial production for the exporting countries, MO_{jt}, can be collected from the International Financial Statistics database of the International Monetary Fund (IMF). Taiwan's retail sales, RS_{kt}, were obtained from National Statistics of Taiwan Directorate-General of Budget, Accounting, and Statistics. Finally, the time-invariant geographic distance between Taiwan and the exporting country, D_{jk}, was obtained from the U.S. Geological Survey.

Although both the Rapp-Rozex index and the Ginarte-Park index are the most often cited indices in measuring the PRs protection of a country, these indices has two drawbacks. First, these indices are constructed either for a particular point of time (the Rapp-Rozex index) or for every five years (the Ginarte-Park index). Hence, these indices can only be used for cross-sectional (Ferrantino, 1993; Maskus and Penubarti, 1995; Smith, 1999; Smith, 2001; Rafiguzzaman, 2002) or pooled data analysis (Smith, 2002; Liu and Lin, 2005) and not panel data analysis. Second, these indices only measure PRs protection at the national level and not at the industry level. PRs protection may vary across industries. A new industry-level PRs index was proposed by Plasmans and Tan (2004) to address the two drawbacks. The authors defined PRs index, PI_{ijkt}, as:

$$PI_{ijkt} = \frac{FP_{ijt}}{DP_{ikt}}, \tag{5}$$

where PI_{ijkt} is the country k's industry-level PRs index for industry i in period t, FP_{ijt} is the country j's patent applications in country k for industry i in period t, and DP_{ikt} is the country k's domestic patent applications for industry i in period t.

Table 2 presents the original classifications of imitative threats by Smith (1999): a country with strong domestic imitative threat is defined as an importing country with both strong imitative ability and weak PRs protection; a country with weak domestic imitative threat is defined as the importing country with both weak imitative ability and strong PRs protection. On the one hand, when the importing country exhibits strong domestic imitative threat, exports to this country would decline. On the other hand, when the importing country shows weak domestic imitative threat, exports to this country will increase. As opposed to Smith (1999), Plasmans and Tan (2004) applied the PI_{ijkt} concept to measure PRs protection at the industry level. The authors suggested that foreign patent applications, FP_{ijt}, will increase if the importing country, country k, improves its PRs protection. Hence, the authors classified a higher FP_{ijt} value as an indicator of stronger PRs protection in country k and a lower FP_{ijt} value as an indicator of weaker PRs protection. Meanwhile, a higher the number of domestic patent applications, DP_{ikt}, for industry i in country k indicates a stronger innovation ability of country k. Consequently, a higher DP_{ikt} value denotes a stronger imitative ability, and a lower DP_{ikt} value illustrates a weaker imitative ability of country k. In this paper, domestic imitative threat is higher when the *PI* value is lower, and we expect it to adversely affect imports. By contrast, a higher *PI* value represents a weaker domestic imitative threat and positively affects imports. Both foreign patent applications, FP_{ijt}, and domestic patent applications, DP_{ikt}, were collected from Taiwan Intellectual Property Office. The corresponding harmonized system code and international patent classification code for each industry are explained in Table 3. The detailed data descriptions and sources are summarized in Table 4. Table 5 provides a summary of the statistical data of these variables for each industry.

Table 2: Definitions of Imitation Threats and Their Effects on Import

Foreign patent applications	Domestic patent applications	
	High (strong imitation ability)	Low (weak imitation ability)
High (strong patent rights protection)	ambiguous (＋/－)	weak threat (＋)
Low (weak patent rights protection)	strong threat (－)	ambiguous (＋/－)

Source: Smith (1999) and Plasmans and Tan (2004).

Table 3: Harmonized System (HS) and International Patent Classification (IPC) Codes for Four Selected High-Tech Industries

Industry	HS code	IPC code
Optical	9001, 9002	G02B
Semiconductor	8541, 8542	H01L
Communication	8517, 8525, 8526	H04B, H04H, H04M, H04N, H04L
Information	8471, 8528	G06F, G11B

Table 4: Variable Explanation and Data Source

Abbreviation	Variable explanation	Period	Source
m_{ijkt}	Country *k*'s imports from country *j* in industry *i*	1989:m1-2006:m2	Taiwan Customs, Trade Database (http://customs.iii.org.tw) and Taiwan Bureau of International Trade, Trade Statistics (http://cus93.trade.gov.tw/fsci/)
MO_{jt}	Industrial production in country *j*	1945-2003	International Monetary Fund International Financial Statistics CD-ROM database
RS_{kt}	Retail sales in country *k*	1981-2005	Taiwan National Statistics (http://www.dgbas.gov.tw)
IE_{ijkt}	Export of country *j* / imports of country *k*	1960-2003	WDI Database and Taiwan National Statistics (http://www.dgbas.gov.tw)
PI_{ijkt}	Patent application ratio of countries *j* to *k* in industry *i* at the importing country	1974:m1-2006:m4	Taiwan Patent Database (http://www.twpat.com)
D_{jk}	Geography distance between countries *j* and *k*		U.S. Geological Survey (ftp://kai.er.usgs.gov/pub/)
Q_{jt} / N_{jt}	Real GDP per capita in country *j*	1960-2003	WDI Database
POP_{jt}	Population of country *j*	1960-2003	WDI Database

Based on the preceding discussions and our empirical framework according to Equation (4), we expect Taiwan to import more high-tech products from a country with a higher industrial production (MO_{jt}), higher ratio of exports to Taiwan's imports (IE_{ijkt}), higher per capita real GDP (Q_{jt} / N_{jt}), larger population (POP_{jt}), or shorter geographic distance from Taiwan (D_{jk}). The high-tech imports will also increase when Taiwan's domestic demand (RS_{kt}) is stronger. After controlling these explanatory variables, we focus on the effect of Taiwan's imitative threat on high-tech imports. We expect that a weaker imitative threat (or a higher *PI* ratio) in

Taiwan should increase high-tech importation in the selected industries.

Table 5: Summary of Statistical Data

	Optical		Semiconductor		Information		Communication	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
m_{ijkt}	2.8×10^7	8.75×10^7	9.28×10^8	1.19×10^9	3.14×10^8	1.37×10^9	1.22×10^8	1.81×10^8
MO_{jt}	89.12	13.50	89.12	13.50	89.28	12.91	89.28	12.91
RS_{kt}	8.2×10^5	1.7×10^5	8.2×10^5	1.7×10^5	8.2×10^5	1.7×10^5	8.2×10^5	1.7×10^5
IE_{ijkt}	3.67	2.45	3.67	2.45	3.35	2.48	3.35	2.48
PI_{ijkt}	0.39	0.59	0.37	0.65	0.13	0.24	0.18	0.33
D_{jk}	4767.13	2128.55	4767.13	2128.55	4815.78	2010.63	4815.78	2010.63
Q_{jt} / N_{jt}	24195.18	8277.75	24195.18	8277.75	25145.46	8260.73	25145.46	8260.73
POP_{jt}	8.26×10^7	7.91×10^7	8.26×10^7	7.91×10^7	7.42×10^7	7.83×10^7	7.42×10^7	7.83×10^7
Observations	120		120		135		135	

4 Empirical Results

4.1 Specification Tests

In this paper, we aim to conduct a panel data analysis for each industry. Thus, we included four different sets of panel data. Before running regression analysis, we first tested the four sets of panel data to determine if the sets are stationary to avoid invalid estimation. Both Levin, Lin, and Chu’s (2002) *t*-statistic and Im, Pesaran and Shin’s (2003) *W*-statistic (not reported) rejected the null hypothesis and concluded that no unit root exists in any set of panel data. We tested the correlation between variables in each set of panel data. We determined a strong correlation (above 0.9) between population in country j (POP_{jt}) and the ratio of exports of country j to the imports of Taiwan (IE_{jkt}) in all sets of panel data. Thus, we employed the two variables individually in our estimation to avoid the potential multicollinearity problem.

4.2 System GMM Estimation

Panel fixed-effect or random-effect models are usually prone to endogeneity problems. Thus, a more reliable estimating technique should be adopted to address this problem.[4] The System GMM approach with appropriate instrumental variables to deal with the endogenous variable provides asymptotically efficient estimators even under a weak assumption of disturbance, and it is robust in the presence of heteroskedasticity across countries. To provide consistent estimates of this kind of model, Arellano and Bond (1991) proposed the "difference GMM" estimator, which considers the first difference of the data and uses the lagged values of the endogenous variables as instruments. However, Arellano and Bover (1995) point out that lagged levels are usually poor instruments for first differences when explanatory variables present a strong autoregressive component (such as income or capital). Thus, Blundell and Bond (1998) suggested a more efficient "System GMM" estimator to solve the poor instrument problem by utilizing additional moment conditions. Although two-step estimation is asymptotically more efficient, the reported two-step standard errors tend to be severely downward biased (Arellano and Bond, 1991; Blundell and Bond, 1998). Thus, we applied finite-sample correction to the two-step covariance matrix derived by Windmeijer (2005). This framework enables us to consider the presence of unobserved country-specific effects that are correlated with the lagged dependent variable and make OLS estimation inconsistent. However, this framework also deals with potential endogeneity problems.

In this paper, the explanatory variable (such as real GDP per capita, industrial production, and the IPR regime) and high-tech imports can affect each other. Thus, an endogenous problem may occur. Plasmans and Tan (2004) were unable to address certain endogenous problems when they measured the effects of PRs protection on trade. The authors determined that China's imports may be proportional to the industrial production of the exporting country. To reduce estimation bias caused by the endogenous problem, we estimated the effect of domestic imitative threats on imports using the System GMM method to allow the serial correlation among variables and release the exogenous assumption on the variables. To establish the

[4]The traditional two-stage least squares method (2SLS) can also solve the endogeneity problem. However, the choice of IVs in 2SLS could be arbitrary, compared with the System GMM approach where STATA automatically searches for the most efficient IVs. Moreover, with additional moment conditions, the System GMM approach is more capable of addressing the poor instrument problem than is 2SLS.

System GMM framework, we need to test for autocorrelation because the framework is assumed to have first-order autocorrelation and no second-order autocorrelation in the errors. The regression analyses only utilized internal instruments for instrumental variables. Specifically, the System GMM estimator employs the first difference of all exogenous variables as standard instruments and the lags of the endogenous variables to generate the GMM-type instruments. Moreover, the lagged differences of the endogenous variables are used as instruments for the level equation. To effectively reduce the number of instruments, we limited the number of lags of the dependent variable used as instruments to one. The number of lags of the endogenous or predetermined variables is restricted to three.

Table 6 summarizes the results of System GMM estimations for each industry. The System GMM estimation passes the Wald test, AR(1), and AR(2) tests. For each industry, we conduct two estimations using $\ln IE_{ijkt}$ and $\ln POP_{jt}$ to avoid the multicollinearity problem. Thus, Columns (a), (c), (e), and (g) employ $\ln IE_{ijkt}$, and the remaining columns use $\ln POP_{jt}$ instead. We determined that only columns (b) and (h) (the optical and the communication equipment industries with $\ln POP_{jt}$) have positive and statistically significant effects of industrial production of the exporting country ($\ln MO_{jt}$) on Taiwan's high-tech imports. Thus, we can only conclude that Taiwan imports more high-tech products from a country with higher industrial production in optical and the communication equipment industries. Plasmans and Tan (2004) also obtained similar results in their case study on China. Conversely, the size of the industrial production of the exporting country does not significantly influence Taiwan's importation of semiconductor and information products.

Columns (a), (c), and (d) (the optical industry with $\ln IE_{ijkt}$ and semiconductor industry with $\ln IE_{ijkt}$ and $\ln POP_{jt}$) demonstrate the positive effect of the domestic demand (retail sales, $\ln RS_{kt}$) on Taiwan's importation of high-tech products. Our previous assumption, which states that Taiwan should import more high-tech products when the domestic demand of Taiwan (retail sales) is stronger, is applicable in the optical and semiconductor industries. By contrast, the effects are positive but insignificant in the information and the communication equipment industries. This result is also consistent with the findings of Plasmans and Tan

(2004).

The assumption that Taiwan should import more high-tech products from the country with a higher ratio of exports to Taiwan's imports ($\ln IE_{jkt}$) is further confirmed at the 1% significance level in all industries, except for the communication equipment industry with a positive but insignificant estimate. The results are consistent with those of Plasmans and Tan (2004). However, we are unable to obtain evidence from our study to support the assumption that Taiwan should import more high-tech products from a country with a higher real GDP per capita, $\ln(Q_{jt} / N_{jt})$. All industries have negative and insignificant estimates, which is different from our assumption and the results of the existing studies. One possible explanation for this unexpected and insignificant parameter indication is that the simultaneous use of industrial production ($\ln MO_{jt}$) in our augmented Gravity model may disregard some of the positive effects on the imports from the estimates of actual GDP per capita.

The assumption, which states that Taiwan should import more high-tech products from the country with a larger population ($\ln POP_{jt}$), is confirmed in three of the four industries. The estimates are positive and significant at the 1% significance level in the semiconductor, information, and communication equipment industries. The only exception is the optical industries with a positive but insignificant estimate. In addition, as expected, the geographic distance between Taiwan and the exporting country ($\ln D_{jk}$) and imports of high-tech products are negatively related. This result implies that, as trade cost increases with distance, the importation of high-tech products decreases as the distance between trading countries increases. The findings of $\ln POP_{jt}$ and $\ln D_{jk}$ are consistent with the expectations of the original Gravity model in previous studies.

Finally, we determine that all industries exhibit a significantly positive effect of weaker domestic imitative threat (i.e., a higher $\ln PI_{ijkt}$ value) on imports of high-tech products, which was expected. The coefficients of $\ln PI_{ijkt}$ also demonstrate that the magnitude of the effect varies across industries: the optical industry benefits the most, whereas the semiconductor industry benefits the least. Thus, we conclude that Taiwan can import more high-tech products from foreign countries when Taiwan's domestic imitative threat is reduced. This empirical finding provides some meaningful policy implications that a country could benefit from the international knowledge spillovers if it successfully reduces the domestic imitative threat, which sequentially results in more high-tech imports.

Table 6: Estimation of System GMM

Dependent Variable $\ln m_{ijkt}$	Optical		Semiconductor		Information		Communication	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
$\ln MO_{jt}$	0.461	0.828 **	-0.588	-0.226	-0.624	-0.130	0.956	1.014 *
	(0.392)	(0.386)	(0.375)	(0.311)	(0.579)	(0.537)	(0.634)	(0.607)
$\ln RS_{kt}$	0.816 **	0.506	1.260 ***	1.114 ***	0.360	0.297	0.267	0.222
	(0.338)	(0.324)	(0.337)	(0.300)	(0.370)	(0.367)	(0.449)	(0.440)
$\ln IE_{jkt}$	0.450 ***		0.511 ***		0.487 ***		0.233	
	(0.149)		(0.147)		(0.174)		(0.155)	
$\ln PI_{ijkt}$	0.105 ***	0.119 ***	0.031***	0.012***	0.048***	0.108***	0.053***	0.056***
	(0.006)	(0.005)	(0.004)	(0.003)	(0.008)	(0.008)	(0.008)	(0.007)
$t \times \ln D_{jk}$	-0.461 ***	-0.235 *	-0.336 ***	-0.281 ***	-0.601***	-0.476 ***	-0.456 **	-0.2807
	(0.142)	(0.126)	(0.126)	(0.103)	(0.216)	(0.182)	(0.190)	(0.186)
$\ln(Q_t / N_{jt})$	-0.022	0.026	-0.179	-0.065	-0.003	-0.022	-0.180	-0.087
	(0.228)	(0.239)	(0.162)	(0.162)	(0.271)	(0.291)	(0.321)	(0.349)
$\ln POP_{jt}$		0.140		0.386 ***		0.358 ***		0.311***
		(0.089)		(0.085)		(0.123)		(0.110)
Sargan test H_0: overidentifying restrictions are valid								
P-value	0.53	0.76	0.37	0.19	0.62	0.70	0.27	0.22

Note：1. The model includes the constant term and the one-period lag of $\ln m_{ijkt}$. Their coefficients are omitted to conserve space. 2. Standard errors are in parentheses. 3. *, ** and *** represents significance level at 10%, 5%, and 1%. 4. The number of observations is 112 for columns (a)–(d) and 126 for columns (e)–(h).

5 Concluding Remarks

By utilizing a panel data of four Taiwanese high-tech industries in 1989–2003 with an augmented Gravity model, we concluded that reducing domestic imitative threat significantly increased Taiwan's importation of high-tech products. If these high-tech imports provide knowledge spillovers across borders as expected, the importing country (Taiwan), which focuses on improving its PRs protection (in other words, reducing its imitative threats), will benefit from the increase in productivity, which will in turn result in higher economic growth.

Our analysis differs from that of previous studies of the PRs–trade nexus in several perspectives. First, our work empirically examines the relationship of imitative threat and importation from the perspective of the importing country instead from that of the exporting country, as conducted in previous studies. Second, this paper applied the System GMM methodology in analyzing the PRs–trade issue to avoid the biased estimation of the effects of IPRs on trade by considering the potential endogenous problem. Thus, the empirical result is believed to be more reliable than the previous work. Third, we utilized the concept of *PI* ratio, which was introduced by Plasmans and Tan (2004), to gauge the domestic imitative threat at the industry level. This new measurement can more precisely identify the true degrees of imitative threat in different industries than can other national-level PRs indices.

The empirical results from our work are limited by certain constraints. The period in our sample covers only 15 years (1989–2003), and the number of studied exporting countries is only nine. To provide more concrete and updated evidence on the relationship of domestic imitative threats and high-tech imports, more exporting countries into the sample should be considered and the period should be extended to more recent years. In addition, if the industry-level data for retail sales, the industrial production of the exporting country, and the ratio of the exports of the exporting country to the imports of Taiwan are available, using these industry-level data may provide some deeper insights from the industrial perspective. Furthermore, in contrast to the study of PRs–trade nexus in the middle-income country (Taiwan), which is examined in this paper, a further investigation on some fast-growing, low-income countries, such as China, India, Brazil, and Russia, will be worthwhile in this research area.

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