Exports and Intellectual Property Rights Policies: Does Product Time-to-Imitation Matter?*

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Abstract

I build a partial equilibrium model to analyse the sensitivity of US exports to changes in intellectual property rights (IPR) in destination countries. In the model, a profit maximising firm in the North with innovative product decides which countries to export. Countries are heterogeneous in their level of IPR protection, imitation risk and per capita income, and products have different product time-to-imitation and lifecycle length. The firm faces a trade-off between market expansion and market power. By exporting to all countries, the firm increases its sales and profit but faces the risk of imitation on its output which robs it of its market power. The model predicts that strengthening IPR laws in countries in the South leads to increased exports from the North especially in sectors with relatively shorter time-to-imitation. By using yearly panel datasets (1989-2006) consisting of US product-destination data, country-level IPR index and cross-sectional product time-to-imitation and lifecycle length data, I find our empirical results are consistent with the model's predictions. These results point to the importance of IPR policies in determining sectoral patterns of trade flows between countries.

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1 Introduction

There is a huge debate on whether developing countries should adopt intellectual property rights[1] (IPR). One side of the debate argues that adoption of IPR will result to a drop in reverse engineering of existing foreign products which may slow down industrialization[2]. In addition, adopting IPR will increase the market power of innovators, resulting to a rise in prices of patented products (Duggan et al., 2016) which reduces welfare[3]. The other side of the debate argues that adopting IPR reforms in developing countries would lead to a rise in exports in high technology sectors (Ivus, 2010, Lin and Lincoln (2017)) and expansion of industrial activities (Branstetter et al. (2011), Bilir (2014a) etc) from developed countries to developing countries. This will improve welfare through productivity growth from imported inputs (Halpern et al. (2015), Goldberg et al. (2010)) and wage increase from imported machinery (Koren and Csillag, 2016). Thus, a tradeoff associated with IPR reforms[4].

IPR reforms would lead to a rise in high tech exports from developed countries because it ameliorates the concern by innovators that knowledge embodied in their products will be copied by imitators in countries with weak IPR[5]. Existing anecdoctal evidence supports this. An example is the case study on microwave ovens which was imitated by Samsung in

[1]In this paper, we restrict our focus on patents and we do not consider other types of intellectual property rights. Whenever we use IPR in this paper, we imply patent and vice-versa.

[2]This argument was used by Japan and Switzerland to refuse IPR recognition until 1976 and 1978 respectively (see Kim, 1997 page 38), and is inline with the World Trade Organization's (WTO) policy which allows least developed countries to copy and produce some patented products https://www.wto.org/english/news_e/news15_e/trip_06nov15_e.htm.

[3]Chaudhuri et al. (2006) investigates the welfare effects of adopting patent protection using data in the pharmaceuticals sector in India. They find that adoption of patent protection led to the withdrawal of domestic pharmaceutical products which is associated with large welfare losses in India.

[4]Grossman and Lai (2004) shows that a country's optimal patent policy depends on two opposing mechanisms. On one hand, the losses resulting for the extra deadweight loss from strengthening IPR granted to domestic firms and the loss in consumer surplus from the expansion of the fraction of imported products from the North which will now be subject to monopoly pricing. On the otherhand, it comes with some benefits which includes the provision of greater incentives to firm for innovation and the flow of innovative products in the country. Helpman (1993) analysed the tradeoffs associated with strengthening in a series of model variations and shows that developing countries do not benefit from strengthening IPR.

[5]Firm's protects potential profits due to their invention through several mechanisms which includes patent (Cohen et al., 2000).

South Korea around the late 1970's[6]. Microwave ovens became very popular and in high demand. Samsung intrigued by this new technology decided to negotiate for licencing to enable them copy and produce the technology. After being turned down from several attempts to licence the technology from Japanese and U.S. producers, Samsung formed a team to developed its microwave oven by reverse engineering existing models. Twenty years later, Samsung became one of the largest exporter of microwaves with a global market shares of 17%. This anecdote is consistent with existing industry-level data for several high technology sectors in South Korea. Figure (1) and (2) shows the dynamics of export and import share in GDP of products in the domestic electrical equipment industry and pharmaceutical goods industry respectively from early 1960s to late 1980's. Two patterns stand out in this figure. First export share in GDP was near zero for most parts of the 1960's. Second, import surge (high demand) occurred first in the late 1960's which was followed by an export surge in early or mid 1970's. However, for products in the agricultural sectors (see figure 4 and 3), import surge is observed, we do not see evidence for export surge, suggesting that imitators target high technology sectors.

In this paper, I provide evidence that US exports sensitivity to IPR in the South is determined by the ease of product imitation[7]. By doing this, I make two contributions to the literature. First, I quantify this effect using industry-level US export-destination data to 117 countries, in 37 sectors during the period 1989-2006. I construct data for product time-to-imitation by exploring the differences between import and export surge for each product in South Korea between 1960s to 1980s - A period well-documented on how South Korea metamorphosed from an imitative economy to an innovative one. Applying the newly constructed dataset with US export-destination and IPR index data, I provide new evidence that US export sensitivity to IPR reforms in the South strongly depends on product time-to-imitation. That is, US exports of products with high time-to-imitation, are less sensitive to IPR reforms compared to products with lower time-to-imitation.

[6]See Kim (1997) pages 136-140 for a detail discussion on this

[7]Which I call product time-to-imitation (PTI). Qian (2008) finds that both foreign and domestic firms makes strategic investments in attributes that are difficult to imitate in reaction to weakened IPR enforcements in China.

Second, I show that this pattern is consistent with a model where an innovator faces a tradeoff on whether to export to a country with imitation risk or whether not to export. This is because exporting to the additional destination with imitation risks increases its profits, but comes at a cost of high rate of product imitation which strips the innovator of his market power. The decision will depend on IPR, product time-to-imitation (PTI), product lifecycle length (PLC) and country's economic size. The model predicts that product time-to-imitation determines the sensitivity of US industry-level exports to IPR improvements in destination countries. That is, products in industries with shorter time-to-imitation are the most sensitive to IPR improvements because innovators are concerned that the technology embedded in their products can be easily imitated, so IPR reforms nudges them to increase their exports to the South. I also show empirically that US export sensitivity to IPR depends on PTI at the extensive margins. This results are important from a policy perspective in developing countries as it helps in understanding the categories of products that are more sensitive to exports from the US if it embarks on IPR reforms.

Bilir (2014a) showed that countries with improvements in their IPR attract more multinational activities, but the sensitivity of this effect depends on the product lifecycle length (PLC). I integrate product lifecycle length into my model to ascertain if the sensitivity of exports to IPR also depends on PLC. While, I find theoretical predictions in this direction, the empirical results are inconclusive - positive and significant in some specifications, and insignificant in others.

I proceed the analysis in section 2, where I propose a partial equilibrium model to illustrate the trade-off faced by exporting firms in choosing whether to export to a country with high imitation risk, and I derive a relationship between industry exports, IPR, PTI and PLC which I take to data. My model is built on two main assumption supported by existing research findings. The first is that - weak patent rights are a barrier to U.S. (northern) exports, but only to countries that poses a strong threat of imitation (Smith, 1999) - A direct implication is that countries with weaker patent laws than the

US can be partitioned based on whether they pose a strong threat of imitation. As such, I assume a world populated by 3 countries, North, South 1 and South 2. Both southern countries have lower patent laws compared to the North , however imitation risk in South 1 country is very low while imitation risk in South 2 is high. The second main assumption is borrowed from Bilir (2014a) which assumed that US industries are different in their level of PLC and PTI , and that products within an industry share the same PTI and PLC. While products have associated PTI and PLC, assuming that products within an industry share similar PTI and PLC was done to circumvent some data shortcomings in the empirical analysis because I observe most of this products at the industry level. Otherwise, the model is consistent with PTI and PLC variability at the product level. I consider a representative firm in the North that has a new innovative product. This patented product has an associated imitation time and a product lifecycle length. Since imitation risk is low in South 1, the firm sells its products in the North and South 1, and decides whether to sell to South 2 because imitation occurs there. If he sells in South 2 and if imitation occurs there, then the firm will compete with South 2 in both southern countries. The firm's decision will be based on comparing the net present discounted value of selling to South 2 and not selling there.

The model predicts that following an improvement in IPR regulation in South 2, there is an increase in exports of products with shorter product time-to-imitation but this happens at a diminishing rate. That is, firms that manufacture products with lower PTI are more sensitive to IPR reforms compared to those with larger PTI. The intuition is that imitation is more likely to occur in the absence of IPR for products with shorter PTI. Therefore, IPR induces these firms with shorter PTI to raise their exports to such destination. The implication as shown in Lemma (1) is that in the absence of IPR reforms, products with higher PTI are exported to South 2 more than the ones with lower PTI. The model also predicts that following an IPR reforms in South 2, there is an increase in exports of products with longer PLC, but this happens at a diminishing rate. That is, firms that manufacture products with lower PLC are insensitive to IPR reforms since imitation is less likely to occur during the product life. However, firms with products having relatively higher PLC are more sensitive, but this sensitivity is decreasing for very high PLC. The intuition is that very high PLC imply higher risk of product imitation during the product's life resulting to reduced sensitivity to IPR reforms. The model also incorporates a profit shifter for firms in any given destination which is assumed to be per capita GDP. We find a positive effect of destination country's per capita GDP on US exports they receive. Firms will likely make more profits in richer countries than poorer ones, increasing its incentive to export to such destinations.

In section (3), I described the data, PTI index construction, cleaning procedures and summary of some basic trends. I also provided additional descriptives in the appendix. The data comes from several publicly available data sources combined together for this analysis. The first dataset is a panel of US yearly 10-digit product-level export data from 1989-2006 assembled by Feenstra (1997). In this data, I observe a highly disaggregated product, its export destination, export sales, quantity and its industry in each time period. The second dataset is a panel of country-level patent protection index developed in Ginarte and Park (1997) and extended in Park (2008). This data assigns a numeric index ranging between 0 and 5 which reflects the level of patent protection across a country in each time period. The third dataset is an index of product time-to-imitation which I constructed using import and export level data for South Korea between 1962-1990. I choose South Korea because it is one of the few economies that experienced rapid transition from being an imitative economy to a highly innovative industrialized economy in 1980s and because of data availability[8]. I refer the reader to the details of its construction in section (3.4). The fourth is a cross-sectional data of product life-cycle lengths by industry for 37 high technology industries developed in Bilir (2014b). The final dataset is the macro data from Penn World table 8.1 (Feenstra et al., 2015) consisting

[8]The four Asian tigers (Hong Kong, Singapore, South Korea and Taiwan) experience large and very rapid industrialization with high rate of growth between early 1960s to late 1990s. While Hong Kong and Singapore success was centered around financial services, South Korea and Taiwan'a became global leaders in manufacturing. South Korea was choosen over Taiwan for our PTI index because of data availability.

of information on real GDP and population. I merge the 4 datasets and aggregate our observations to the 3-digit Standard Industrial Classification (SIC-3). I refer the reader to the relevant subsections for a detailed description of each of the datasets. I also provide some additional descriptives of the dataset.

In section 4, I present our econometric framework, discuss the identification strategy and quantify the prediction of the model using datasets already discussed. Since our theoretical results suggest that the sensitivity of US exports to patent reforms is decreasing in PTI but at a diminishing rate and increasing in PLC at a diminishing rate, our main specification is a country-level regression of US industry exports flows on an interaction term between (1) IPR index and PTI, (2) IPR index and PLC whilst controlling for unobserved country-time fixed effect and sector-time fixed effects. We also estimate a specification where we test for the diminishing effect by interacting each quadratic terms of PTI and PLC by IPR, and a flexible regression of the form in equation (14).

In section 5, I present results from the empirical framework, and additional results from a number of alternative econometric specifications. My analysis reveals that products with shorter PTI responds more to strengthened IPR. That is, countries that improves IPR receive more US exports in sectors with relatively shorter PTI compare to sectors with longer PTI. This finding shows that sector-level effects reflect different modes of firm's response to increasing IPR reforms. From a Southern country's welfare perspective, it shows that IPR laws affect the distribution of innovative goods available to consumers and firms which will have effects on consumption and productivity. I also find that products with longer PLC responds more to IPR compared to products with shorter PLC, however, I find insignificant effects for some specifications, although with the expected sign.

Duggan et al. (2016) finds that pharmaceutical firms increased the prices of their patented products by about 3-6 percent after India passed the TRIPs agreement to law. This implies that our results could be driven by prices since improved patent laws increase the market power of firms[9]. To check for this possibility, I repeat the empirical analysis using data on quantity as the dependent variable instead of revenue and the results remain significantly unchanged as reported in Table(5). I test for the extensive margin effects by computing the number of 10-digits products within each 3-digit SIC sector exported to a destination in each time period as the dependent variable. Specifically, I study whether more products within an industry is exported to a destination given an improvement in patent reforms, and how the PTI influences this relationship. Our estimates reported in Table 7 are similar to our main specification in Table (3) but the coefficients of IPR interacted with PTI is smaller. These findings suggest that the estimated effect of patents protection on US exports of innovative products is not driven by prices.

I conclude the analysis in section 6 and present additional data information, and robustness results in the appendix.

Our paper is related to a myriad of theoretical and empirical literature studying the effect of patent reforms in southern countries on inventing activities and export patterns from countries in the North. On the theoretical side, Chin and Grossman (1988) and Deardorff (1992) find that extending IPR from the North which innovates to the south which does not innovate encourages Northern firms to develop new technologies[10]. Chin and Grossman (1988) shows that stricter patent laws reduces welfare in the south, except if countries in the south comprises a large share of market for goods whose technology is subject to improvement. Our paper is also related to Maskus and Penubarti (1997) which finds that if stronger patent rights prevents product imitation, then production of imitated products in the South drops and demand for original Northern products rises. Results from these papers imply an expected increase in Northern firms exports to the South. I contribute to these literature by showing that the product time-to-imitation can explain the sensitivity of Northern firm's exports to patent reforms.

[9]Higher prices may reflect higher quality of new products (Bils, 2009) exported due to IPR reforms and not necessarily higher prices due to market power.

[10]This idea is consistent with Aghion and Howitt (1992) that shows that economic growth is the result of technological progress, from research firms which innovates. The paper shows that research firms innovates more because of monopoly rents from patented innovation

Our model builds mainly on Grossman and Helpman (1991) and Bilir (2014a). Similar to both papers, I assumed that northern firms enjoy monopoly profits on their innovative products until the products are imitated in the South. While Grossman and Helpman (1991) assumes that innovator's profit is zero once her product is imitated in the south due to lower manufacturing costs[11], I assume a monopolistic market where the innovator enjoys a fraction of their initial profits once their products is imitated[12]. Unlike Grossman and Helpman (1991) who defined product cycle as the time which a product is imitated such that the product has zero economic value to the innovator, I borrow from Bilir (2014a) to define product cycle as the lifetime of an innovative idea used in producing a product. This idea could span several versions of a product and independent of product imitation. Grossman and Helpman (1991) model was aimed at understanding the interactions between imitation in the south and innovation in the north and how policies such as subsidies, labour supply in the south and north affects the level of product creation and destruction in a global equilibrium, while my framework aims to understand how imitation affects north and south trade in a partial equilibrium settings. My model also differs from Bilir (2014a) which focused mainly on understanding how the interaction between IPR and PLC affects the decision of North's multinational firms to shift manufacturing abroad, while I focus on understanding how IPR and PTI affects export flows between North and South. I borrow some assumption from their model, but employs a different modelling framework[13].

On the empirical side, several literatures have studied the effects of strengthen IPR on innovation, and industrial activity from the North to South. Lerner (2009) investigates the impact of changes in patent laws on innovation using a sample of 177 most significant changes in patents laws across 60 countries over 150 years, and finds no effect of strengthening IPR on innovation. Branstetter et al. (2006) examines the effect of IPR

[11]The implicit assumption here is homogeneous goods and competition on prices (Betrand competition), where the firm with the lowest marginal costs takes the market

[12]Imitators do not necessarily have to sell under the brand name of the innovators. This is true for the case of Samsung discussed earlier in this paper

[13]My approach builds on Bellman's equation for solving dynamic programming problems, different from theirs which solves an optimal timing problem.

reforms in sixteen countries between the period 1982-1999 on technology transfer within U.S. multinational firms. They find an increase in royalty payments for technology transferred to affiliates and a rise in affilate's research and development (R&D) expenditures and patent applications.

Other empirical studies use aggregate manufacturing industry-level data to study the effects of stronger patent reforms in the South on exports from North to South. Ferrantino (1993) finds no impact of strengthening of IPRs, Smith (1999) finds a mixed impact which depends on the imitative ability of the south and Ivus (2010), Maskus and Penubarti (1995), Rafiquzzaman (2002) etc. finds significantly positive impact. One of the biggest identification threats in these literature comes from the fact that IPR reforms are done alongside domestic policies making separate identification of the effect of patents on exports difficult. Ivus (2010) tries to overcome this challenge by using colonial origins as an instrument for patent protection. While most of this literature focused on the intensive margin effect, a very few recent literature have looked at the extensive margin effects (Lin and Lincoln (2017), Ivus (2015) etc). For example, Lin and Lincoln (2017) studies the extensive margin effect using a comprehensive firm-level dataset on exports and patents filings and study the role of intellectual property rights in determining the trade patterns across countries. They find that more profitable firms in the North are more sensitive to patent reforms than other firms. Duggan et al. (2016) studied the effects of improved IPR regulation on prices of patented pharmaceutical molecules in India and finds a positive effect (3-6 percent increase) for prices and little impacts for quantities sold. Relative to these literature, I re-validate the results in support of a positive relationship between improved IPR protection and exports irrespective of whether exports is defined as revenue or quantity. I focus on exploring factors that drives industry level export sensitivity to IPR reforms (PTI and PLC). In addition, I also show that the number of 10 digit products that are exported increases with patent reforms. Finally, my model sheds some light on why improved patent laws in the south may or may not have an effect on exports from the North, and this depends on the product time-to-imitation and lifecycle length of the industry considered, reconciling contradicting findings in the literature.

This paper is also related to another strand of the literature studying the effect of improved patent laws on foreign direct investment (FDI) inflows in developing countries. In particular, Javorcik (2004) studies the effects of IPR protection on the composition of FDI inflows using firm-level data set from the former Soviet Union and Eastern European countries. They find that weak patent protection deters foreign investors in technology-intensive sectors that rely heavily on IPRs.

2 A model of the decision to export

The model developed here is a partial equilibrium model of an innovator's decision on whether to export to a market with high imitation risk. The model builds on the work of Grossman and Helpman (1991) and Bilir (2014a), but differs in several directions as already discussed in section (1). Predictions of the model are validated in the empirical section of this paper.

2.1 Setup

I consider a world with three countries North, South 1 and South 2. For simplicity, I denote the countries as A, B and C respectively. Country A is an inventing country with strong IPR laws. Countries B and C have weaker patent laws compared to A. I incorporate the empirical findings in Smith (1999) by distinguishing between two types of countries in the South - one with weak imitative ability and the other with strong imitative ability. I assume Country B to have weak imitative ability. This country could be seen as countries with either low human capital development or strong aversion for imitation, thus imitating new innovations never happens. Country C has strong imitative abilities. Country C can be viewed as countries with higher human capital development and low aversion for imitation, thus imitation risk is high. This specification takes into account the heterogeneity of countries in the South. Most literatures (with an exception of Auriol et al. (2012)) have assumed a homogeneous South which is not very realistic because it is not necessarily true that least-developed countries can free-ride on patented innovations in the same way as emerging economies such as China, Taiwan or South Korea. For simplicity, I assume that the three countries are symmetric in all aspects except in their levels of per capita income, IPR regulations and imitation risk and they all have monopolistically competitive markets. I assume time to be continuous and consider a continuum of horizontally differentiated varieties of products in each industry j such that $j = 1, ..., J$.

Firms in country A manufactures products using innovations which have been patented and enjoys monopoly profit. Each manufactured product has a sector specific lifecycle length on its patents after which the product becomes obsolete with no economic value. Each product also has a sector-specific ease of imitation measured as the time for which the product could be imitated. In order to maximize the lifetime profits for a product with patent, the monopolist sells its products in its home market, country B and decides whether to sell to country C. In deciding whether to sell to C, the firm faces a trade-off. On one hand, selling to C increases its profit since its market size is larger and on the other hand is faced with imitation risk. If imitation is successful, imitators compete with the monopolist in market B and C only. Therefore, the monopolist enjoys monopoly profits until its product is either imitated or obsolete. This setup deviates from the assumption in a two country setting (North and South) where imitators in the South competes with inventors in the North and South markets.[14]

Sectors are distinguished by their pace of product obsolescence which is assumed to be determined by technological developments specific to each sector but exogenous to individuals firms (Bilir, 2014a). Let P_j be sector-j's life-cycle length shared by all products within sector-j. Hence, for any given product in sector-j, the product lifecycle

[14]The setup in this article reflects more of reality. Imitators cannot succesfully re-export products with patent infringements to countries in the North. According to U.S. Customs and Border Protection's Office of Trade, in 2018, 87% of all counterfeit products seized at U.S. ports came from mainland China or Hong Kong.

length determines the poisson rate of product obsolescence denoted by δ_j.

I assume that potential imitators exists in country C and only imitates successful products (i.e. products in high demand). Imitators with access to proprietary knowledge necessary for production may commence reverse-engineering of the product. I further assume that imitation arrives at a poisson rate λ_j which depends on the time-to-imitation success T_j. Both δ_j and λ_j is taken as given and constant over time. Every successful imitator competes with inventing firms wherever patents are not enforced until the variety becomes obsolete.

2.1.1 An Innovative Monopolist Problem

Consider a representative innovative monopolist in the North who introduced a new product j in the market. We assume that technologies embodied in goods can be imitated. To produce this good, the monopolist use product-specific technology which has been patented, and earns the exogenous profits $\pi_{aj}(l_a) > 0$, $\pi_{bj}(l_b) > 0$, $\pi_{cj}(l_c) > 0$ if products are sold in country A, B and C respectively such that $\pi_{aj}(l_a) \neq \pi_{bj}(l_b) \neq \pi_{cj}(l_c)$. l_i is defined as the aggregate GDP per capita in country i which captures the country's economic size, and profits is assumed to be an increasing function of l_i (i.e. $\pi'_{ij}(l_i) > 0$ $\forall$ $i \in \{A, B, C\}$). Thus, selling to the 3 countries give a profit $\pi_{aj}(l_a) + \pi_{bj}(l_b) + \pi_{cj}(l_c)$ and to A and B only gives $\pi_{aj}(l_a) + \pi_{bj}(l_b)$. Notice that exporting to country C gives the firm a higher profit (since $\pi_{cj}(l_c) \geq 0$) but this comes at a cost of imitation risk. If products are imitated, the monopolist competes with the imitator in country B and C. I assume that innovating firms protect proprietary information formally by patents and imitators can copy an existing knowledge by direct access to the products[15]. Imitators are not aware about a potential product to imitate until a direct contact with the product, which enable them to reverse-engineer the product[16]. This implies that cross-border knowledge

[15] In applying for a patent, inventors are obliged to provide a description of their invention. Thus, by having a direct access to a product and a description of its invention, imitators are able to copy the product.

[16] Imitators are usually concerned about the success of a new product before imitating it. Therefore, if a new product has not been exported to their destination, they are unaware of its success in their home market, and in some cases may not be aware of its existence. One counter-argument is that imitators

and access to products is costly, so imitators are economically constrained to pursue only those varieties that are locally available.

Imitation affects the innovators export decisions because entry by an imitator results to profit losses. Firms competing with imitators gets a fraction of the per-period profits. Denote a variable $\gamma_i \in [0, 1]$ as the level of patent enforcement regulation in country i. From the narratives above, it implies that $\gamma_a = 1, \gamma_b < 1$ and $\gamma_c < 1$. This variable captures laws prohibiting patents infringements such that an increase in γ_i implies an increase in IPR. Following Bilir (2014a), I modelled this as a share of profit which the monopolist receives if his product is imitated. Since Imitation will not occur if either there is a strong patent enforcement regulation or low imitative abilities in country i, I assume $\gamma_b = 1$. This implies that imitation is not likely to occur in country B, so the monopolist share of profit in B is 1.

Faced with the trade-off in exporting to country C, the monopolist would compare its expected present value from selling in country A and B denoted by V_{ab} with the expected present value from selling in all three countries denoted by V_{abc}, given a fixed discount rate r. I treat the value of the product when product obsolescence occurs to be $V_\delta = 0$, and I denoted the value of the product when imitation occurs to be V_o.

If the monopolist in sector-j, does not export to country C, the firm's Bellman equation is:

$$rV_{ab} = \pi_{aj}(l_a) + \pi_{bj}(l_b) + \delta_j(0 - V_{ab}) \tag{1}$$

Equation (1) shows that the firm will earn profits in country A and B, and at the constant poisson rate $\delta_j = \frac{1}{P_j}$ - which depends on the length of the product lifecycle-, the product will be obsolete with zero economic value ($V_\delta = 0$).

in country C may import such patented products from country B and reverse-engineer them. While this may be true, I argue that the probability of reverse-engineering in this case is very low, due to the following reasons. Imitators are faced with some uncertainty of the product success and market acceptance in their own market, would have to pay the variable and fixed cost of importing prior to investing in imitation.

For the case where the firm exports to country C (in addition to selling in countries A and B), the Bellman equation characterising the value of the firm is defined:

$$rV_{abc} = \pi_{aj}(l_a) + \pi_{bj}(l_b) + \pi_{cj}(l_c) + \delta_j(0 - V_{abc}) + \lambda_j(V_o - V_{abc}) \tag{2}$$

Where $\lambda_j = \frac{1}{T_j}$, the constant poisson rate depends on the product time-to-imitation. Here the firm makes profits in the three countries and as in the previous case (equation 1), product obsolescence also occurs at the rate δ_j. The key difference here is that at the rate λ_j, imitation occurs and the change in the value of the firm becomes $V_o - V_{abc}$ where V_o is the value of the firm when imitation occurs. I specify the Bellman equation for V_o below as:

$$rV_o = \pi_{aj}(l_a) + \gamma_c(\pi_{bj}(l_b) + \pi_{cj}(l_c)) + \delta_j(0 - V_o) \tag{3}$$

If imitation occurs, the firm will compete with imitators in country B, thus they will earn a fraction of profits (γ_c) in both countries B and C. Combining equation (2) and (3) we can express the value from exporting to the three markets (V_{abc}) as:

$$V_{abc} = \frac{\pi_{aj}(l_a)}{r + \delta_j} + \frac{(r + \delta_j + \lambda_j\gamma_c)(\pi_{jb}(l_b) + \pi_{jc}(l_c))}{(r + \delta_j + \lambda_j)(r + \delta_j)} \tag{4}$$

Combining equation (4) and (1), we derive the expected net present value of exporting to country C as the difference between the net present value of exporting to all three countries (V_{abc}) and exporting to countries A and B (V_{ab}).

$$V_c \equiv V_{abc} - V_{ab} = \frac{\pi_{jc}(l_c)(r + \delta_j + \lambda_j\gamma_c) - \pi_{jb}(l_b)\lambda_j(1 - \gamma_c)}{(r + \delta_j + \lambda_j)(r + \delta_j)} \tag{5}$$

This value is increasing in IPR reforms if ($\frac{\partial V_c}{\partial \gamma_c} > 0$), increasing in product lifecycle length ($\frac{\partial V_c}{\partial \delta_j} < 0$), and increasing in time-to-imitation success ($\frac{\partial V_c}{\partial \lambda_j} < 0$). The intuition is straightforward. IPR reforms increases the market power of the innovator. It is clear from equation (5) that the fraction of profit lost in country B ($-\pi_{jb}(l_b)\lambda_j(1-\gamma_c)$) reduces with IPR reforms, and the fraction of profits from country C ($\pi_{jc}(l_c)(r + \delta_j + \lambda_j\gamma_c)$) increases with IPR reforms. The rise in V_c due to the level of product lifecycle length is unrelated to the decision to export to country C as this pattern is also observed in V_{ab} (see equation (1)). Finally the intuition for the rise in V_c due to product time-to-imitation is simple. The innovator will enjoy more rents from product with longer time to imitate over the product's life.

2.2 Comparative Statics

The monopolist will export if $V_c > 0$. By rearranging equation (5) and after some algebra, I show that the monopolist will export to country C if the following condition is satisfied (note: I have substituted δ_j and λ_j with their corresponding expressions):

$$\frac{\pi_{jc}(l_c)}{\pi_{jc}(l_c) + \pi_{jb}(l_b)} - \frac{P_j(1-\gamma_c)}{r(P_j+1)T_j + P_j} > 0 \tag{6}$$

Let $G(\pi_{jc}, \pi_{jb}, P_j, T_j, \gamma_c) = \frac{\pi_{jc}}{\pi_{jc}+\pi_{jb}} - \frac{P_j(1-\gamma_c)}{r(P_j+1)T_j+P_j}$. If $G(.)$ is increasing, this implies that more of product j is exported to country C and vice-versa. From this expression, I derive the set of comparative statics described in Lemma (1) below.

Lemma 1 *The export of sector j's products to Country C is*

1. *Increasing in the level of IPR*

$$\frac{\partial G(.)}{\partial \gamma_c} = \frac{P_j}{r(P_j+1)T_j + P_j} > 0 \tag{7}$$

2. *Increasing in average income per capita in country C*

$$\frac{\partial G(.)}{\partial l_c} = \frac{\partial G(.)}{\partial \pi_{jc}(l_c)} \frac{\partial \pi_{jc}(l_c)}{\partial l_c} = \underbrace{\frac{\pi_{jb}(l_b)}{(\pi_{jb}(l_b) + \pi_{jc}(l_c))^2}}_{>0} \times \underbrace{\pi'_{jc}(l_c)}_{>0} > 0 \tag{8}$$

3. Decreasing in average income per capita in country B

$$\frac{\partial G(.)}{\partial l_b} = \frac{\partial G(.)}{\partial \pi_{jb}(l_b)} \frac{\partial \pi_{jb}(l_b)}{\partial l_b} = \underbrace{-\frac{\pi_{jc}(l_c)}{(\pi_{jb}(l_b) + \pi_{jc}(l_c))^2}}_{<0} \times \underbrace{\pi'_{jb}(l_b)}_{>0} < 0 \tag{9}$$

4. Decreasing in product lifecycle length

$$\frac{\partial G(.)}{\partial P_j} = -(1-\gamma_c)\left[\frac{rT_j}{(r(P_j+1)T_j + P_j)^2}\right] < 0 \tag{10}$$

5. Increasing in product time-to-imitation

$$\frac{\partial G(.)}{\partial T_j} = \frac{rP_j(1-\gamma_c)^2(P_j+1)}{(r(P_j+1)T_j + P_j)^2} > 0 \tag{11}$$

Intuition: First, IPR reforms in countries with imitation risk increases north's exports since the stricter laws will serve as a caution to potential imitators. Second, average income per capita in country C would increase exports from the north to country C since expected profits is larger and this compensates for expected losses if imitation occurs. Third, an increase in income per capita in country B (which has low imitation risk) would lead to a reduction in exports of product j to country C. This is so because if products are imitated in country C, it faces competition in B and expected losses arising from such situation is larger. Fourth, the higher the product lifecycle length, the larger the expected loss over the life of the product. This will attenuate exports to country C which has high imitation risk. Finally, the higher is the time-to-imitation success of a product, the more of such product is exported to country C. Since such products are difficult to imitate, innovators are less worried about imitation.

This lemma provides some insights in understanding factors that may affect trade flows between northern and southern countries. I now derive some testable predictions of interest.

Result 1 *Given an increase in IPR in country C with high imitation risk, there is an in-*

crease in exports of products with shorter product time-to-imitation, however this increase happens at a diminishing rate.

The proof is straightforward (i.e. take first and second derivatives of equation 7). This result captures the sectoral effect of IPR reforms on exports to countries with imitation risk. It is non-trivial, as it sheds some light on how sector-level characteristics determine the sensitivity of IPR reforms on exports from the north to the south. The result suggests that exports in sectors with shorter time-to-imitation are more sensitive to IPR reforms compared to sectors with higher product time-to-imitation. The intuition is that innovators with products that are difficult to imitate will always export to countries with imitation risk irrespective of IPR reforms (see equation 11), and conditional on demand. Therefore, they are less sensitive to IPR reforms. While patent reforms alleviates the concerns on product imitation for innovators with products that are easier to imitate, thereby inducing them to increase their exports to country C. From a developing country perspective, if sectors are partitioned by their time-to-imitation, the results shed some lights on which sectors will attract more exports from the US. This is necessary for policymakers in weighing (ex-ante) the potential gains and losses in adopting IPR.

We explore other sector level characteristics that determines the sensitivity of IPR reforms on exports from North to the South. In the spirit of Bilir (2014a) that finds that sector-level product lifecycle length determines the sensitivity of US multinationals location decision to IPR improvements, we derive some predictions between exports, IPR, and product lifecycle length below.

Result 2 *Given an increase in IPR in countries with high imitation risk, there is an increase in exports of products with longer product life-cycle length, however this increase happens at a diminishing rate.*

The proof is similar to result (1). This result suggests that exports in sectors with higher product lifecycle length are more sensitive to patent reforms, however this sensitivity is non-linear. Notice that without IPR reforms, exports of products with longer lifecycle length are lower than that with shorter product lifecycle length (see equation 10), thus stronger IPR reforms in the south encourages firms in the north with longer product lifecycle length to export more of their products to such destination because the risk of product imitation, and the expected loss of profits over the product life is lower. The non-linearity results from the idea that firms in sectors with very high product lifecycle length have more to lose if their product is imitated.

In the next section, I describe the data, and provide some descriptives.

3 Data and Descriptive Statistics

The data comes from different data sources merged together and used to test the theoretical predictions of the model. I outline the data sources below:

3.1 US Yearly Export Data

This consist of US product level export-destination panel data from 1989 to 2006 assembled by Feenstra (1997) for National Bureau of Economic Research (NBER). It consists of highly disaggregated data at the 10-digit Harmonized System (HS-10) product level which has also been aggregated to the 1987 4-digit Standard Industrial Classification (SIC 4) codes. This data is freely available at The Center for International data, University of California Davis website. The full data consists of 5,679,468 observations, 183 countries, 11,473 unique HS-10 and 458 unique SIC-4 product lines. Since this data is useful in this analysis only if it is merged with other datasets such as the product lifecycle length, product time-to-imitation and country-level patent protection data, I aggregate the export data to 1987 SIC-3 to enable me merge this dataset with other data sources. I convert the 1987 SIC-3 product code to 1972 SIC-3 using a concordance table from the NBER webpage.[17] I do this because, the main identifier in the product life-cycle length data is the 1972 SIC-3 product code.

[17]See: http://www.nber.org/nberces/nberces5811/conc_sic72_sic87_documentation.pdf

3.2 Country Level Intellectual Property Rights Protection Data

This consist of proxies computed every 5-year period that represents the strength of patent protections across 122 countries from the period 1960 to 2005 developed in Ginarte and Park (1997) and updated in Park (2008)[18]. This index has been widely used in several literatures (Bilir (2014a), Ivus (2010), McCalman (2004), Smith (1999), among others) because of its extensive coverage and detailed construction. The index is constructed from five distinct categories related to national patent laws namely: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms and (5) duration of protection. Thus, it captures both the *de jure* and *de facto* aspects of patent laws. For each country and time pair, each of the 5 categories was given a score ranging from 0 to 1 depending on whether the existing patent laws meet some specific criteria. The overall index for a country-time pair is the unweighted sum of the five values and thus, it ranges between 0 and 5 with higher values indicating stronger patent protection[19]. The results in the empirical section is based on the overall index. I assign every year for which there is no index in the IPR data during the period 1989-2006 to the closest available in the IPR data[20]. For example, 1990 IPR index is assigned to countries in the export data for the years: 1989, 1990, 1991 and 1992; 1995 IPR index is assigned to countries in the export data for the years 1993, 1994, 1995, 1996 and 1997.

3.3 Product Life-Cycle Lengths by Industry

Product life-cycle length is a cross-sectional dataset developed in Bilir (2014a). This index reflects the idea that a product life-cycle is not based on several versions of a prod-

[18]An updated version up till 2010 is available on http://fs2.american.edu/wgp/www/

[19]This index shows that the 5 countries with the highest protection on average between 1960-2005 are USA,Belgium, Netherlands, United Kingdom, and Germany and the 5 with the lowest protection are Myanmar, Papau New Guinea, Angola, Mozambique and Ethiopia which might not be surprising. For extensive discussions on the construction of the index, we refer the reader to Ginarte and Park (1997) and Park (2008)

[20]We are not the first to use this assignment method in the literature. For example, Bilir (2014a) also used this assignment method

uct developed using the same innovative idea. But instead, the economic lifetime of the innovative idea which may span more than one version of the product. The main implication of this idea is that innovative ideas overlaps several versions of a product and once imitated, the firm suffers a loss in profit from current and future versions of a product[21]. The employed measurement approach captures cross-sectoral variation in the lengths of product life-cycle by examining the economic durability of embedded technologies. This index is constructed using detailed data on US registered patents and citations from NBER US Patent citation dataset (Hall et al., 2001). The authors used the "forward citation" lag[22] method in constructing the index. The measured industry lifecycle length $\hat{T}_j$ is the average forward citation lag within an industry[23]. $\hat{T}_j$ is mapped to the export data using the SIC-3 identifier. In table (2), I present the top 5 sectors with the longest product lifecycle length and bottom 5 sectors with the shortest product lifecycle length. From the table, Heating equipments (except electric); metal cans and shipping containers; screw machine products, bolts, nuts, screws; fabricated structural metal products; and miscellaneous fabricated metal product are the 5 sectors with the longest product lifecycle length. The 5 shortest are: watches, clocks and clockwork operated devices; computer and office equipments; agricultural chemicals, electronic machineries and industrial inorganic chemicals. The full list of the sectors and their product lifecycle length is presented in Table (A.1). In figure (13), I show the distribution of the product lifecycle length. One thing that comes out clear here is that the range of this measure is narrow (7.37-10.89) leaving one to wonder if this measure really matter. However, Bilir (2014a) showed that this measure, although narrow, strongly determines the sensitivity of US multinational firms activities in countries with improvements in their IPR.

[21]Broda and Weinstein (2010) finds that the entry of new products within a firm is larger than the exit of new products. This product lifecycle length index captures the technology embedded in creating new products. So it spans several versions of a product

[22]This is the time lapse between the grant date of the cited patent and its subsequent citation

[23]for a detailed explanation see: Bilir (2014b). The full-data is freely available on: $https://www.aeaweb.org/articles?id=10.1257/aer.104.7.1979$.

3.4 Product Time-to-Imitation

There are no known index that captures the time it take to imitate a product. One of the aim of this paper is to provide such index. To achieve this objective, a natural thing to explore is the four Asian Tigers (Hong Kong, Singapore, South Korea, Taiwan) which underwent massive industrialization and maintain high growth rates between 1960s to 1990s. While Hong Kong, Singapore achieved rapid progress in their financial services sectors, South Korea and Taiwan saw large growth in industrialization becoming world leaders in device and electronics manufacturing in the mid 1990s. I focus on South Korea because of the availability of data. Kim (1997), describe how South Korea in its early stages of industrialization focused on imitating successful foreign products, infringing on IPRs of high technology products before adopting patents in late 1980s.

To construct an index of product time-to-imitation, I look at the product import and export dynamics in South Korea between 1962 to 1990s. Specifically, I make two important assumption.

I First, I assume that imitators would imitate successful foreign products with success defined as products with high demand in South Korea. This is a plausible assumption because imitation involves large sunk costs (assembling a team of researchers and engineers, buying several versions of the products etc). Therefore, knowledge of the product demand in the domestic market is important for commencement of imitation.

II Second, I assume that imitators would imitate products from differentiated goods sectors. Since imitators would compete with innovators, product differentiation ensures that innovator's cost advantage (if any) would not drive them out of the market.

To this end, I employ data from the United Nations Comtrade database. This data covers imports and exports of products defined at the 4-digit standard international trade classification revision 1 (4-digit SITC Rev. 1) in South Korea. I construct this index in the following way:

1. Defining a cutoffs for both import and export surge, and take the difference between import surge and export surge of a product. That is:

$$\text{imports surge cutoff: } imports_t - imports_{t-2} > 200,000 \text{ USD}$$
$$\text{exports surge cutoff: } exports_t - exports_{t-2} > 200,000 \text{ USD}$$
$$\text{time-to-imitation} \;=\; \text{year of export surge} \;-\; \text{year of import surge}$$

2. Select only products that are classified as differentiated products using Rauch product classification (Rauch, 1999)

As an example, in figure (5), I show the export and import dynamics for domestic electrical equipment (SITC Rev. 1: 7250). The solid vertical line is the import surge, while the dashed vertical line is the export surge. Clearly, import surge is seen in 1966 while export surge occurred in 1972. The product time-to-imitation is 8 years. In figure 6, 7 and 8, I show similar graph for the pharmaceutical, Raw sugar, beet and cane, and evaporated and condensed Milk & cream products respectively. We find similar pattern as domestic electrical equipments for pharmaceutical goods. For the latter two product categories, while there was import surge, they was no export surge. This will amount to missing values for these products and other products with similar pattern. In the baseline econometric specification, I omit these observations and for robustness, winsorize them by assigning high values to it. For some products, export surged was observed before import surge. These products were assigned negative values for product time-to-imitation. I create dummies for these observations and include them in the empirical exercise discussed in section (4).

In figure (9), I show the distribution of product time-to-imitation. It is normally distributed and centered between 1 and 5. In table (1) I present the top 5 products with the largest PTI and the bottom 5 products with the smallest PTI>0. In the appendix, I provide a complete list of products and their PTI.

One possible concern with our measure of PTI is endogeneity. That is, Korea may be putting a lot of resources at more profitable sectors, and the measure of PTI may capture amount of resources thrown into the sectors. This is not a problem in my analysis as I am not interested in how T_j is determined, but on how innovators perceive the time it takes to imitate their products. Moreover, I omit South Korea in our baseline analysis, and I use a time period (1989-2006), different for the period my index was constructed.

3.5 Macro Data

The macro data used in this work comes from Penn World table 8.1 described in Feenstra et al. (2015) and it consists of data on gross domestic product, population, output, inputs, income, and productivity etc. covering 167 countries between 1950 and 2011. I construct the real GDP per capita using Real GDP and population variables. I also use Data on Human Development Index (HDI) from United Nations Development Programme (UNDP) database[24]. HDI data is used in only the descriptive analysis.

3.6 Data Merging and Cleaning

Among the 120 countries (excluding the US and South Korea) in the patent protection index data, I observe export information for 116 countries, so I keep the data for 116 countries in the patent protection index and US exports dataset. I average the 4-digit SITC rev. 1 product time-to-imitation to the 3-digit SIC sector. There are some 4-digit SITC products for which there are no observations on product lifecycle length, and there are some 3-digit SIC sectors for which there are no observations on time-to-imitation. I considered only the observations for which I observe both product lifecycle length and time-to-imitation. This corresponds to 27 3-digit SIC sectors[25] Finally, I keep observations for only these sectors in the US export dataset.

I start by merging the export data with the product lifecycle and time-to-imitation index dataset using the 3-digit SIC sector identifier. Then, I merged this dataset with the

[24] Available on: *http : //hdr.undp.org/en/data#*

[25] In the appendix, I show a specification where I use the entire 4-digit SITC products without averaging at the SIC 3 level. Thus, I do not control for product lifecycle in the regression.

country-level patent protection index and macro data set using the country-year identifier. After merging and cleaning up these datasets, our export data sample size reduced to 40,666 US export-destination observations to 116 countries in 27 SIC-3 sectors.

3.7 Comparing Product Time-to-Imitation with Lifecycle Length

To understand whether and how both variables (product lifecycle length and time-to-imitation) capturing different characteristics of products within an industry are related. I show a scatter plot of PLC and PTI in figure (10). Clearly, there is a negative relationship between PLC and PTI (coefficient of -0.02), although weak because both variables were constructed using unrelated methodologies and data from different settings.

3.8 Relationship Between Exports, IPR, PTI and GDP

In this section, I partition PTI into 4 groups (i.e. group 1: $0 \leq PTI \leq 3$; group 2: $4 \leq PTI \leq 6$; group 3: $7 \leq PTI \leq 9$; group 4: $PTI \geq 10$). I present the scatter plot and linear fit (see figure(A.1) in the appendix) of the log of US exports on patents for different partitions of product time-to-imitation in order to ascertain if this correlation is constant across different partitions. From the figure, it is clear that the fitted value for the regression of exports on patent is stronger in the first partition with a coefficient of 0.87 and correlation of 0.34 compared to the other partitions. However, this relationship weakens are PTI increases, which is consistent with our model.

Finally, I explore the relationship between GDP and IPR. In figure (11), I show that average level of patent protection is strongly positively correlated with average per capita GDP with a correlation coefficient of approximately 0.63. This implies that richer countries have better IPR, and suggests that GDP be included as a regressor in the empirical analysis.

4 Econometric Framework

In the model presented in section 2, I assume that a representative innovator in sector j with patents on its product decides whether to export to a country with imitation risk (Country C) and this depends on the net present value of exporting to country C. The derived results highlight the implications of varied country-level IPR, product time-to-imitation, and lifecycle lengths on the distribution of patent sensitive products across countries. To validate the model's predictions, I start with the intensive margin effects of patent enforcement, product time-to-imitation, and lifecycle length on exports. Below is the description of our econometric approach.

4.1 Baseline Estimation

Our theoretical results show that the sensitivity of North's exports to patent protection in the south is decreasing in product time-to-imitation at a diminishing rate, and increasing in product lifecycle length at a diminishing rate. These results inform the baseline specification below:

$$ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_2 IPR_{it} \times P_j + \eta_{it} + \eta_{jt} + \epsilon_{ijt} \tag{12}$$

where Y_{ijt} denotes export value (in USD) or the quantity of goods in sector j exported to country i at time t, IPR_{it} denotes IPR index in country i at time t, T_j denotes the time-to-imitation in sector j, P_j denotes the product lifecycle length in sector j, η_{it} is the country-time fixed effects, n_{jt} is the industry-time fixed effects and I include some controls such as the log of GDP per capita $ln(gdppc)_{it}$ in some specifications. In equation (12), the main coefficients of interest is β_1 - which captures the differential effect of IPR reforms on export patterns across sectors with different product time-to-imitation T_j-, and β_2 - which captures the differential effect of IPR reforms on export patterns across sectors with different product life-cycle length P_j.

This baseline specification includes some important controls such as the sector-time fixed effects (η_{jt}) and country-year dummies (η_{it}). Sector-time dummies control for unobserved time-variant sector-level characteristics such as total size of the industry, average industry productivity, sector-specific preferences, time-varying global demand[26] etc. The country-year fixed effects η_{it} accounts for unobserved time-varying country-level characteristics that affects export activity between the US and countries in our panel. This includes bilateral trade agreements, distance, level of development, language, colonial relationships, competition levels, etc. The residual term ϵ_{ijt} accounts for omitted variables that are orthogonal to the covariates. Standard errors are robust and clustered at the country level.

4.2 Identification

Identifying the effects of IPR improvements have been a major empirical challenge. This is because IPR reforms is done alongside with other domestic policies which encourages exports from the developed world. For example, when countries join WTO, they align themselves to the patent protection requirement of the Trade Related Intellectual Property Rights (TRIPS) agreement. Since joining the WTO comes with a reduction of trade barriers such as tariffs, this makes identification of the separate effects of patents improvement difficult. More so, countries that joins WTO has a clear motives of improving its trade relations and as a result may implement other domestic policies which increase trade. This makes causal inference from a simple regression of exports on IP protection impossible.

In the model developed in Section (2), variation in product time-to-imitation and lifecycle lengths (T_j, P_j), determines US exports sensitivity to patent reforms, while US firm's sensitivity to other domestic policies is theoretically independent of T_j. Thus, cross-sectional variations in T_j and P_j captures the relative effect of patent laws separately from

[26] It could be that industry-specific shocks are correlated with country-level IPR index. For example, due to a global rise in demand for products from a specific industry (say pharmaceuticals), a country may improve its IPR regulation. Industry-year dummy (η_{jt}) addresses this possibility.

the effects of other domestic policies. It is very unlikely that product time-to-imitation T_j will be correlated with destination-country patent laws since it is measured using data from South Korea, and I dropped observations for South Korea. It is also unlikely that product lifecycle length P_j will be correlated with destination-country patent laws since it is measured using US data.

Another potential concern is reverse causality. Our identification relies on the assumption that IPR reforms is independent of US exports. The rationale for this assumption is the following. First, as already mentioned, as part of the rules governing the membership of WTO, countries are required to align their national laws to the TRIPS requirements which includes regulations for IP rights. So it is unlikely that IPR will depend on US exports. Second, our measure of IPR reflects the extent to which patents is incorporated into the written laws governing a country. Since the introduction of new laws comes with a huge cost of abrogation, it is unlikely that it is influenced by US industry exports. However, just like in any non-randomized controlled experimental studies, I do not completely rule out this possibility, but argues that it is very unlikely.

5 Main Results

As a first step, I start by estimating the relationship between US exports, IPR reforms and the interaction between IPR reforms and product time-to-imitation (PTI), while controling for the log of GDP per capita, industry, country, and year fixed effects. I report the results in Table (3) column 1. I find a positive and significant relationship between IPR index and US exports. Interestingly, I also find a strong and negative relationship between US exports and the interaction between IPR and PTI. This finding implies that *ceteris paribus*, a rise in IPR reforms by one standard deviation in a country is related to an increase in US exports by 11.4% in an industry with 1 year of PTI. However, for an industry with say 5 years of PTI, the rise in US exports is about 8.7%, while for an industry with 10 years PTI, this rise is 5.5%. This result suggests that product time-to-imitation determines the sensitivity of US exports to IPR reforms. While the coefficient of IPR is consistent with similar studies, there are some potential identification issues associated with this specification as discussed in section 4.2. If there are domestic policies such as a reduction in tariffs introduced simultaneously with IPR reforms, this leads to an omitted variable bias, which overstates the coefficient of IPR reforms[27]. However, this omitted variable concern, does not bias the coefficient of of the interaction between IPR and PTI (β_2) because (as already discuss in section 4.2) PTI captures the relative effect of IPR reforms across industries separately from the effects of domestic policies. In column 2 of table (3), I use a specification with IPR index and an interaction betweeen IPR and product lifecycle length (PLC), including the same controls as in column (1). The estimate implies that industries with longer lifecycle are more responsive to IPR reforms compared with industries with shorter lifecycle length.

The results presented so far might be driven by some unobserved time-variant industry-specific shocks that are correlated with country-level IPR or time-variant country-level characteristics which might influence export activity between the US and the countries in our panel. This includes but limited to R&D investments, changes in global tastes, reduction in transport costs, bilateral trade agreements, level of education etc. To address these concerns, I focus solely on the differential effect of IPR on exports across sectors with different product time-to-imitation in order to control for industry-time and country-time fixed effects. In column (3) of table (3), I show the results of log US exports on an interaction between IPR and PTI. Addressing this potential concern, the new estimate is similar to the previous result which states that products with shorter time-to-imitation are more sensitive to IPR reforms than products with longer time to imitation. In column (4), I present the result for the case where the regressor of interest is the interaction between IPR and PLC, I still find that US exports of products with longer lifecycle length are more sensitive to IPR reforms, however this sensitivity

[27]Identification requires an instrument which is correlated with patents but uncorrelated with the omitted variables. Ivus (2010) uses colonial origin as an instrument. Our main interest is not in this specification but on the differential effect of patent protection on US export across sectors with different product life-cycle length.

is marginal. I attribute this to large standard errors as the range of PLC is narrow (i.e PLC $\in (7.37, 10.89)$), thus its variation is minimal. In columns (5), I include both the interaction IPR×PTI and IPR×PLC. The coefficient of IPR×PTI does not change and still very significant, however that for IPR×PLC is insignificant. In column (6), I control for the interaction between log GDPpc and PLC, and the coefficients of IPR×PTI remains unchanged and significant, further supporting the main results of the model that PTI determines the sensitivity of exports to IPR reforms. The intuition is: innovators with products that can be copied easily are less opened to exporting to countries with lower IPR index compared to innovators with products that are difficult to copy, because the probability that their product will be imitated is high. With IPR reforms in such countries, these innovators are more willingly to export than innovators with products with high PTI. In column (7), I include the interaction between log GDP and PTI, I find that the coefficient of IPR×PTI becomes positive and marginally significant. This is because IPR×PTI is collinear with Log GDPpc ×PTI with a correlation of 0.89. Figure (12) shows the bin scatter plot for this two variables. Overall, this suggests the exclusion of Log GDPpc ×PTI from the regression[28].

Predictions from the theoretical model suggests that the relationship between PTI and exports, and PLC and exports happens at a diminishing rate (See result 1 and 2 in section (2)). To test for this, I employ two approaches. In the first, I include a quadratic term of T_j and P_j interacted with IPR in the main specification (12) to capture this diminishing rate. From the model results, the coefficient of the quadratic term should have an opposite sign compared to its corresponding linear term. I present this specification as:

$$ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_2 IPR_{it} \times T_j^2 + \beta_3 IPR_{it} \times P_j + \beta_4 IPR_{it} \times P_j^2 + \eta_{it} + \eta_{jt} + \epsilon_{ijt} \quad (13)$$

[28] I also checked for the correlation between Log GDPpc ×PLC and IPR ×PLC and this stands at 0.64 (see figure A.2). Which implies that Log GDPpc ×PLC could be included as a regressor in the regression

In the second, I estimate a flexible regression. This specification allows the coefficients to vary flexibly across the PTI and PLC. This approach captures the differential effect of IPR across the different partitions of the PTI and PLC distribution. I partition PTI (T_j) into 5 groups namely ($S_{0T} : T_j < 1$; $S_{1T} : 1 \leq T_j \leq 3$; $S_{2T} : 3 < T_j \leq 6$, $S_{3T} : 6 < T_j \leq 9$, $S_{4T} : T_j > 9$) and create dummies corresponding to each group. For PLC, I partition P_j into N groups $(S_{1P}, S_{2P}, ..., S_{N-1P}, S_{NT})$. The estimation equation is expressed in (14) and (15).

$$\ln(Y_{ijt}) = \beta + \sum_{m=1}^{4} \beta_m IPR_{it} \times \mathbf{I}_{T_j \in S_{mT}} + \eta_{jt} + \eta_{it} + \epsilon_{ijt} \tag{14}$$

$$\ln(Y_{ijt}) = \gamma + \sum_{m=2}^{N} \gamma_m IPR_{it} \times \mathbf{I}_{P_j \in S_{mP}} + \eta_{jt} + \eta_{it} + \epsilon_{ijt} \tag{15}$$

Equation (14) interacts a dummy corresponding to each group of PTI with IPR. The omitted group is S_{0T}. In equation 15, I interact dummy corresponding to each of the top $N - 1$ groups. In the baseline estimation, I choose $N = 4$ (quartiles), but the results are consistent with N=6 (sextiles) and N=10 (deciles). β captures the effect of IPR reforms on sectors in the omitted group in equation (14) and γ captures captures the effect of IPR reforms on sectors in the first quartile of P_j distribution. β_m is the difference in the impact of IPR reforms on US exports between sectors in the $m > 0$ partition of the PTI compared to sectors in the $m = 0$ partition. While γ_m is the difference in the impact of IPR reforms on US exports between sectors in the $m > 1$ quartile of PLC and sectors in the first quartile.

I report the results for both approaches (equation 13 and 14, 15) in table (4). In column (1), the estimates imply that products with shorter time-to-imitation are more sensitive to IPR reforms, however this effect occurred at a diminishing rate. This could be seen in column (4) where I report the estimates for the flexible regression. Here, we see that a rise in IPR index by one standard deviation in a country is related to an increase in US exports to such destination by 11% in an industries with PTI that lies between 1 and 3 years compared to an industry with PTI less than 1 year. This effect is about

8% for industries with PTI that lies above 3 years and below 6 years. This diminishing effects persists throughout the range of the PTI. I show this in figure (14).

In column (2), I present the diminishing effect results for PLC. While the estimates are in the expected direction as predicted by the model, these effects have large standard errors due to less variability in PLC as already discussed. In column (6), I report the estimates for the flexible regression corresponding to PLC. I also plot this result in figure (15). Clearly, the estimates are in line with the theoretical results. In column (3), I estimate a specification which has the linear and quadratic terms of PTI and PLC interacted with IPR. The results in column (1) and (2) remains unchanged. In column (4), I control for GDP interacted with the linear and quadratic terms of PLC and the results remains unchanged. In sum, the empirical result provides strong support that PTI determines the sensitivity of US exports to IPR, stronger for products with shorter PTI and weaker for products with longer PTI. However, the empirical results does not provide a strong support for PLC. I attribute this large standard errors to the narrow range of PLC. In an unreported regression, I include the observations for South Korea between (1990-2006) and our results are unchanged. In subsequent regressions, I include observations for South Korea.

IPR increases the market power of innovators, so our findings maybe driven by prices and not quantity. Duggan et al. (2016) finds that the introduction of patent regulations into India laws increased the price of newly patented pharmaceutical molecules by between 3 to 6 percent, with very slight effect on quantity sold. This is inline with some of the critics of the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement which argues that IPR reforms increases the price of products with patents, limiting the access of new technologies in catching up countries. I check for this possibility in the next estimation by using log quantity of exports as the dependent variable. This is important because it isolates the effect of changes in price from that in quantity[29]. Table 5, column

[29]There are some limitations to the usage of this variable. In cases where the unit of measurement is unknown or in different units, the quantity variable takes the value zero. We drop these zeros observations and this led to a loss of about 3% of the total observations.

1 through 6 shows that the estimates are consistent to that obtained when *log value of exports* was used as the dependent variable. I also report the results for the diminishing effects in table (6) and plot the results of the flexible regression in figure (16). In sum, these results suggest that IPR reforms raises US exports quantity to such destination, and the PTI determines the sensitivity of the exports.

A natural question that arises is whether these effects are sizable. I take a case of China with an IPR of 1.33 in 1990 and consider two industries: Television Broadcast receivers (SITC rev. 1: 7241) with a PTI of 1 year and Medical Instruments (SITC rev. 1: 8617) with a PTI of 6 years. Assuming China has an IPR index of 2.5 in 1990, our result implies that US exports to China in Television Broadcast receivers will be approximately 7% more than US exports in medical instruments[30]. Clearly PTI has a sizable effect on the sensitivity of US exports to IPR reforms.

5.1 Extensive Margin Effects

We have shown so far that improvement in IPR is associated with an increase in US exports to such destination, and that PTI determines its sensitivity. This rise in export sales might be driven by firms increasing the quantity of exports to such country, or by entry of new firms to such destinations. In this section we aim to investigate whether more firms enter a market as a result of IPR reforms in such markets and whether the sensitivity of such entry is driven by the PTI.

Unfortunately, I do not observe firms in my data but I do observe products at the 10-

[30]Assuming two industries j and k in country i and consider an increase in IPR in i between period t and $t+1$ denoted by $\Delta IPR_{i,t+1}$, the percentage changed in exports in industry j due to IPR reforms in i is expressed as

$$\frac{Y_{ij,t+1}}{y_{ij,t}} = \exp((\beta_1 \times P_j + \beta_2 \times P_j^2)\Delta IPR_{i,t+1})$$

The above equation is similar to the percentage change in export in industry k dues to IPR reforms. So the difference in the percentage change in industry j and k due to IPR reform is:

$$\frac{Y_{ij,t+1}}{y_{ij,t}} - \frac{Y_{ik,t+1}}{y_{ik,t}} = \exp((\beta_1 \times P_j + \beta_2 \times P_j^2)\Delta IPR_{i,t+1}) - \exp((\beta_1 \times P_k + \beta_2 \times P_k^2)\Delta IPR_{i,t+1})$$

Substituting values for $P_j = 1$, $P_k = 6$, $\beta_1 = -0.026$, $\beta_2 = 0.002$ and $\Delta IPR_{t+1} = 1.17$, we arrive at the estimate.

digit level which is the highest level of product disaggregation. I construct the number of 10 digit products in each 3-digit sector exported to each country in each period as our dependent variable. The independent variables are the same as in table(3). I run similar regressions as in equation (12) and report the results in table (7). I find that the coefficients are consistent with the intensive margins results, however their magnitudes are halfed. This result suggests that more number of US products within a sector is shipped to a destination with improved IPR, the sensitivity of this effect depends on the PTI. I also find that the diminishing effects is also similar as the intensive margin results as shown in figure (18). I report the full regression table in the appendix table (B.1).

5.2 Robustness

I employ two alternative specifications and data re-definitions to test if our results are sensitive to these specifications. I outline them below and present the results in the appendix.

5.2.1 Alternative Cutoffs For Import and Export Surge

In constructing the PTI for our baseline regressions, I defined import (export) surge to be a period where the difference between imports (exports) in period t and period $t-2$ is \$200,000. I now test if our results is sensitive to this cutoff. I re-define both import and export surge cutoffs to be \$500,000, and construct the PTI in a similar way as defined in section (3.4). By doing this, I lose approximately 4 percent of my observations. I report the results in table (B.2 and B.3) in the appendix. The results are consistent with our baseline results but with weaker magnitude. In an unreported regression, I check for the sensitivity of the results using a cutoff of \$1,000,000. While this result is consistent with our baseline results, the magnitude of the coefficients is very marginal[31]. In sum, using a higher cutoff is consistent with our baseline specification.

[31] β_1 was around -0.001 as against -0.007 in our baseline result

5.3 Estimation at the 4-Digit SITC 1 Level

In the baseline estimation, I aggregate the data to the SIC 3-digit level because the data on PLC comes at this level. I now estimate a regression specification where I aggregate the data to the 4-digit SITC 1. I estimate a flexible regression similar to equation (14). I report the results in table (B.4) and figure (B.1) in the appendix for the case where I winsorize the data such that I assign a value 10 years for observations with missing PTI. In table (B.5) and figure (B.2) I report the result for the case where I delete the missing observations. Overall, the results are consistent with the baseline specification results.

6 Conclusion

This article contributes to the body of literature examining the sensitivity of US exports to destination-countries intellectual property rights. I employ both theoretical and empirical approaches in this work. Using a partial equilibrium model of firm's export destination decisions, I find predictions with respect to the spatial and sectoral consideration of US exports. In particular, the model predicts that the sensitivity of exports to destination-country patent reforms is concentrated in sectors with relatively shorter product time-to-imitation and longer lengths of product lifecycle.

I validate the theoretical predictions using a panel of US product-level export data in 37 SIC-3 sectors to 118 countries during the period 1989-2006. I construct a new index that captures a product time-to-imitation and merge this index with the export data, cross-sectional data on product lifecycle length, country-level panel data of patent protection index and GDP per capita. By interacting patent protection index with product time-to-imitation index and lifecycle length, I provide an explanation about the systematic variations in US export (measured by both export sales and quantity) patterns. The results provide evidence that cross-sector differences in product time-to-imitation are strong determinants of US export sensitivity to patent reforms in destination countries. I also find suggestive evidence that differences in product lifecycle length are determinants of US export sensitivity to patent reforms in destination countries. However, this evidence is not conclusive as its underlying coefficients becomes insignificant in some specifications.

Our finding suggests that patent laws affect the distribution of innovative sector goods available to individuals in an economy. This is likely to have an effect on consumption through availability of varieties and productivity of firms through its usage as imported inputs and machinery[32]. These findings are important in understanding factors that shape export patterns in the US.

[32] Halpern et al. (2015) finds that firms that use imported inputs are more productive that others, Koren and Csillag (2016) finds imported machinery to increase productivity of worker-firm matches

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7 Tables and Figures

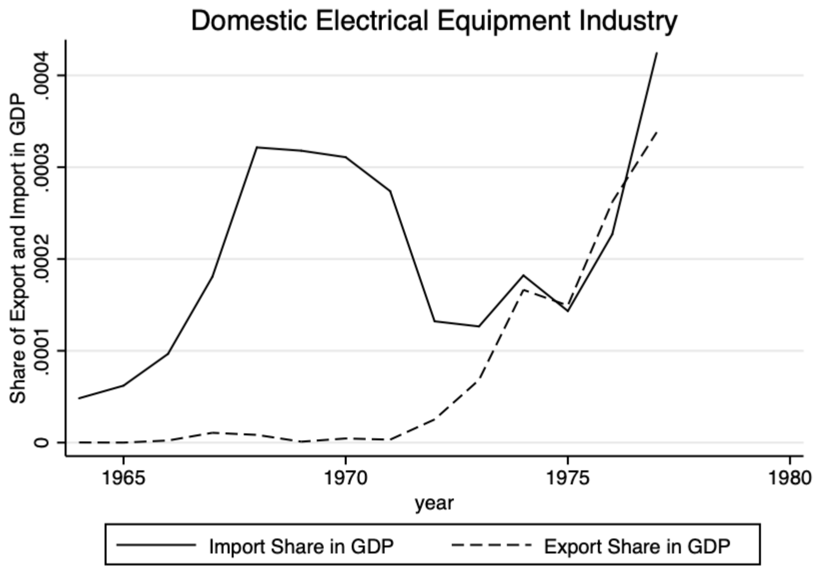


Figure 1: Domestic Electrical Equipment Industry

Figure 2: Pharmaceutical Goods Industry

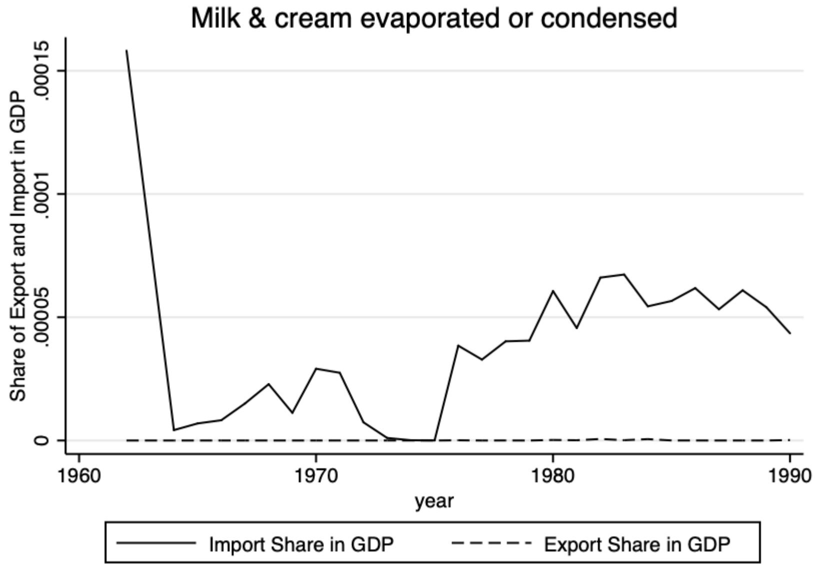


Figure 4: The Milk & Cream Evaporated or Condensed Industry

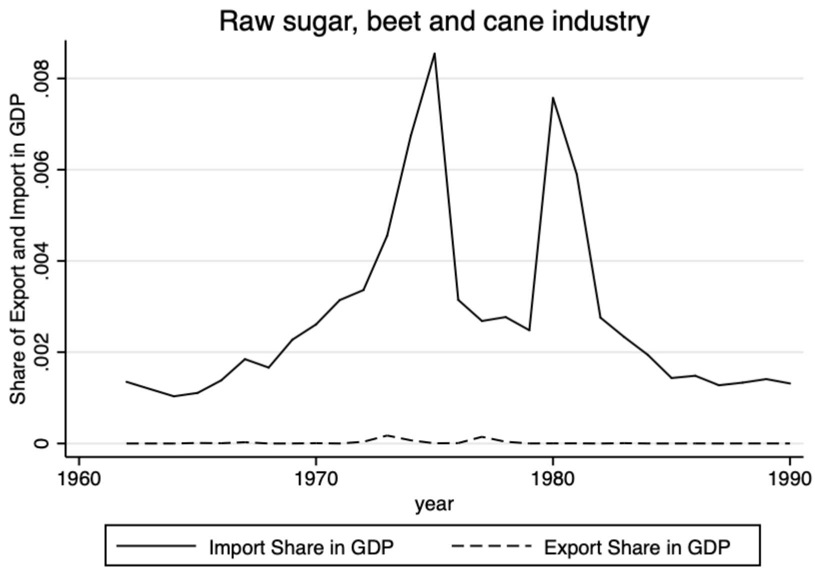


Figure 3: Raw Sugar, Beet & Cane Industry

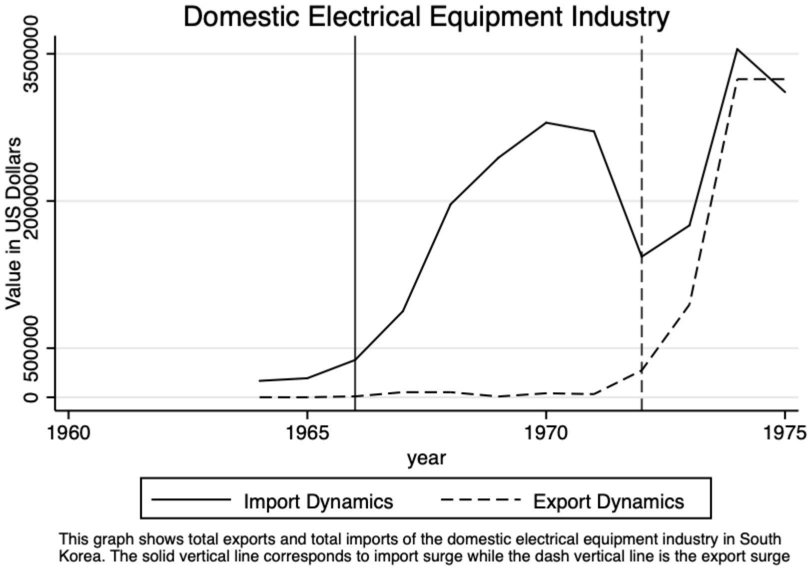


Figure 5: Domestic Electrical Equipment Industry

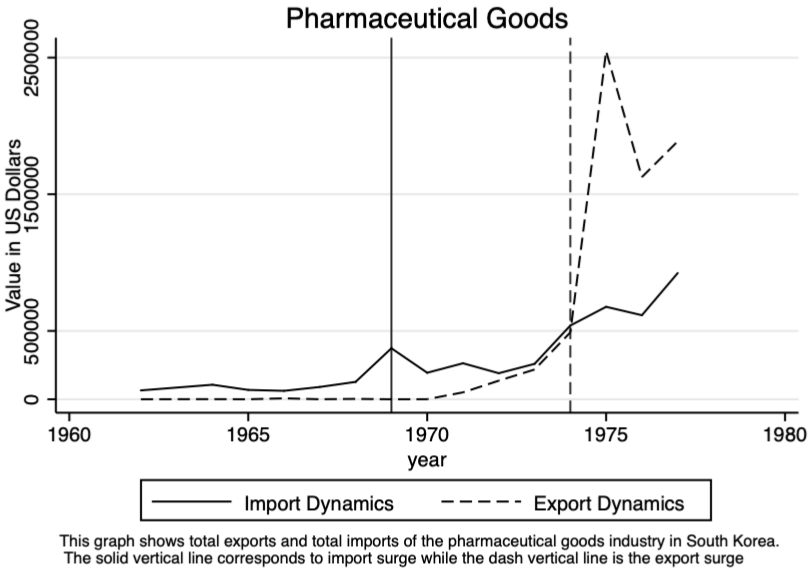


Figure 6: Pharmaceutical Goods Industry

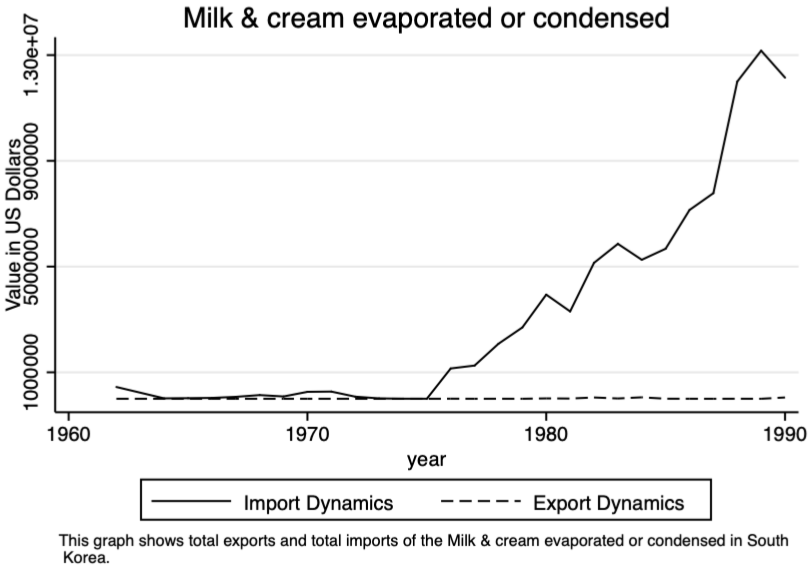


Figure 8: The Milk & Cream Evaporated or Condensed Industry

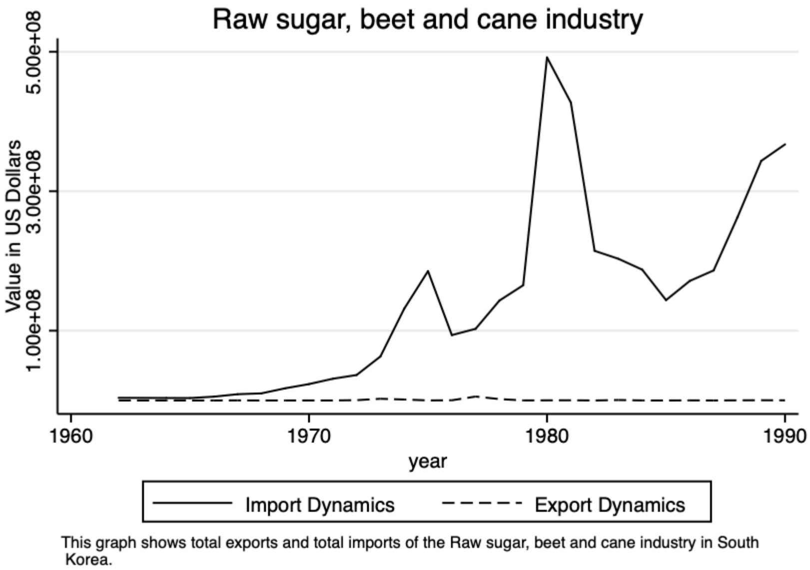


Figure 7: Raw Sugar, Beet & Cane Industry

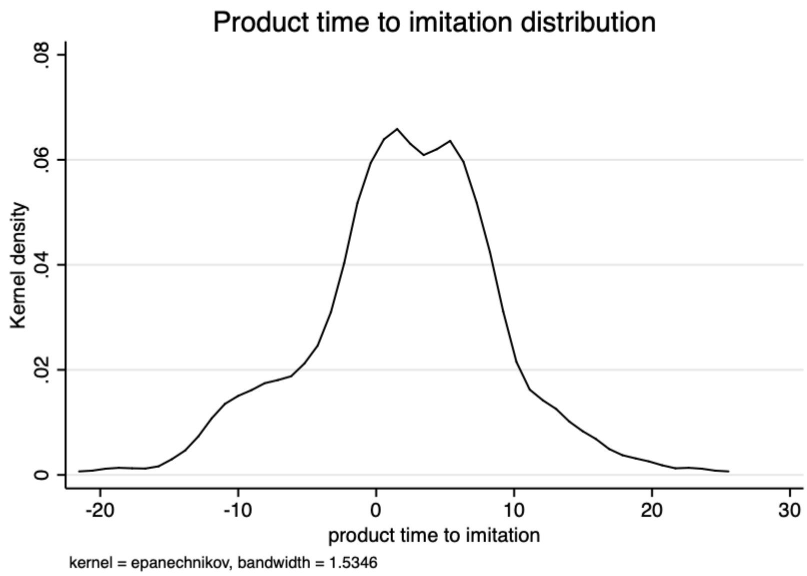


Figure 9: Distribution of Product Ease of Imitation

Table 1: Top 5 and Bottom 5 of Product Time-to-Imitation (PTI)

Top 5	PTI	Bottom 5 (Snapshot)	PTI
Alkaloids of opium,cocaine,caffein, quinine etc.	24	Television broadcast receivers	1
Railway locomotives, not steam or electric	18	Sugars & syrups incl.art. honey & caramel	1
Natural gums,resins,balsam and lacs	18	Perfumery & cosmetics, dentifrices etc.	1
Agricultural machinery and appliances, nes	18	Manufactured articles of wood nes	1
Waste of wool and of other animal hair, nes	16	Nails, tacks, staples, spikes, etc.	1

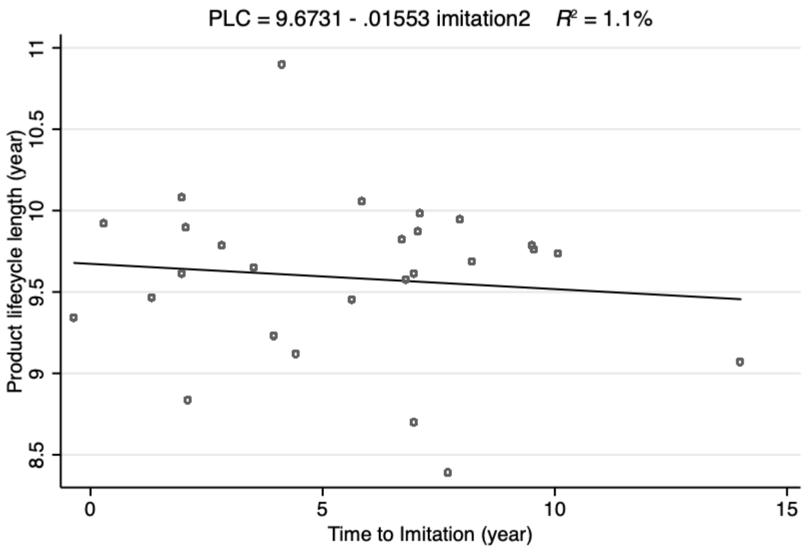
This tables shows the top 5 and bottom 5 of PTI for only products with positive time-to-imitation ($PTI > 0$). For the bottom 5, there are more than one product with 1 year of PTI. For preciseness, I randomly present 5 of such products.

Table 2: Top 5 and Bottom 5 of Product Lifecycle Length

Top 5	PLC	Bottom 5	PLC
Heating Equipment, except Electric etc.	10.89	Watches, Clocks, Clockwork operated devices	7.37
Metal Cans and shipping Containers	10.63	Computer and Office Equipment	8.38
Screw Machine Products, Bolts, Nuts, Screws	10.42	Agricultural Chemicals	8.69
Fabricated Structural Metal, Products	10.25	Electronic Components and accesories	8.83
Miscellaneous Fabricated Metal Product	10.08	Industrial Inorganic Chemicals	9.06

This tables shows the top 5 and bottom 5 of PLC. We present the entire products and their PLC in the appendix

Figure 10: Bin Scatter of Log of GDP per Capita on IPR



Graph shows a scatter plot and a fitted regression of product lifecycle length on time to imitation

Figure 11: Bin Scatter of Log of GDP per Capita on IPR

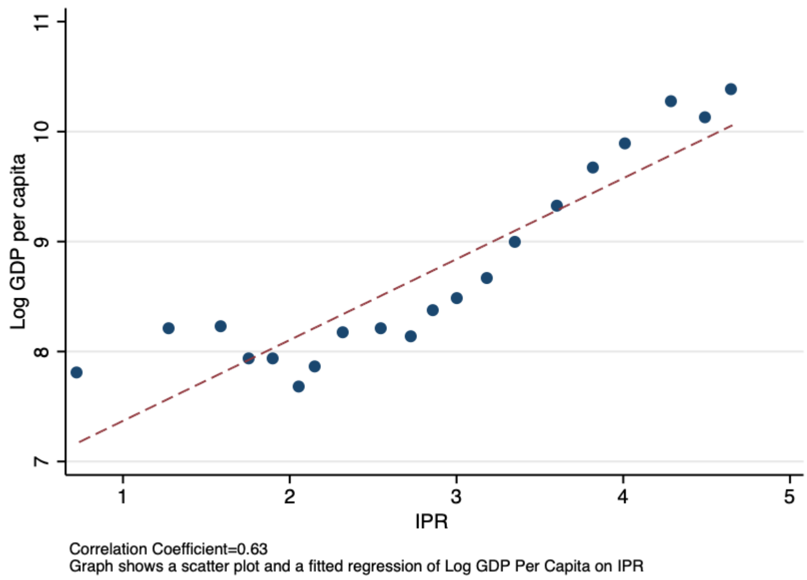


Figure 12: Bin Scatter of (Log of GDP per Capita x PTI) on (IPR x PTI)

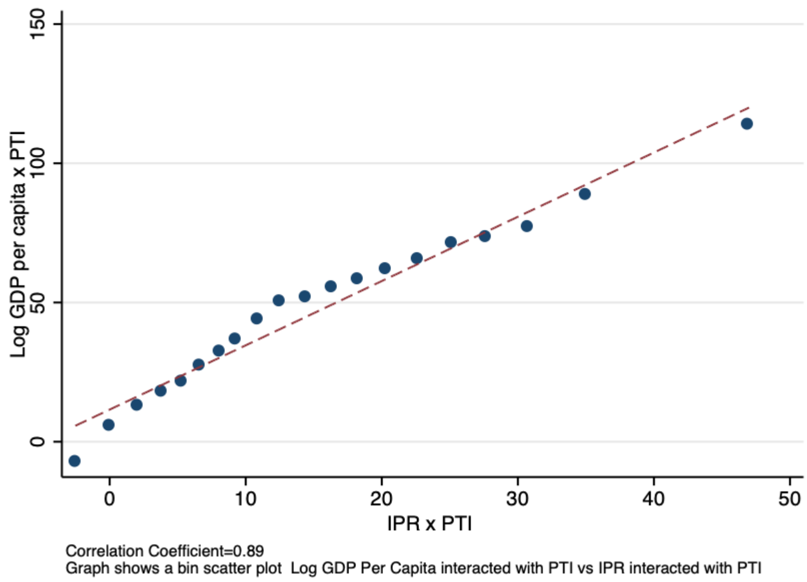


Figure 13: Distribution of product Lifecycle Length

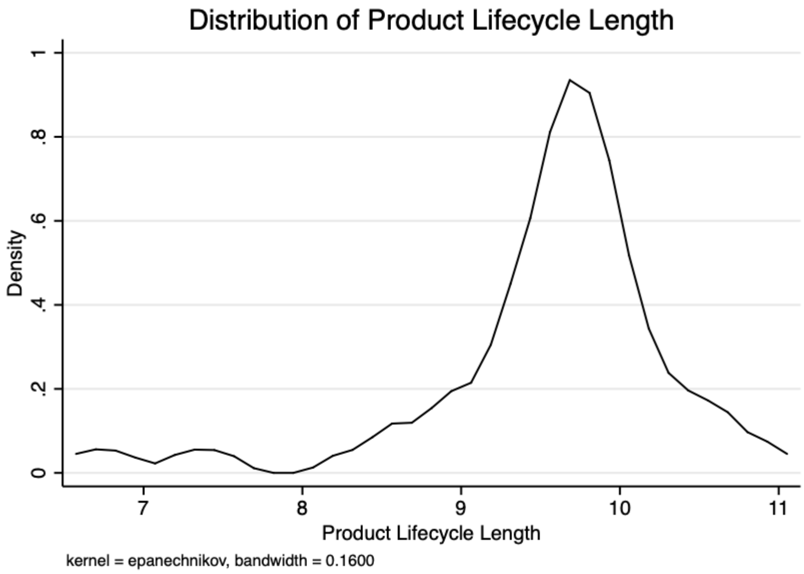


Table 3: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Value of Exports						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Patent	0.114	-0.461					
	(0.039)**	(0.235)+					
log GDPpc	1.216	1.210					
	(0.192)**	(0.192)**					
Patent x PTI	-0.006		-0.007		-0.007	-0.007	0.006
	(0.002)**		(0.002)**		(0.002)**	(0.002)**	(0.004)+
Patent x PLC		0.057		0.055	0.049	-0.018	-0.011
		(0.024)*		(0.031)+	(0.031)	(0.043)	(0.043)
log GDPpc x PLC						0.084	0.078
						(0.045)+	(0.044)+
log GDPpc x PTI							-0.007
							(0.002)**
$\text{Dummy}_{PTI \leq 0}$			-0.340	-0.266	-0.331	-0.320	-0.416
			(0.068)**	(0.067)**	(0.069)**	(0.070)**	(0.079)**
Industry, Year, Country FE	yes	yes	no	no	no	no	no
Industry-year FE	no	no	yes	yes	yes	yes	yes
Country-year FE	no	no	yes	yes	yes	yes	yes
Observations	40180	40180	40180	40180	40180	40180	40180
R squared	0.849	0.849	0.875	0.875	0.875	0.875	0.876

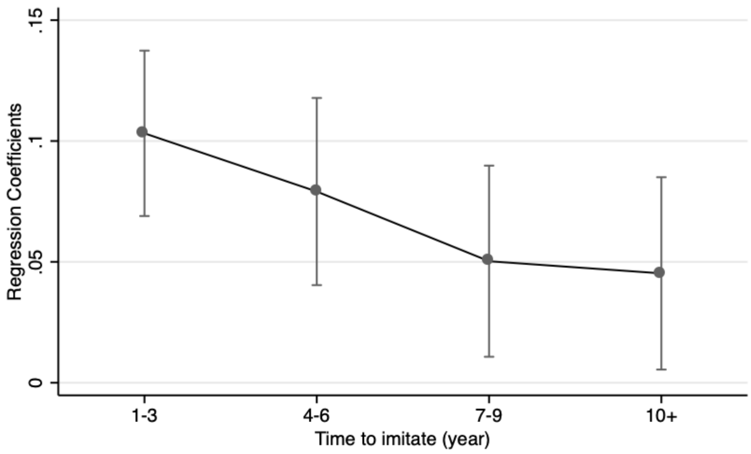
Notes: This table report the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_3 IPR_{it} \times P_j + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$. The sample period is 1989-2006 and observations for South Korea was omitted in the regression. In column (1) and (2), I control for industry FE, year FE, and country FE. In the remaining columns, I control for Industry-year FE and Country-year FE. Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 4: Country Patent Laws and US Exports - Diminishing Effects

	Dependent Variable: Log Value of Exports					
	(1)	(2)	(3)	(4)	(5)	(6)
	Adding quadratic terms					
Patent x PTI	-0.027		-0.026	-0.026		
	(0.004)**		(0.004)**	(0.004)**		
Patent x PTI^2	0.002		0.002	0.002		
	(0.000)**		(0.000)**	(0.000)**		
Patent x PLC		0.400	0.564	0.810		
		(0.608)	(0.593)	(0.859)		
Patent x PLC^2		-0.018	-0.027	-0.044		
		(0.033)	(0.032)	(0.046)		
log GDPpc x PLC				-0.360		
				(0.930)		
log GDPpc x PLC^2				0.023		
				(0.051)		
	Flexible Regression					
Patent x $\mathbf{I}_{\{1\leq PTI\leq 3\}}$					0.104	
					(0.021)**	
Patent x $\mathbf{I}_{\{3<PTI\leq 6\}}$					0.080	
					(0.024)**	
Patent x $\mathbf{I}_{\{6<PTI\leq 9\}}$					0.050	
					(0.024)*	
Patent x $\mathbf{I}_{\{PTI>9\}}$					0.047	
					(0.024)$^{+}$	
Patent x Q_2						0.054
						(0.029)$^{+}$
Patent x Q_3						0.105
						(0.029)**
Patent x Q_4						-0.084
						(0.040)*
Industry-year FE	yes	yes	yes	yes	yes	yes
Country-year FE	yes	yes	yes	yes	no	no
Country FE	no	no	no	no	yes	yes
Observations	40180	40180	40180	40180	40180	40180
R squared	0.875	0.875	0.876	0.876	0.854	0.854

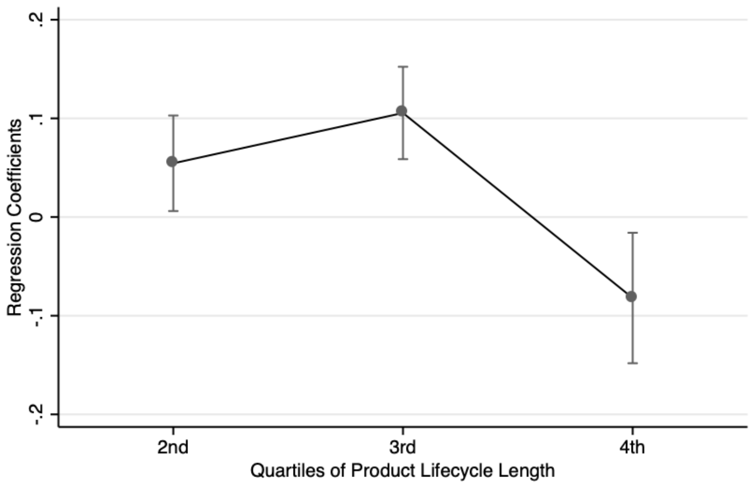
Notes: Columns (1-4) reports the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_2 IPR_{it} \times T_j^2 + \beta_3 IPR_{it} \times P_j + \beta_4 IPR_{it} \times P_j^2 + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$. In column (5), I report results of a regression of log exports value on IPR interacted with dummies corresponding to different groups of PTI. I create these groups by splitting PTI into 5 groups (PTI$<$1, $1 \leq PTI \leq 3$, $4 \leq PTI \leq 6$, $6 \leq PTI \leq 9$, $PTI > 9$). The reference is $PTI < 1$. In column (6), I report results of a regression of log exports value on IPR interacted with dummies corresponding to different quartiles of PLC. The reference is quartile 1 (Q_1). The sample period is same as in table (3). Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Figure 14: Log exports value on IPR interacted with cutoffs of PTI



Notes
Graph of coefficients of a flexible regression. I regress log export value on IPR interacted with dummies that represent different cutoffs of PTI. Cutoff 1-3 represents 1<=PTI<=3; Cutoff 4-6 represents 3<PTI<=6; Cutoff 7-9 represents 6<PTI<=9; and Cutoff 10+ represents PTI>9. The reference cutoff is PTI<1

Figure 15: Regression of Exports on Patents interacted with PLC Quartiles



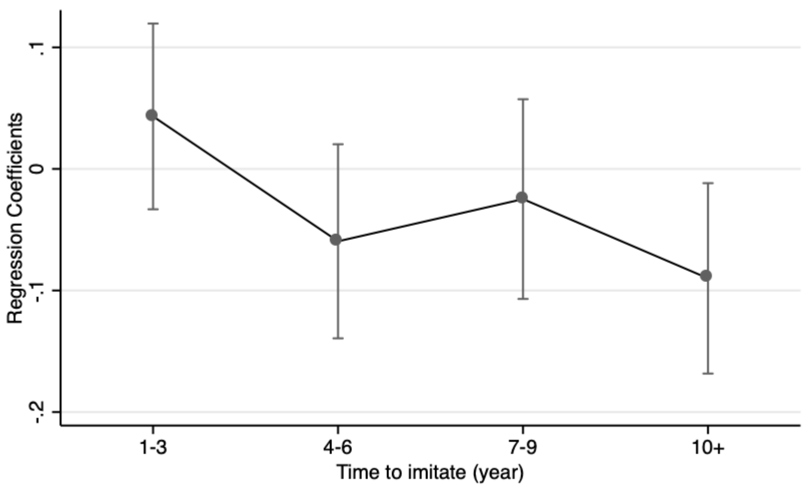
Notes
Graph of coefficients of a flexible regression. I regress log export value on IPR interacted with dummies quartiles of product lifecycle length. The first quartile is the reference quartile

Table 5: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Export Quantity					
	(1)	(2)	(3)	(4)	(5)	(6)
Patent	0.132	-2.509				
	(0.091)	(0.498)**				
Patent x PTI	-0.005		-0.008		-0.006	-0.006
	(0.003)$^{+}$		(0.004)*		(0.003)*	(0.004)
Patent x PLC		0.273		0.230	0.225	0.059
		(0.049)**		(0.064)**	(0.024)**	(0.086)
log GDPpc	1.321	1.312				
	(0.365)**	(0.364)**				
log GDPpc x PLC						0.207
						(0.089)*
Dummy$_{PTI \leq 0}$			0.125	0.220	0.166	0.189
			(0.117)	(0.120)$^{+}$	(0.085)$^{+}$	(0.123)
Industry, Year, Country FE	yes	yes	no	no	no	no
Industry-year FE	no	no	yes	yes	yes	yes
Country-year FE	no	no	yes	yes	yes	yes
Observations	40281	40281	40281	40281	40281	40281
R squared	0.746	0.747	0.800	0.800	0.801	0.801

Notes: This table report the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_3 IPR_{it} \times P_j + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$, where Y_{ijt} is the export quantity. The sample period is 1989-2006. In column (1) and (2), I control for industry FE, year FE, and country FE. In the remaining columns, I control for Industry-year FE and Country-year FE. Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Figure 16: Log exports value on IPR interacted with cutoffs of PTI



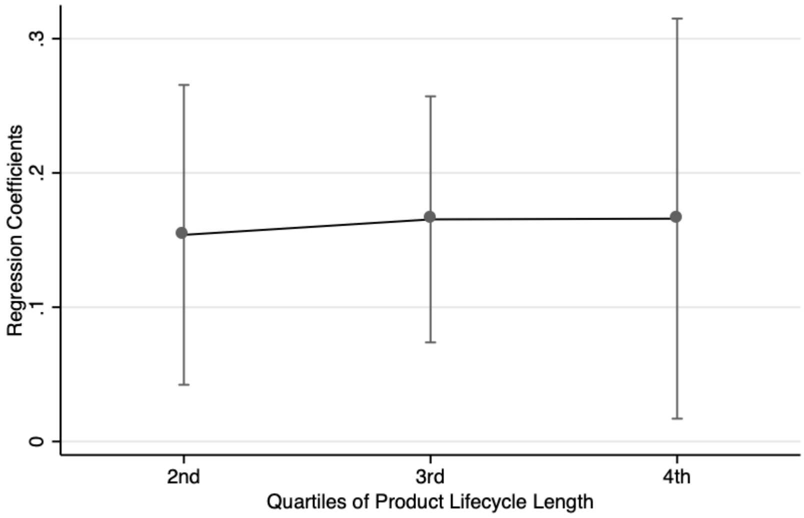
Notes
Graph of coefficients of a flexible regression. I regress log export quantity on IPR interacted with dummies that represent different cutoffs of PTI. Cutoff 1-3 represents 1<=PTI<=3; Cutoff 4-6 represents 3<PTI<=6; Cutoff 7-9 represents 6<PTI<=9; and Cutoff 10+ represents PTI>9. The reference cutoff is PTI<1

Table 6: Destination Country Patent Laws and US Exports

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Log Export Quantity					
	Adding quadratic terms					
Patent x PTI	-0.036		-0.033	-0.032		
	(0.007)**		(0.007)**	(0.007)**		
Patent x PTI^2	0.003		0.003	0.002		
	(0.001)**		(0.001)**	(0.001)**		
Patent x PLC		0.744	0.931	0.791		
		(1.307)	(1.291)	(1.466)		
Patent x PLC^2		-0.027	-0.038	-0.039		
		(0.071)	(0.070)	(0.080)		
log GDPpc x PLC				0.030		
				(1.627)		
log GDPpc x PLC^2				0.009		
				(0.089)		
	Flexible Regression					
Patent x $\mathbf{I}_{\{1\leq PTI\leq 3\}}$					0.019	
					(0.046)	
Patent x $\mathbf{I}_{\{3<PTI\leq 6\}}$					-0.087	
					(0.050)$^{+}$	
Patent x $\mathbf{I}_{\{6<PEI\leq 9\}}$					-0.050	
					(0.051)	
Patent x $\mathbf{I}_{\{PTI>9\}}$					-0.116	
					(0.049)*	
Patent x Q_2						0.154
						(0.056)**
Patent x Q_3						0.165
						(0.046)**
Patent x Q_4						0.166
						(0.075)*
Industry-year FE	yes	yes	yes	yes	yes	yes
Country-year FE	yes	yes	yes	yes	no	no
Country FE	no	no	no	no	yes	yes
Observations	40281	40281	40281	40281	40281	40281
R squared	0.800	0.801	0.801	0.801	0.748	0.766

Notes: Columns (1-4) reports the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_2 IPR_{it} \times T_j^2 + \beta_3 IPR_{it} \times P_j + \beta_4 IPR_{it} \times P_j^2 + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$. In column (5), I report results of a regression of log exports quantity on IPR interacted with dummies corresponding to different groups of PTI. I create these groups by splitting PTI into 5 groups (PTI<1, $1 \leq PTI \leq 3$, $4 \leq PTI \leq 6$, $6 \leq PTI \leq 9$, $PTI > 9$). The reference is $PTI < 1$. In column (6), I report results of a regression of log exports quantity on IPR interacted with dummies corresponding to different quartiles of PLC. The reference is quartile 1 (Q_1). The sample period is same as in table (5). Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Figure 17: Regression of Exports on Patents interacted with PLC Quartiles



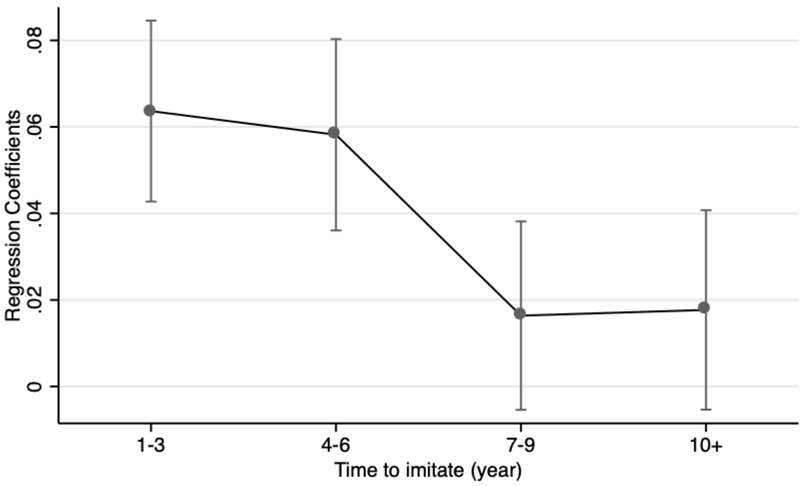
Notes
Graph of coefficients of a flexible regression. I regress log export quantity on IPR interacted with dummies quartiles of product lifecycle length. The first quartile is the reference quartile

Table 7: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Number of 10-Digit Products					
	(1)	(2)	(3)	(4)	(5)	(6)
Patent	0.055	0.108				
	(0.020)**	(0.089)				
log GDPpc	0.566	0.563				
	(0.091)**	(0.091)**				
Patent x PTI	-0.003		-0.003		-0.003	-0.003
	(0.001)**		(0.001)**		(0.001)**	(0.001)**
Patent x PLC		-0.007		-0.007	-0.010	-0.013
		(0.009)		(0.012)	(0.012)	(0.016)
log GDPpc x PLC						0.004
						(0.015)
$\text{Dummy}_{PTI\leq 0}$			-0.138	-0.109	-0.140	-0.139
			(0.033)**	(0.031)**	(0.033)**	(0.033)**
Industry, Year, Country FE	yes	yes	no	no	no	no
Industry-year FE	no	no	yes	yes	yes	yes
Country-year FE	no	no	yes	yes	yes	yes
Observations	40666	40666	40666	40666	40666	40666
R squared	0.858	0.858	0.885	0.885	0.885	0.885

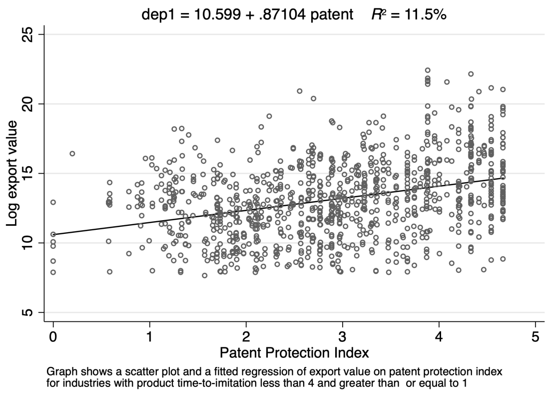
Notes: This table report the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_3 IPR_{it} \times P_j + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$, where Y_{ijt} is the number of products within each 3-digit SIC industry. The sample period is 1989-2006. In column (1) and (2), I control for industry FE, year FE, and country FE. In the remaining columns, I control for Industry-year FE and Country-year FE. Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Figure 18: Log exports value on IPR interacted with cutoffs of PTI

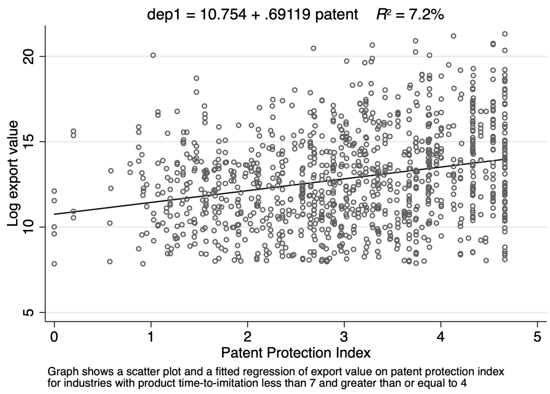


Notes
Graph of coefficients of a flexible regression. I regress log number of 10-digit products on IPR interacted withdummies that represent different cutoffs of PTI. Cutoff 1-3 represents 1<=PTI<=3; Cutoff 4-6represents 3<PTI<=6; Cutoff 7-9 represents 6<PTI<=9; and Cutoff 10+ represents PTI>9. The reference cutoff is PTI<1

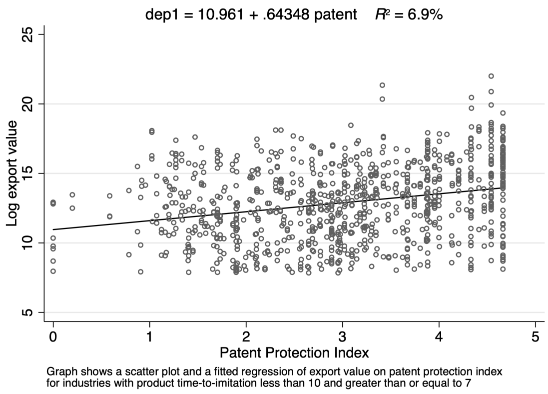
Appendix A Data Description



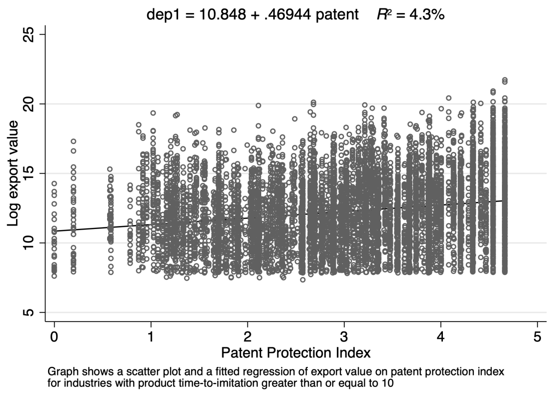
(a) Industry with $1 \leq PTI \leq 3$



(b) Industry with $4 \leq PTI \leq 6$



(c) Industry with $7 \leq PTI \leq 9$



(d) Industry with $PTI \geq 10$

Figure A.1: Scatter Plots: Log Exports vc Patent Index (By PTI Cutoffs)

Table A.1: Product Lifecycle length by Industry

SIC	Sector Name	Life-cycle length of Products (years)
281	Industrial Inorganic Chemicals	9.06
283	Drugs	9.11
284	Soap, Detergents, Cosmetics	9.22
285	Paints, Varnishes, Lacquers, Enamels	9.81
287	Agricultural Chemicals	8.69
289	Miscellaneous Chemical Products	9.73
331	Steel Works, Blast Furnaces, Mills	9.46
335	Rolling, Drawing, Extruding Of Metals	9.87
341	Metal Cans And Shipping Containers	10.63
342	Cutlery, Handtools, And General Hardware	10.41
343	Heating Equipment, Except Electric	10.89
344	Fabricated Structural Metal Products	10.25
345	Screw Machine Products, Bolts, Nuts, Screws	10.42
346	Metal Forgings And Stampings	9.63
349	Miscellaneous Fabricated Metal Products	10.08
351	Engines And Turbines	9.91
352	Farm And Garden Machinery And Equipment	9.78
353	Construction, Mining, And Materials Handling	10.05
354	Metalworking Machinery And Equipment	9.81
355	Special Industry Machinery, Except Metalworking	9.56
356	General Industrial Machinery And Equipment	9.44
357	Computer And Office Equipment	8.38
358	Refrigeration And Service Industry Machinery	9.98
359	Miscellaneous Industrial And Commercial	9.68
363	Household Appliances	9.78
364	Electric Lighting And Wiring Equipment	9.33
366	Communications Equipment	9.94
367	Electronic Components And Accessories	8.83
369	Miscellaneous Electrical Machinery, Equipment	9.88
371	Motor Vehicles And Motor Vehicle Equipment	9.64
379	Miscellaneous Transportation Equipment	9.6
381	Detection and Navigation Instruments, Equipment	9.42
384	Surgical, Medical, Dental Instruments And Supplies	9.75
386	Photographic Equipment And Supplies	9.61
387	Watches, Clocks, Clockwork Operated Devices	7.37

This table was taken from Bilir (2014a)

Figure A.2: Bin Scatter of (Log of GDP per Capita x PLC) on (IPR x PLC)

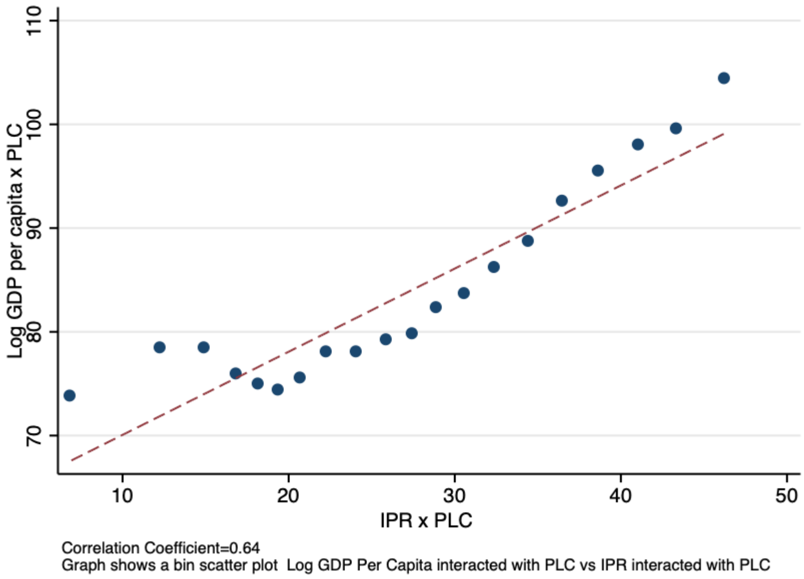
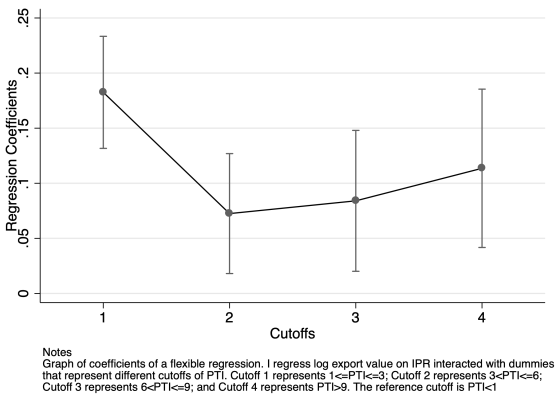


Table A.2: Countries, Quartile of Average Patent Protection Index and Average HDI

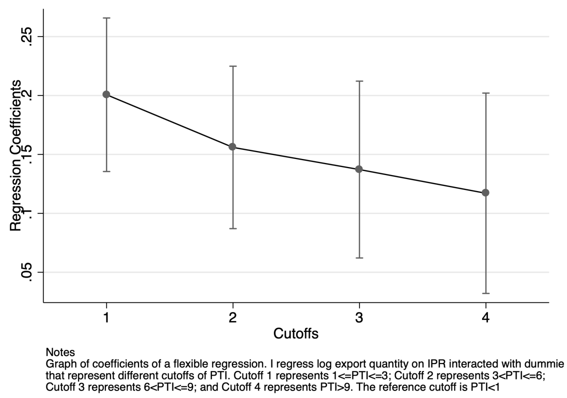
Countries in 1st Quartile Avg PPI. Avg. PPI =1.69 Avg. HDI = 0.48	Countries in 2nd Quartile Avg. PPI Avg. PPI =2.36 Avg. HDI = 0.51	Countries in 3rd Quartile Avg. PPI Avg. PPI = 2.99 Avg. HDI = 0.64	Countries in 4th Quartile Avg. PPI Avg. PPI =4.07 Avg. HDI = 0.82
Angola	Bolivia	Algeria	Australia
Benin	Brazil	Argentina	Austria
Bangladesh	Burkina Faso	Bulgaria	Belgium
Burma	Cameroon	Cyprus	Canada
Burundi	Chad	Ghana	Chile
Costa Rica	China	Haiti	Czech Republic
Egypt	Colombia	Hong Kong	Denmark
Ethiopia	Congo	Iceland	Finland
Guatamela	Central Africa	Israel	France
Guyana	Dominica Republic	Jamaica	Germany
Indonesia	Fiji	Lithuania	Greece
Iran	Gabon	Malaysia	Hungary
Iraq	Honduras	New Zealand	Ireland
Jordan	Ivory Coast	Nigeria	Italy
Liberia	Mali	Philippines	Japan
Madagascar	Malta	Poland	South Korea
Malawi	Mauritania	Portugal	Netherlands
Mazambique	Mexico	Romania	Norway
Mauritius	Morocco	EL Salvador	Russia
Nepal	Panama	Sierra Leone	Singapore
New Guinea	Peru	Slovakia	Spain
Nicaragua	Senegal	Sri Lanka	Sweden
Niger	Sudan	Taiwan	Switzerland
Pakistan	Tanzania	Trinidad & Tobago	South Africa
Paraguay	Togo	Turkey	United Kingdom
Rwanda	Tunisia	Uganda	Ukraine
India	Ecuador	Kenya	
Saudi Arabia	Uruguay		
Somalia	Venezuela		
Syria	Vietnam		
Thailand	Zimbabwe		
Zaire			
Zambia			

[a] HDI is human capital development data from.For each country, I took average of its HDI for years 1990-2005 consistent with the original data in this article. Finally I took the average of the averages for countries within each quartile of Average Patent Protection Index.
[b] PPI implies patent protection index.

Appendix B Additional Results

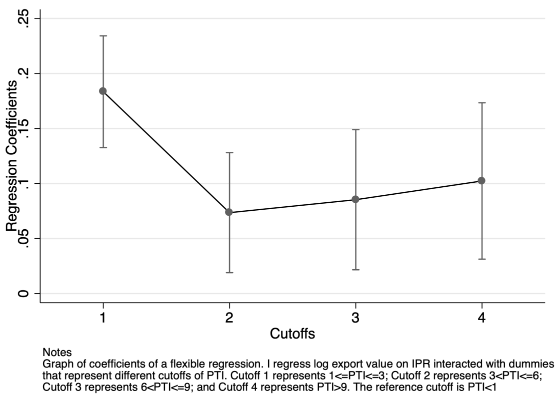


(a) Log Export value

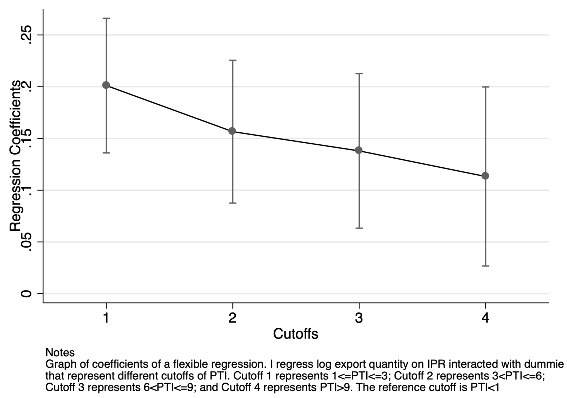


(b) Log Export Quantity

Figure B.1: Flexible Regression: Exports on IPR interacting Cutoffs of PTI



(a) Log Export value



(b) Log Export Quantity

Figure B.2: Flexible Regression: Exports on IPR interacting Cutoffs of PTI

Table B.1: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Number of 10 digit products					
	(1)	(2)	(3)	(4)	(5)	(6)
	Adding Quadratic terms					
Patent x PTI	-0.006		-0.006	-0.006		
	(0.002)**		(0.002)**	(0.002)**		
Patent x PTI2	0.000		0.000	0.000		
	(0.000)*		(0.000)*	(0.000)*		
Patent x PLC		-0.285	-0.252	0.003		
		(0.302)	(0.298)	(0.417)		
Patent x PLC2		0.015	0.013	-0.001		
		(0.016)	(0.016)	(0.022)		
log GDPpc x PLC				-0.326		
				(0.460)		
log GDPpc x PLC2				0.017		
				(0.025)		
	Flexible Regression					
Patent x $\mathbf{I}_{\{1\leq PEI\leq 3\}}$					0.064	
					(0.013)**	
Patent x $\mathbf{I}_{\{3<PEI\leq 6\}}$					0.058	
					(0.013)**	
Patent x $\mathbf{I}_{\{6<PEI\leq 9\}}$					0.016	
					(0.013)	
Patent x $\mathbf{I}_{\{PEI>9\}}$					0.018	
					(0.014)	
Patent x Q_2						0.078
						(0.017)**
Patent x Q_3						-0.036
						(0.013)**
Patent x Q_4						-0.019
						(0.015)
Industry-year FE	yes	yes	yes	yes	yes	yes
Country-year FE	yes	yes	yes	yes	no	no
Country FE	no	no	no	no	yes	yes
Observations	40666	40666	40666	40666	40666	40666
R squared	0.885	0.885	0.885	0.885	0.836	0.869

Notes: Columns (1-4) reports the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_2 IPR_{it} \times T_j^2 + \beta_3 IPR_{it} \times P_j + \beta_4 IPR_{it} \times P_j^2 + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$. In column (5), I report results of a regression of log exports quantity on IPR interacted with dummies corresponding to different groups of PTI. I create these groups by splitting PTI into 5 groups (PTI<1, $1 \leq PTI \leq 3$, $4 \leq PTI \leq 6$, $6 \leq PTI \leq 9$, $PTI > 9$). The reference is $PTI < 1$. In column (6), I report results of a regression of log exports quantity on IPR interacted with dummies corresponding to different quartiles of PLC. The reference is quartile 1 (Q_1). The sample period is same as in table (5). Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table B.2: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Value of Exports Sales							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent	0.094	0.120						
	(0.038)*	(0.039)**						
log GDPpc	1.126	1.128						
	(0.190)**	(0.190)**						
Patent x PEI		-0.005	-0.008	-0.008	-0.012	-0.012	-0.012	-0.012
		(0.002)*	(0.002)**	(0.002)**	(0.003)**	(0.003)**	(0.003)**	(0.003)**
Patent x PTI^2					0.000	0.000	0.000	0.000
					(0.000)*	(0.000)$^+$	(0.000)$^+$	(0.000)$^+$
Patent x PLC				0.074		0.071	0.383	0.602
				(0.033)*		(0.034)*	(0.600)	(0.867)
Patent x PLC^2							-0.016	-0.032
							(0.032)	(0.047)
log GDPpc x PLC								-0.330
								(0.948)
log GDPpc x PLC^2								0.022
								(0.052)
Dummy$_{PTI \leq 0}$			-0.381	-0.370	-0.403	-0.390	-0.391	-0.382
			(0.063)**	(0.062)**	(0.064)**	(0.065)**	(0.065)**	(0.064)**
Industry FE	yes	yes	yes	yes	yes	yes	yes	yes
Country-year FE	yes	yes	yes	yes	yes	yes	yes	yes
Observations	39371	39371	39371	39371	39371	39371	39371	39371
R squared	0.859	0.859	0.879	0.879	0.879	0.879	0.879	0.879

Sensitivity 1 Redefinition of export and import cutoff to \$500,000: This table report the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_2 IPR_{it} \times T_j^2 + \beta_3 IPR_{it} \times P_j + \beta_4 IPR_{it} \times P_j^2 + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$. The sample period is 1989-2006. Robust standard errors are clustered at the country level and appears below each estimate. $^+$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table B.3: Destination Country Patent Laws and US Exports

	Dependent Variable: Log Value of Export Quantity							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent	0.119	0.151						
	(0.090)	(0.090)$^+$						
log GDPpc	1.218	1.221						
	(0.364)**	(0.363)**						
Patent x PTI		-0.006	-0.007	-0.006	-0.017	-0.015	-0.015	-0.015
		(0.004)$^+$	(0.004)$^+$	(0.004)	(0.004)**	(0.004)**	(0.004)**	(0.004)**
Patent x PTI^2					0.001	0.001	0.001	0.001
					(0.000)**	(0.000)**	(0.000)**	(0.000)**
Patent x PLC				0.220		0.213	0.715	0.564
				(0.066)**		(0.066)**	(1.311)	(1.457)
Patent x PLC^2							-0.026	-0.027
							(0.071)	(0.079)
log GDPpc x PLC								0.049
								(1.634)
log GDPpc x PLC^2								0.008
								(0.089)
Dummy$_{PTI \leq 0}$			-0.157	-0.127	-0.217	-0.182	-0.182	-0.164
			(0.111)	(0.114)	(0.115)$^+$	(0.118)	(0.118)	(0.119)
Industry FE	yes	yes	yes	yes	yes	yes	yes	yes
Country-year FE	yes	yes	yes	yes	yes	yes	yes	yes
Observations	38991	38991	38991	38991	38991	38991	38991	38991
R squared	0.767	0.767	0.800	0.800	0.800	0.801	0.801	0.801

Sensitivity 1: This table report the results for the regression $ln(Y_{ijt}) = \beta + \beta_1 IPR_{it} \times T_j + \beta_2 IPR_{it} \times T_j^2 + \beta_3 IPR_{it} \times P_j + \beta_4 IPR_{it} \times P_j^2 + \eta_{it} + \eta_{jt} + \epsilon_{ijt}$. The sample period is 1989-2006. Robust standard errors are clustered at the country level and appears below each estimate. $^+$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table B.4: Flexible Regression: Country Patent Laws and US Exports

Dependent Variable:	Log Value of exports	Log exports quantity
	(1)	(2)
Patent x $\mathbf{I}_{\{1 \leq PEI \leq 3\}}$	0.183	0.201
	$(0.031)^{**}$	$(0.039)^{**}$
Patent x $\mathbf{I}_{\{3 < PTI \leq 6\}}$	0.072	0.156
	$(0.033)^{*}$	$(0.042)^{**}$
Patent x $\mathbf{I}_{\{6 < PTI \leq 9\}}$	0.084	0.137
	$(0.039)^{*}$	$(0.045)^{**}$
Patent x$\mathbf{I}_{\{PTI > 9\}}$	0.114	0.117
	$(0.043)^{**}$	$(0.051)^{*}$
Industry-Year FE	yes	yes
Country FE	yes	yes
Observations	118360	118360
R squared	0.696	0.754

This table reports the results for the flexible regression $\ln(Y_{ijt}) = \beta + \sum_{m=1}^{4} \beta_m IPR_{it} \times \mathbf{I}_{PTI_j \in S_{mT}} + \eta_{jt} + \eta_i + \epsilon_{ijt}$, when I interact dummies that correspond with different cutoffs of PTI with IPR index. The sample period is 1989-2006. I winsorized observations with missing PTI buy assuming it has a number equal or larger than 10. Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table B.5: Flexible Regression: Country Patent Laws and US Exports

Dependent Variable:	Log Value of exports	Log exports quantity
	(1)	(2)
Patent x $\mathbf{I}_{\{1 \leq PEI \leq 3\}}$	0.183	0.201
	$(0.031)^{**}$	$(0.039)^{**}$
Patent x$\mathbf{I}_{\{3 < PTI \leq 6\}}$	0.074	0.157
	$(0.033)^{*}$	$(0.042)^{**}$
Patent x $\mathbf{I}_{\{6 < PTI \leq 9\}}$	0.085	0.138
	$(0.038)^{*}$	$(0.045)^{**}$
Patent x $\mathbf{I}_{\{PTI > 9\}}$	0.102	0.113
	$(0.043)^{*}$	$(0.052)^{*}$
Industry-Year FE	yes	yes
Country FE	yes	yes
Observations	115698	115698
R squared	0.696	0.756

This table reports the results for the flexible regression $\ln(Y_{ijt}) = \beta + \sum_{m=1}^{4} \beta_m IPR_{it} \times \mathbf{I}_{PTI_j \in S_{mT}} + \eta_{jt} + \eta_i + \epsilon_{ijt}$, when I interact dummies that correspond with different cutoffs of PTI with IPR index. The sample period is 1989-2006. I dropped observations with missing PTI. Robust standard errors are clustered at the country level and appears below each estimate. $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Appendix C Additional Descriptive Statistics

Table (C.1), I document a number of facts with respect to product life-cycle length, patent protection and exporting. I start by partitioning countries according to their quartile of average patent protection index in columns (1-4) and column (5) consists of all countries. I have the number of countries in row (1) and each cell, say cell (1,1) (i.e. row-1, column-1) with 34 implies that there are 34 countries in the first quartile of countries classified by their average patent protection index. Total exports are in row (2) and in rows (3-6), I partition exports according to their quartile of product life-cycle length. For example, cell (3,1) implies that a total of \$81.9 Billion dollars of exports was sold to countries in the first quartile of average patent protection index. The percentage values in each cell in rows (3-6) is the change in total exports in a quartile of product life-cycle length relative to total exports in the first quartile of product life-cycle length[33]. I find a couple of relationships which I briefly summarise and discuss below.

Fact 1 *US exports to countries are non-monotonically increasing in country-level average patent protection index both in aggregate exports and in exports partitioned by their product life-cycle length.*

While the number of countries in each quartile of patent protection index is somewhat symmetric (row 1), I observe that the total exports across these destinations varies largely in patent protection index. This is also true when I consider average exports to a country (i.e. divide row 2 by row 1). US exports are increasing non-monotonically in countries with stronger patent laws. Even when we partition US total exports by quartiles of their product life-cycle length, I still find this pattern (Table C.1 row 3-6). For example, in cell (2,3), I observe that these countries receive a total US exports of \$561 Bn compared to \$1,000 Bn in cell (2,2), however this amount is larger than the amount \$235 Bn for countries in the first quartile - cell (2,1). This pattern persist when I breakdown exported

[33]For example, in cell (4,1), -25.64% is computed as $\frac{60.9-81.9}{81.9}$. Similar reasoning is applied for other cells

products into quartiles of the product life-cycle length. This is not very surprising since the imitation risk is likely the highest within these group of countries. I show that countries in the third quartile of average patent protection includes two Chinese provinces Hong Kong and Taiwan etc (see table Table A.2), which has been in the forefront of public debate on duplicative imitation[34].

Fact 2 *US exports is non-monotonically decreasing in product life-cycle length across all countries and within countries in different quartiles of patent protection index. Moreover, the sensitivity of exports to product life-cycle length depends on the level of patent protection index.*

In column 5, row 3-6 of Table (C.1), I observe that total US exports is sensitive to product life-cycle length - decreasing as product life-cycle increases. This pattern persists for each subsample of countries partitioned according to the quartile of their patent protection index (rows 3-6, columns 1-4). Comparing total exports to all countries between products in the first, second, third and fourth quartiles of product life-cycle length (Table C.1, column 5), I observe a decrease of 14.89%, 51.44% and 58.30% respectively.

Additionally, export of products with longer product life-cycle length reacts differently across the quartiles of country's patent protection index. Strongest for countries in the third quartile of average patent index and weaker in other quartiles. For example, in cell (4,3), there is a 66.23% drop in exports of products in the second quartile of product life-cycle length when compared with exports in the first quartile of product life-cycle length-cell(3,3). Comparing this with countries in the first, second and fourth quartiles of patent protection index (Table (C.1) columns 1, 2 and 4), we see a lesser drop of 25.64%, 8.87% and 2.52%. Similar pattern emerges for products in the third and fourth quartile of product life-cycle length. This shows that the sensitivity of exports to product-life cycle length depends on the level of patent protection index; strongest for countries in the 3rd quartile of average patent index.

[34]For example see : http://www.businessinsider.com/most-counterfeit-goods-are-from-china-2013-6 http://www.businessinsider.com/donald-trump-accuses-china-massive-theft-intellectual-property-unfair-taxing-tawian-2016-12

Table C.1: US Exports by Product Life-Cycle and Country's Level of IPR Protection

	Countries in 1st Quartile of avg. Patent Index (1)	Countries in 2nd Quartile of avg. Patent Index (2)	Countries in 3rd Quartile of avg. Patent Index (3)	Countries in 4th Quartile of avg. Patent Index (4)	All Countries in Sample (5)
Number	34	31	27	27	119
Total Exports (89 -06) ($Bn)	235	1000	561	3450	5250
Exports (89 -06) ($Bn)1st Quartile Product life-cycle	81.9	327	308	1190	1906.9
Exports (89 -06) ($Bn)2nd Quartile Product life-cycle	60.9 -25.64%	298 -8.87%	104 -66.23%	1160 -2.52 %	1622.9 -14.89%
Exports (89 -06) ($Bn)3rd Quartile Product life-cycle	38.2 -53.36%	185 -43.43%	70.7 -77.05%	632 -46.89%	925.9 -51.44%
Exports (89 -06) ($Bn)4th Quartile Product life-cycle	54.1 -33.94%	193 -40.98%	79.0 -74.35%	469 -60.59%	795.1 -58.30%

This table shows the total US exports of products by quartile of product life-cycle to different groups of countries defined by their product life-cycle. All values are in Billion US dollars. Due to some approximation errors, the values in rows 4, 5, 6 and 7 of column 6 do not add up exactly as the values in column row 3 column 6. Percentage decreases is computing the change from quartile 1-product life cycle value of exports to its corresponding current value of export.