Intellectual Property Protection and Patterns of Trade[*]

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November 11, 2009

Abstract

The paper provides a simple theoretical model for understanding how the difference in the level of intellectual property rights protection determines trade patterns. In particular, I examine how countries' levels of patent rights protection affect exports in industries with different degrees of reliance on innovation. In contrast to most models of institutional comparative advantage, which predict that countries with superior institutions specialize in industries that are very dependent on institutions, I show that higher patent rights protection does not necessarily lead to specialization in industries that rely heavily on innovation. There may exist a threshold beyond which occurs a reversal of specialization patterns, a consequence of monopoly power inherent in intellectual property rights protection. I then use the model's implications to assess empirically whether such predicted patterns hold in cross-country trade data and find evidence for general patterns of specialization as well as a reversal of such patterns among countries with high levels of patent rights protection.

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[*] I would like to thank Gene Grossman, Marc Melitz, and Esteban Rossi-Hansberg for their advice and guidance throughout. I am also grateful to Alfonso Cebreros, Arpita Chatterjee, Rafael Dix Carneiro, Jan de Loecker, and Satoru Shimizu, as well as other participants of the student trade workshop for their valuable comments, and the Center for Economic Policy Studies Fellowship and the International Economics Section Summer Fellowship for research support.

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1 Introduction

The past few decades have witnessed significant improvements in the standards of intellectual property rights protection throughout the world. Some of these improvements were matters of domestic policy, designed to stimulate local invention through broader patent coverage or stricter patent rights enforcement, while others stemmed from international pressure, as developed countries imposed minimum standards of intellectual property protection on developing countries as requirements for joining trade agreements. One of the prime examples is the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which has a list of minimum standards concerning different types of intellectual property protection that WTO members had to adopt within certain time frames.

While higher standards of intellectual property protection are likely to foster further innovation in the economy as a whole, it is evident that the effect of intellectual property policy varies from one industry to another, depending on how significant a role innovation plays in each industry. This paper provides a simple theoretical model for understanding how the difference in the level of intellectual property rights protection determines trade patterns in different industries. In particular, I examine how countries' levels of patent rights protection affect exports in industries with different degrees of reliance on innovation. In contrast to most models of institutional comparative advantage, which predict that countries with superior institutions specialize in industries that are very dependent on institutions, I show that higher patent rights protection does not necessarily lead to specialization in industries that rely heavily on innovation. There may exist a threshold beyond which occurs a reversal of specialization patterns, a consequence of monopoly power inherent in intellectual property rights protection.

The theoretical model is a Ricardian model with a continuum of goods, whereby production of different goods employs labor and sector-specific intermediate goods in different intensities. Intermediate goods need to be invented and the formulation of the invention process is based on Grossman and Lai (2004). I find that among countries with low levels of patent rights protection, which correspond to most developing countries, countries with relatively high protection specialize in industries that are innovation-intensive, while countries with very low protection specialize in industries that are non-innovation-intensive. In contrast, the pattern may be reverse among countries with high levels of patent rights protection; countries with especially high protection specialize in industries that are non-innovation-intensive, while countries with only reasonably high protection specialize in industries that are innovation-intensive. The rationale behind this reverse pattern is that while higher patent rights protection encourages innovation activities, the enforcement that accompanies such protection is embodied in higher prices of patented products. On one hand, higher innovation activities reduce the prices of final goods through the availability of more varieties of intermediate goods (variety effect). The increase in intermediate varieties is, however, tempered by the fact that more varieties imply lower equilibrium output per variety (crowding effect), which lowers innovating firms' expected profits. On the other hand, increasing patent rights protection puts an upward pressure on final good prices through higher markups of patented products (market power effect).

Since the variety effect is subject to diminishing returns to labor in research and development, raising the level of patent rights protection has a smaller impact on the creation of new varieties, the higher the initial level of protection. Meanwhile, the market power effect is not subject to any diminishing returns; a higher level of patent rights protection increases final good prices by simply raising the fraction of intermediate varieties that are protected. This is precisely why the market power effect may dominate the variety effect at high levels of protection, leading to a reversal of specialization patterns among countries with superior patent protection.

In the context of optimal patent policy, the dichotomy between the variety effect and the market power effect is better known as the trade-off between under-provision and monopoly distortions. As pointed out by Nordhaus (1969), central to optimal patent policy is the fact that insufficient patent protection leads to sub-optimal levels of innovation while excessive patent protection lowers consumer welfare through the monopolistic price setting of patent owners. Instead of studying optimal patent policy, as in Gilbert and Shapiro (1990) or Grossman and Lai (2004), my model takes countries' patent policies as given and derives patterns of trade that arise from the difference in those policies.

I then use the model's implications to assess whether such predicted patterns appear in cross-country trade data from 1980 to 1995. I make extensive use of the patent database provided by the United States Patent and Trademark Office (USPTO) to construct proxies for innovation intensity in different industries. For measures of patent rights protection across countries, I use the patent rights protection index developed by Ginarte and Park (1997) as well as information on patent reform episodes that occurred during the sample period. I found evidence for general patterns of specialization as well as a reversal of such patterns among countries with high levels of patent rights protection.

It is well-known that the adoption of intellectual property standards is subject to domestic influence in the form of lobby groups and various government policies as well as foreign influence, often as prerequisites for joining trade agreements. In view of these factors, I control for the potential endogeneity issue by adopting the instrumental variable approach, using legal origins as proxies for the level of patent rights protection, and find similar results.

Recently there has been a significant body of literature on institutional sources of comparative advantage, the manifestations of which include financial market development, contractual enforcement, intellectual property rights, among others. Rajan and Zingales (1998) examines whether financial development facilitates economic growth. Their hypothesis is that industries that are very dependent on external financing develop faster in countries in which the financial system is well-developed. The empirical finding corroborates this, despite the potential bias in estimates due to omitted variables and, more importantly, reverse causality. Nunn (2007) looks at how contractual enforcement affects export volumes. He tests whether industries in which products use inputs that require sizeable numbers of relationship-specific investments export more in countries with good contractual enforcement, and finds that contractual enforcement explains patterns of trade very well, in fact better than physical capital and human capital combined. Cunat and Melitz (2007) develops a model that links labor market flexibility, industry volatility, and trade flows, and find that countries with more flexible labor markets display a comparative advantage in industries that are subject to high-variance shocks. Similarly, Manova (2008) studies the impact of financial liberalization on exports patterns and finds that liberalization increases exports disproportionately in financially vulnerable industries, those that rely heavily on external finance.

This paper focuses on a particular legal channel through which the institutional setting can influence trade patterns across industries, namely intellectual property rights protection. The empirical literature on this channel includes Maskus and Penubarti (1995), which studies whether different levels of patent rights protection across countries influence bilateral trade flows, using an estimation approach based on an augmented version of the Helpman-Krugman bilateral gross imports equations. They find that stronger patent rights protection leads to higher bilateral imports.

Similarly, Smith (1999) studies whether weak patent rights are barriers to US exports. Specifically, she uses a commodity version of the gravity model to examine the effect of differences in patent rights standards on the volumes of bilateral trade between the US (exporter) and other countries (importers). The analysis also takes into account the degree of threat of imitation by importing countries. Her finding is that export volumes depend on patent rights standards; weak patent rights discourage US exports to countries that pose a strong threat of imitation. Fink and Primo Braga (1998) evaluates the effect of patent rights protection on two types of trade flows: non-fuel trade aggregate and high technology trade. Their results confirm previous findings of a positive link between patent rights protection and trade flows for non-fuel trade aggregate but do not find any significant effect of patent rights protection on high technology trade.

Most studies on the importance of intellectual property rights make use of the gravity equation and focus on bilateral trade. In Maskus and Penubarti (1995), industrial bilateral trade is estimated as a function of the exporter's industrial output and the importer's market size, strength of patent enforcement, and trade-resistance measures. Meanwhile, Smith (1999) uses the gravity specification; her key explanatory variables are the relative differences in patent rights between two regions.

This paper also uses each country's quality of patent rights protection as a key variable. However, in order to see the effects that patent rights protection has on different industries, we need to take into consideration each industry's relative dependence on patent rights protection. It is therefore the interaction between a country's overall level of patent rights protection and patent intensities of different industries that ultimately drives patterns of trade flows.

On the theoretical front, there are several studies that show mechanisms by which countries that are different in some institutional aspect specialize in different industries. Nunn (2005) studies how countries' different contracting environments affect specialization patterns. With industries heterogeneous in the degree of reliance on relationship-specific investments, he finds that countries with better contracting environments specialize in industries that are more reliant on relationship-specific investments. Addressing labor market flexibility, Cunat and Melitz (2007) presents a framework in which within-industry dispersion of shocks is different across industries and find that countries with more flexible labor markets specialize in industries with high volatility. In Costinot (2009b), the dimension along which industries differ is complexity, defined as the number of tasks required for production. He finds that countries that have better institutions specialize in more complex industries; these are industries that require a high degree of coordination among many workers, and countries with superior judicial systems, through better contract enforcement, are more able in forming larger teams of workers.

These studies, as well as this paper, derive patterns of trade by using the Dornbusch-Fischer-Samuelson structure of a continuum of industries and obtaining Ricardian sources of comparative advantage through exogenous differences in institutional quality.[1] Costinot (2009a) presents an unifying theory for this class of models, using the mathematical concept of log-supermodularity of country-level and sector-level characteristics to generate patterns of trade. However, contrary to most studies on institutional comparative advantage, my paper demonstrates that when the institution in question is the protection of intellectual property rights, we may observe a reversal of specialization patterns.[2]

The modeling of product innovation is based on Grossman and Lai (2004), which studies the determination of patent rights protection policies in a noncooperative framework. Their formulation of the innovation process and its corresponding market structure is used in the intermediate production stage of the economy in this paper, yielding closed-form solutions of the trading equilibrium.

The paper is organized as follows. Sections 2 outlines the theoretical model and Section 3 derives patterns of comparative advantage. Section 4 describes the estimating equation and identification strategies. Section 5 explains the data sources. Section 6 presents the main results and Section 7 reports the instrumental variable results. Section 8 studies the effect of patent reforms. Section 9 consists of robustness checks. Section 10 concludes.

2 Model

In this section, I construct a simple model to illustrate how the difference in the level of patent rights protection acts as a source of comparative advantage and determines trade patterns. Unlike

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[1] Alternatively, Chor (2009) develops a multi-country Ricardian model based on Eaton and Kortum (2002) to show that comparative advantage is jointly determined by country-level institutional strength and industry-level characteristics.

[2] In the context of Costinot (2009a), the aggregate output function in my model is not always log-supermodular in the quality of countries' patent rights protection and the levels of sectors' dependence on innovation.

most models of institutional comparative advantage, which predict that countries with superior institutions specialize in industries that are very dependent on institutions, I show that higher patent rights protection does not necessarily lead to specialization in industries that rely heavily on innovation. While higher protection encourages more innovation activity due to higher expected profits from invention, the fact that a greater fraction of innovation is protected implies higher average prices of patented products. The opposing effects of patent rights protection are key to understanding the non-monotonicity of specialization patterns.

The model is a Ricardian model with a continuum of sectors $z \in [0,1]$. There are two countries in the economy, H and F, which are identical in all aspects except for their levels of patent rights protection. The representative consumer maximizes the utility function

$$U(t) = \int_{v}^{\infty} u(v) e^{-rv} dv,$$

where $u(t) = \int_0^1 b(z) \ln q(z,t) dz$, $q(z,t)$ is the consumption of good z at time t, and r is the discount factor. The consumer spends the share $b(z)$ of his expenditure on good z, with $\int_0^1 b(z) dz = 1$.

The production of good z has constant returns to scale and takes the Cobb-Douglas form

$$F(L(z), I(z)) = L(z)^{\alpha(z)} X(z)^{1-\alpha(z)},$$

where $L(z)$ and $X(z)$ are the amounts of labor and aggregate intermediate input used in sector z. The share of expenditure on labor is $\alpha(z)$, where we assume $\alpha(z) \leq 1, \alpha'(z) > 0$; the second condition implies that high-z goods are labor-intensive relative to low-z goods. As will be introduced below, $X(z)$ represents the component of final good z that requires innovation. This production structure allows us to capture the fact that sectors are heterogeneous in their degrees of reliance on innovation.

The aggregate intermediate input is sector-specific and is defined as

$$X(z) = \left[\int_0^{n(z)} x(z,i)^{\rho} di \right]^{1/\rho},$$

where each $x(z,i)$ is an intermediate variety, $n(z)$ is an endogenous measure of sector-z varieties, and $\sigma = \frac{1}{1-\rho}$ is the elasticity of substitution among intermediate varieties, with $0 < \rho < 1$.

The production structure of intermediate varieties is based on Grossman and Lai (2004). The flow of new intermediate varieties suitable for sector z at time t is

$$\phi(z,t) = L_r(z,t)^{\beta} K(z,t)^{1-\beta},$$

where $L_r(z,t)$ is the amount of labor engaged in research and development (R&D) in sector z, $K(z,t)$ is the knowledge capital in sector z, and β is the share of labor in producing new varieties. This equation characterizes the R&D process that in equilibrium determines the measure of intermediate varieties available in sector z. The knowledge capital $K(z,t)$ can alternatively be thought of as the exogenous stock of fertile ideas from which inventions in sector z can flow. I make the assumption that, like all other variables in the model except the level of patent rights protection, $K(z,t)$ is identical in both countries, to highlight the channel through which different levels of patent rights protection affect specialization patterns: intermediate varieties.[3]

A Cobb-Douglas production function, as opposed to a linear production function, is chosen for the intermediate variety production stage to introduce diminishing marginal returns to labor in creating new varieties. I will show below that β, which captures the degree of diminishing returns to labor in R&D, is crucial in determining the direction of trade patterns because it governs the strength of the variety effect relative to that of the market power effect.

Each intermediate variety has finite economic life τ. A new intermediate variety is useful in the production of final goods for a period of τ from the time of its creation and its value drops to zero after a period of τ has elapsed.

Patent rights protection in this model applies to intermediate varieties. To fix ideas, we can think of intermediate varieties as production processes and each patent as a "process patent," as opposed to a "design patent."[4] Heterogeneity in the quality of patent rights protection can take many forms, such as patent length, patent rights enforcement, or participation in international agreements. Without loss of generality, I focus on patent rights enforcement as the dimension in which countries differ regarding patent rights protection and therefore assume that patent length is greater than the economic life of intermediate varieties, so that patent length is of no relevance

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[3] Allowing for $K(z,t)$ to differ between two countries only adds one more parameter, relative knowledge capital $\frac{K_H(z,t)}{K_F(z,t)}$, to the determination of specialization patterns but generates the same qualitative results.

[4] Approximately 90% of patents in the USPTO patent database are process patents. The rest are design patents and plant patents.

in the model. The probability that a patent is enforced by country c at any point in time is ω_c, where I assume that $\omega_H > \omega_F$. When a variety is under patent enforcement, the patent owner has exclusive rights to produce and sell the protected variety. When it is not, anyone can produce and sell the variety. Once a variety has been invented, the actual production of each variety requires one unit of labor for a units of output.

Final goods z are homogeneous and tradable, whereas intermediate varieties are differentiated and non-tradable.[5] The mechanisms that operate in the intermediate production stage capture parsimoniously how patent rights protection affects productivity.

3 Equilibrium

Since each final good z is homogeneous, it is produced by either H or F, depending on which country has a lower per-unit cost. If good z is produced in country c, there will be

$$n_c(z) = \tau\phi_c(z) = \tau L_{c,r}(z)^{\beta} K_c(z)^{1-\beta}$$

intermediate varieties. Note that time subscripts have been dropped because in equilibrium all variables are time-invariant after a period of τ has elapsed. For the $\omega_c n_c(z)$ varieties whose patent rights are enforced, each patent holder charges the markup price of $\frac{\mu}{a}w_c$ and earns a profit of $\pi_c(z) = \frac{\mu-1}{a}w_c x_c(z)$, where $\mu = \frac{1}{\rho}$, w_c is the wage in country c, and $x_c(z)$ is the output of a typical variety with an enforced patent. In contrast, the patent rights of the other $(1-\omega_c)n_c(z)$ varieties are not enforced, so any firm can produce them. These firms charge the competitive price of $\frac{1}{a}w_c$.

Profit maximization implies that the marginal value product of labor in the R&D sector is equal to the wage rate. Thus, we have

$$v_c(z)\beta L_{c,r}^{\beta-1}(z)K(z)^{1-\beta} = w_c,$$

where the value of a patent is the discounted value of expected profits,

$$v_c(z) = \omega_c \frac{1-e^{-r\tau}}{r}\frac{\mu-1}{a}w_c x_c(z).$$

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[5] The assumption of non-tradability of intermediate goods is not required for the qualitative results of the model but is adopted because it yields concise expressions that clearly illustrate the model's main mechanisms.

This implies that the amount of labor engaged in R&D in industry z is

$$L_{c,r}(z) = \left(\omega_c \frac{1-e^{-r\tau}}{r} \frac{\mu-1}{a} x_c(z)\beta K(z)^{1-\beta}\right)^{\frac{1}{1-\beta}} .$$

The equation above shows that a higher level of patent enforcement raises the value of a patent, thereby attracting more labor into R&D. Denoting $\psi(z) = \frac{1-e^{-r\tau}}{r}\frac{\mu-1}{a}\beta K(z)^{1-\beta}$, we can now express the number of intermediate varieties as

$$n_c(z) = \tau(\psi(z)\omega_c x_c(z))^{\frac{\beta}{1-\beta}}. \tag{1}$$

The price of the aggregate intermediate input $X_c(z)$ is

$$P_c(z) = \left[\omega_c n_c(z)(\frac{\mu}{a}w_c)^{1-\sigma} + (1-\omega_c)n_c(z)(\frac{1}{a}w_c)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} ,$$

with the first and second terms corresponding to enforced and non-enforced varieties, respectively. Taking the wage in country H as the numeraire and using (1), the relative price of the aggregate intermediate input in industry z is

$$\frac{P_H(z)}{P_F(z)} = \left(\frac{\omega_H}{\omega_F}\right)^{\frac{\beta}{1-\beta}\frac{1}{1-\sigma}} \left(\frac{x_H(z)}{x_F(z)}\right)^{\frac{\beta}{1-\beta}\frac{1}{1-\sigma}} \left(\frac{\omega_H(\mu^{1-\sigma}-1)+1}{\omega_F(\mu^{1-\sigma}-1)+1}\right)^{\frac{1}{1-\sigma}} \frac{1}{w}. \tag{2}$$

The above expression captures the three channels through which the level of patent rights protection affects the price of the aggregate intermediate input. First, the term $\left(\frac{\omega_H(\mu^{1-\sigma}-1)+1}{\omega_F(\mu^{1-\sigma}-1)+1}\right)^{\frac{1}{1-\sigma}}$ captures the market power effect, whereby a higher level of patent rights protection ensures enforcement of patent rights for a greater fraction of intermediate varieties. As a consequence, more varieties command markup prices, leading to an upward pressure on the price of the aggregate intermediate input. There is also the variety effect, represented by $\left(\frac{\omega_H}{\omega_F}\right)^{\frac{\beta}{1-\beta}\frac{1}{1-\sigma}}$; for a given level of output per variety $x_c(z)$, a higher degree of patent rights protection increases expected profits in the R&D sector due to a higher patent value, thereby attracting more labor into innovation activity and resulting in an increase in the number of intermediate varieties and a lower aggregate intermediate input price. Finally, the term $\left(\frac{x_H(z)}{x_F(z)}\right)^{\frac{\beta}{1-\beta}\frac{1}{1-\sigma}}$ captures the crowding effect, whereby a higher number of intermediate varieties–as a result of higher patent rights protection–implies fiercer competition among varieties and, generally, lower equilibrium output per variety. The crowding effect works against the variety effect by lowering expected profits of innovating firms, thereby reducing the incentive to invest in innovation.

In order to solve for the pattern of specialization, we need to characterize the relative price of final goods. Denoting $\widetilde{P}(z)$ as the price of good z, we specifically have to solve for $\frac{\widetilde{P}_H(z)}{\widetilde{P}_F(z)} = \left(\frac{P_H(z)}{P_F(z)}\right)^{1-\alpha(z)} \left(\frac{1}{w}\right)^{\alpha(z)}$. Using the fact that consumers spend the share $b(z)$ of their income on final good z, no matter where it is produced, we can express $\frac{x_H(z)}{x_F(z)}$, which determines the strength of the crowding effect, as $\frac{x_H(z)}{x_F(z)} = \left(\frac{\omega_H}{\omega_F}\right)^{-\beta} \left(\frac{\omega_H+(1-\omega_H)\mu^{\sigma\rho}}{\omega_F+(1-\omega_F)\mu^{\sigma\rho}}\right)^{-(1-\beta)} w^{1-\beta}$ and, combining with (2), finally obtain

$$\frac{\widetilde{P}_H(z)}{\widetilde{P}_F(z)} = \left[\left(\frac{\omega_H}{\omega_F}\right)^{\frac{\beta}{1-\sigma}} \left(\frac{\omega_H(\mu^{1-\sigma}-1)+1}{\omega_F(\mu^{1-\sigma}-1)+1}\right)^{\frac{1-\beta}{1-\sigma}} w^{\frac{\beta}{1-\sigma}}\right]^{1-\alpha(z)} \frac{1}{w}. \tag{3}$$

This expression, the relative price of final good z, pins down the pattern of specialization. Country H has comparative advantage and specializes in all industries z such that $\widetilde{P}_H(z) < \widetilde{P}_F(z)$, while country F has comparative advantage and specializes in all industries z such that $\widetilde{P}_H(z) > \widetilde{P}_F(z)$.

To close the model, note that the amount of labor used in the production of good z is

$$L(z) = L_f(z) + L_i(z)$$

where $L_f(z)$ is the amount of labor used by the final good producer of z and $L_i(z)$ is the amount of labor used in the production of intermediate varieties. The latter term can be broken down into the amount of labor used in R&D, denoted $L_r(z)$, the amount of labor used in the actual manufacturing of enforced intermediate varieties, denoted $L_{m,enf}(z)$, and the amount of labor used in the actual manufacturing of non-enforced intermediate varieties, denoted $L_{m,compet}(z)$. Then the labor market clearing condition for country c can be expressed as

$$L_c = \int_{z\in Z_c} (L_{c,f}(z) + L_{c,r}(z) + L_{c,m,enf}(z) + L_{c,m,compet}(z))dz,$$

where Z_c is the range of z in which country c specializes.

The final equilibrium condition equates savings and investment. Savings are the difference between national income, which equals $w_c \int_{z\in Z_c} L_c(z)dz + r\int_{z\in Z_c} K(z)dz + \int_{z\in Z_c} \omega_c n_c(z)\pi_c(z)dz$, and aggregate spending, denoted E_c, where $w_c \int_{z\in Z_c} L_c(z)dz$ is the income of workers, $r\int_{z\in Z_c} K(z)dz$

is the returns to the stock of fertile ideas, and $\int_{z\in Z_c} \omega_c n_c(z)\pi_c(z)dz$ is the profits of firms holding live patents. I assume that profits earned by patent owners are distributed to consumers equally, like government transfers. All investment is devoted to R&D and this activity has the cost of $w_c \int_{z\in Z_c} L_{r,c}(z)dz + r\int_{z\in Z_c} K(z)dz$. Therefore, we have

$$w_c \int_{z\in Z_c} L_c(z)dz + r\int_{z\in Z_c} K(z)dz + \int_{z\in Z_c} \omega_c n_c(z)\pi_c(z)dz - E_c = w_c \int_{z\in Z_c} L_{c,r}(z)dz + r\int_{z\in Z_c} K(z)dz.$$

We can now obtain the following results:

Proposition 1 *For any pair of arbitrary patent enforcement levels ω_H and ω_F, there exists a unique equilibrium.*

Proof. See Appendix. ■

Proposition 2 *For $\beta > \frac{\mu^\sigma-\mu}{\mu}$, H specializes in low-z goods (patent-intensive) and F specializes in high-z goods (non-patent-intensive).*

For $\beta < \frac{\mu^\sigma-\mu}{\mu}$, the pattern of specialization depends on ω_H and ω_F as follows:

- *If $\omega_H < \frac{\beta\mu}{\mu^\sigma-\mu}$ and $\omega_F < \frac{\beta\mu}{\mu^\sigma-\mu}$, then H specializes in low-z goods (patent-intensive) and F specializes in high-z goods (non-patent-intensive)*
- *If $\omega_H > \frac{\beta\mu}{\mu^\sigma-\mu}$ and $\omega_F > \frac{\beta\mu}{\mu^\sigma-\mu}$, then H specializes in high-z goods (non-patent-intensive) and F specializes in low-z goods (patent-intensive)*
- *Otherwise, the pattern is ambiguous and depends on fundamental variables β, σ, μ.*

Proof. See Appendix. ■

To understand the above results, it is useful to look at the behavior of $m(\omega_c, \sigma, \beta, \mu) \equiv \omega_c^{\frac{\beta}{1-\sigma}} \left(\omega_c(\mu^{1-\sigma}-1)+1\right)^{\frac{1-\beta}{1-\sigma}}$ from (3), which is the average labor requirement per unit of aggregate intermediate product. This term characterizes the interaction among the variety effect, the crowding effect, and the market power effect. Figure 1 shows the plot of $m(\omega_c, \sigma, \beta, \mu)$ when $\beta > \frac{\mu^\sigma-\mu}{\mu}$. In this range of β, note that $m(\omega_c, \sigma, \beta, \mu)$ is monotonically decreasing in ω_c. Intuitively, when the level of patent rights protection increases, innovating firms face an incentive to allocate more labor to the invention of intermediate varieties due to an increase in expected profits guaranteed by a more extensive enforcement of patent rights. The increase in the number of intermediate varieties, however, leads to lower equilibrium output per variety, which dampens the increase in expected profits. Meanwhile, a higher level of protection guarantees enforcement of patent rights for a greater fraction of varieties, resulting in an upward pressure on $m(\omega_c, \sigma, \beta, \mu)$. In this range of β, as the level of patent rights protection increases, the downward pressure on $m(\omega_c, \sigma, \beta, \mu)$ brought about by the net variety effect dominates the upward pressure due to the market power effect. As a result, the country with the higher level of patent rights protection has comparative advantage in innovation and specializes in patent-intensive goods, while the country with the lower level of patent rights protection specializes in non-patent-intensive goods.

When $\beta < \frac{\mu^\sigma - \mu}{\mu}$, however, $m(\omega_c, \sigma, \beta, \mu)$ is no longer monotonically decreasing in ω_c, as can be seen in Figure 2. In this range of β, there are two cases in which patterns of comparative advantage are explicitly determined. The first case is that in which both countries' protection levels are below $\frac{\beta\mu}{\mu^\sigma - \mu}$. In this range of ω_c, $m(\omega_c, \sigma, \beta, \mu)$ is decreasing in ω_c, just as when $\beta > \frac{\mu^\sigma - \mu}{\mu}$, so the country with the higher level of protection has comparative advantage in innovation and specializes in patent-intensive goods. The second case is that in which both countries' protection levels are above $\frac{\beta\mu}{\mu^\sigma - \mu}$. In this range of ω_c, $m(\omega_c, \sigma, \beta, \mu)$ is increasing in ω_c. Therefore, as the level of patent rights protection increases, the net variety effect is dominated by the market power effect, implying that the country with the lower level of protection has comparative advantage in innovation and specializes in patent-intensive goods and the country with the higher level of protection specializes in non-patent-intensive goods. If, however, one country's level of protection is higher than $\frac{\beta\mu}{\mu^\sigma - \mu}$ and the other country's level of protection is above $\frac{\beta\mu}{\mu^\sigma - \mu}$, we cannot immediately determine the direction of comparative advantage because $m(\omega_c, \sigma, \beta, \mu)$ is non-monotonic in ω_c in the range of ω_c in question; we have to look at the actual values of $m(\omega_c, \sigma, \beta, \mu)$ for the two countries. Here, the country with the lower $m(\omega_c, \sigma, \beta, \mu)$ is the one that has comparative advantage in innovation and thus specializes in patent-intensive goods.

We can see that β, the share of labor in producing new varieties, plays an important role in determining patterns of specialization. When β is large, labor is very productive in creating new varieties, magnifying the variety effect relative to the market power effect, whose magnitude is independent of β. If β is sufficiently large enough, e.g. $\beta > \frac{\mu^\sigma - \mu}{\mu}$, the net variety effect trumps the market power effect as ω_c increases, so the country with the higher level of patent rights protection specializes in patent-intensive goods. When β is small, i.e. $\beta > \frac{\mu^\sigma - \mu}{\mu}$, labor is not very productive in creating new varieties. As a result, the net variety effect does not always dominate the market power effect as ω_c increases; the net variety effect dominates the market power effect for low levels of ω_c, while the market power effect dominates the net variety effect for high levels of ω_c. Hence, the opposite pattern of specialization holds among countries with high levels of patent rights protection when β is sufficiently small.

To understand the domination of the market power effect at high levels of ω_c, as opposed to low levels of ω_c, it is useful to look at the behavior of $\big(\omega_c(\mu^{1-\sigma}-1)+1\big)^{\frac{1}{1-\sigma}}$ and $\omega_c^{\frac{\beta}{1-\beta}\frac{1}{1-\sigma}}$, which denote, respectively, the market power component and the variety component of $m(\omega_c, \sigma, \beta, \mu)$. Since the first and second derivatives of $\big(\omega_c(\mu^{1-\sigma}-1)+1\big)^{\frac{1}{1-\sigma}}$ with respect to ω_c are $\frac{1}{1-\sigma}(\mu^{1-\sigma}-1)\big(\omega_c(\mu^{1-\sigma}-1)+1\big)^{\frac{1}{1-\sigma}-1} > 0$ and $\frac{1}{1-\sigma}(\frac{1}{1-\sigma}-1)(\mu^{1-\sigma}-1)^2\big(\omega_c(\mu^{1-\sigma}-1)+1\big)^{\frac{1}{1-\sigma}-2} > 0$, the market power component is increasing and convex in ω_c, suggesting that it increases as a country raises its patent rights protection level and the rate of increase is particularly pronounced at high levels of protection. Similarly, we can show that the variety component is decreasing and convex in ω_c. Therefore, the variety "effect" is increasing and concave in ω_c. As a country raises its protection level, the variety effect also increases, but the rate of increase is attenuated at high levels of protection. In other words, both the market power effect and the variety effect increase as the level of protection rises, but the market power effect increases significantly more than the variety effect at higher levels of protection. This is precisely why it is in the upper range of protection levels where the market power effect can topple the net variety effect.

Intuitively, we can observe that raising the level of patent rights protection affects the price of the aggregate intermediate input by simply increasing the fraction of intermediate varieties that are enforced; this fraction moves one-to-one with the level of protection. In contrast, the effect of higher patent rights protection on the number of intermediate varieties is subject to diminishing marginal returns to labor in R&D. Increasing the level of protection has a smaller impact on the creation of new varieties, the higher the initial level of protection. For this reason, the variety effect pales in comparison with the market power effect at high levels of patent rights protection.

The fact that the model predicts the stark result that in equilibrium each final good z is produced by only one country follows from the assumption that final goods are homogeneous, as in Dornbusch, Fischer, and Samuelson (1977). One can extend the model by assuming that consumers value different varieties of each final good z because they are imperfect substitutes and obtain the less drastic result, shown in Romalis (2004), that all goods are produced by both countries, but the country with a lower cost of producing good z captures a larger share of world trade in good z.

What is most important about my model is not the stark prediction about trade flows but rather how the difference in the level of patent rights protection determines countries' comparative advantage through the costs of intermediate goods. In particular, raising the level of protection induces more innovation activity, resulting in greater varieties of intermediate goods and lower costs of final goods. Meanwhile, a higher level of patent rights protection means that a greater fraction of these varieties is protected and therefore sold at monopoly prices, thereby increasing the costs of final goods. Under certain ranges of parameters, the model shows that the overall effect of increasing the level of patent rights protection on the costs of final goods is non-monotonic in such a way that the net variety effect dominates the market power effect for low levels of protection, while the market power effect dominates the net variety effect for high levels of protection. This is the prediction that I test in the empirical section.

4 Empirics

In this section I use cross-country export data, country-level factor endowments, and sector-level factor intensities to test whether the model's implications on export patterns hold empirically. I estimate the following equation

$$\ln EX_{ict} = \alpha_i + \alpha_c + \alpha_t + \beta_1 P_{ct} + \beta_2 P_{ct} p_i + \beta_3 H_{ct} + \beta_4 H_{ct} h_i + \beta_5 K_{ct} + \beta_6 K_{ct} k_i + \epsilon_{ict}, \qquad (4)$$

where EX_{ict} is the total value of exports in industry i by country c to the rest of the world in year t, H_{ct} and K_{ct} are the human capital and physical capital endowments of country c in year t, and h_i and k_i are the human capital and physical capital intensities of industry i. The terms α_i, α_c, and α_t are industry, country, and year fixed effects, and ϵ_{ict} is the error term, assumed to be independent and identically distributed with mean zero. Lastly, P_{ct} is the quality of patent rights protection in country c in year t and p_i is the patent intensity of industry i, which represents the degree of industry i's reliance on innovation.

While the coefficients β_1, β_3, and β_5 capture the overall effect of each factor of production on exports, the coefficients β_2, β_4, and β_6 capture the extent to which the effect of a given factor of production varies from industry to industry according to the industry's factor intensity. For example, if the effect of human capital endowment on exports is greater for industries that use human capital extensively, we should expect a positive sign for β_4.

The coefficient of interest in this analysis is β_2. I will first perform OLS regressions on the entire sample of observations to see whether there is a general pattern of specialization with respect to patent rights protection. A positive (negative) coefficient estimate of β_2 implies that the effect of patent rights protection on exports is greater (smaller) for more patent-intensive industries. I will then divide the sample according to countries' levels of patent rights protection to determine whether the pattern of specialization reverses among countries with high levels of protection. The model suggests while β_2 is positive in the subsample of low-protection countries, β_2 may be negative in the subsample of high-protection countries.

Rajan and Zingales (1998) uses a similar equation to test whether industries that are relatively more dependent on external financing experience higher growth rates of value added. Romalis (2004) and Levchenko (2007) use this functional form to estimate trade flow patterns. Romalis (2004) finds that countries that are relatively abundant in human capital, physical capital, or raw materials capture large shares of exports to the United States in industries that use those factors of production intensively. He also shows that the quasi-Rybczynski prediction holds in the data, i.e. countries that accumulate a factor more rapidly than the rest of the world tend to have their export composition shift towards industries intensive in that factor. Levchenko (2007) focuses on the role of institutions in explaining trade patterns. In particular, he tests whether countries with superior institutions (comprising quality of contract enforcement, security of property rights, and predictability of the judiciary) export more in industries with high product complexity, measured by the intensity of intermediate input use, because these are industries in which institutional infrastructure is important.

This equation is also used by Nunn (2007) to analyze the effect of contractual enforcement on industries' exports. In his case, p_i captures the degree to which an industry uses inputs of production that rely on relationship-specific contracts, while P_{ct} is the index of the quality of contract enforcement in that country. Cunat and Melitz (2007) also uses this specification to find evidence that countries with more flexible labor markets export relatively more in sectors with higher within-industry dispersions of shocks. More recently, Manova (2008) uses a similar functional form to empirically show that the effect of financial liberalization on export volumes varies significantly across industries according to the extent to which they depend on external financing.

5 Data

Data on export values at the 4-digit SITC Rev.2 industry level are from Feenstra's World Trade Database and aggregated to the 3-digit ISIC level using Haveman's concordance tables. Human and physical capital endowments are from Caselli (2005). As in Barro and Lee (2001), human capital endowments are proxied by human capital per worker, measured as a function of the average years of schooling in the population over 25 years old. To construct physical capital endowments, capital stock estimates are generated from the perpetual inventory equation and divided by the number of workers to obtain capital stock per capita. In the full specification of the estimating equation, two additional interaction terms are included, one related to natural resources and the other to financial markets. Data on natural resource endowments are from the World Bank (1997) and each country's endowment is the value of its minerals, fossil fuels, timber, non-timber forest benefits, cropland, and pastureland, net of what is labeled as protected areas. Financial liberalization intensity data are taken from Bekaert et al. (2005), which calculates the liberalization intensity measure as the fraction of domestic equities available to foreign investors.

Measures of industry-level human capital, physical capital, natural resource, and external finance intensities are from Braun (2003) and are computed using US data. Human capital intensity is measured as the industry's mean wage over that of the whole manufacturing sector. Physical capital intensity corresponds to the industry's ratio of gross fixed capital formation to value added. Natural resource intensity is a dummy variable that takes a value of 1 for the following industries (and 0 otherwise): wood products, except furniture; paper and products; petroleum refineries; miscellaneous petroleum and coal products; other nonmetallic mineral products; iron and steel; and nonferrous metals. External finance intensity is calculated as the ratio of capital expenditures minus cash flow from operations to capital expenditures of firms in each industry.

Regarding patent intensity, an extensive dataset on patents from Hall, Jaffe, and Trajtenberg (2001) is used. This dataset includes information on every patent granted by the United States

Patent and Trademark Office (USPTO) between January 1963 and December 1999. I measure the patent intensity of an industry as the citation-weighted number of patents granted in that industry, weighted by its average share of production value in the economy, throughout the duration spanned by the dataset. Patent intensity p_i is measured as

$$p_i = \ln\left(\frac{\sum_j \sqrt{citations_{ij}}}{prod_i}\right)$$

where $citations_{ij}$ is the number of citations that patent j of industry i has received and $prod_i$ is the average value of production in industry i. Since not all foreign patents are registered in the USPTO database, only US patents are used in the construction of the measure. Correspondingly, US production values are used for $prod_i$. The term $citations_{ij}$ is meant to capture the technological importance of each patent and therefore includes all other patents, domestic and foreign, that cite this patent.

The rationale for such a measure is simply that the number of patents submitted to and granted by the USPTO should be high in industries that rely heavily on innovation. According to this measure, a patent is weighted more heavily the more citations from other patents it receives. Table 1 shows the patent intensities of all industries in the dataset. According to this measure, the most patent-intensive industries are professional and scientific equipment, non-electrical machinery, and other manufactured products, and the least patent-intensive industries are food products, petroleum refineries, and paper products.

Regarding industry assignment, each patent in the USPTO database corresponds to one of 3-digit United States Patent Classification System (USPCS) technological classes to which it is most related. I use a concordance table provided by Hall, Jaffe, Trajtenberg (2001) to match USPCS to SIC72 codes and Haveman's concordance tables to convert them to ISIC Rev.2, which is the level at which export data are available.

To measure the quality of patent rights protection, I use the index of patent rights from Ginarte and Park (1997). This index is on a 0-to-5 scale and is the arithmetic sum of 5 indices, each one capturing an aspect of patent law in that country. These include extent of coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms, and duration of patents.

In particular, extent of coverage refers to the patentability of various kinds of inventions. Despite the fact that in general patents are granted for novel, industrially applicable, or non-obvious inventions, for most countries there are certain inventions that are designated as unpatentable. High scores in the category of extent of coverage are given to countries that have relatively few unpatentable inventions. The measure of membership in international patent agreements is the extent to which the country is willing to provide national, nondiscriminatory treatment to foreigners regarding patent law. The three major agreements are the Paris Convention of 1883 (and its subsequent revisions), the Patent Cooperation Treaty of 1970, and the International Convention for the Protection of New Varieties of Plants of 1961. Countries with the highest score in this category are those that have signed all three of the above agreements.

Loss of protection measures the country's protection against losses arising from working requirements, compulsory licensing, and revocation of patents. Enforcement refers to the mechanisms of enforcement when patent rights are violated. These mechanisms include preliminary injunctions, contributory infringement pleadings, and burden-of-proof reversals. Lastly, duration of protection refers to the length of the patent term; longer patent terms are more conducive to innovative activity due to longer streams of financial returns. The standard term is 20 years of protection.

Tables 2 and 3 show average levels of patent rights protection for countries with the highest and lowest protection levels over the 1980-1995 period. Countries with the highest levels are the United States, the United Kingdom, the Netherlands, France, and Germany, and those with the lowest levels are Jordan, Guatemala, Guyana, Nicaragua, and Peru.

In order to check for the robustness of results, I also use the Rapp-Rozek index of patent rights protection, the discussion of which is provided in the robustness section.

6 Results

In this section, I first show regression results for the whole sample of observations to see the overall effect of patent rights protection on export volumes. If high levels of protection are associated with high (low) export volumes in patent-intensive industries, we should expect the coefficient of the patent interaction $P_{ct}p_i$ to be positive (negative). I then divide the dataset into smaller samples based on countries' levels of protection and run similar regressions on these subsamples. If the value of β is less than $\frac{\mu^{\sigma}-\mu}{\mu}$, then the model's prediction is that the coefficient of the patent interaction variable is positive for samples comprising countries whose levels of patent rights protection are lower than $\frac{\beta\mu}{\mu^{\sigma}-\mu}$ and negative for samples comprising countries whose levels of patent rights protection are higher than $\frac{\beta\mu}{\mu^{\sigma}-\mu}$.

The baseline regression results of equation (4) are presented in Table 4. I estimate the full panel of log exports of 86 countries and 24 industries in the 1980-1995 period. Column (1) shows the result of a regression of log exports on only the patent law and the patent interaction variables, controlling for industry, country, and year fixed effects. We can see that the coefficient estimate is positive and significant, providing preliminary evidence that the effect of patent rights protection is biased positively towards patent-intensive industries.

However, the above regression is likely to suffer from omitted variable bias, since there are other variables that are correlated with the patent interaction variable but are not included in the regression. One of these variables is country income, which is known to be highly correlated with quality of patent law.[6] Column (2) thus includes in the regression log real GDP as well as the interaction between log real GDP and patent intensity. Even after controlling for these two variables, the coefficient estimate for the patent interaction variable still remains significantly positive.

The next two specifications, shown in Column (3) and (4), control for other factor interaction terms that may be correlated with patent intensity. These include human capital, physical capital, and natural resource endowments and their interactions with factor intensities. As recent papers have suggested, external financial dependence plays a crucial role in determining trade patterns, so I also include a financial liberalization measure and its interaction with external financial dependence. The full specification of the estimating equation takes the form

$$\begin{aligned}\ln EX_{ict} &= \alpha_i + \alpha_c + \alpha_t + \beta_1 P_{ct} + \beta_2 P_{ct} p_i + \\ &\quad \beta_3 H_{ct} + \beta_4 H_{ct} h_i + \beta_5 K_{ct} + \beta_6 K_{ct} k_i + \\ &\quad \beta_7 N_{ct} + \beta_8 N_{ct} n_i + \beta_9 F_{ct} + \beta_{10} F_{ct} f_i + \\ &\quad \beta_{11} GDP_{ct} + \beta_{12} GDP_{ct} p_i + \epsilon_{ict},\end{aligned}$$

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[6] See Maskus (2000).

where N_{ct} and n_i denote, respectively, the natural resource endowment of country c in year t and the natural resource intensity of industry i, and F_{ct} and f_i denote, respectively, the extent of financial liberalization of country c in year t and the external financial dependence of industry i. The coefficient estimate for the patent interaction remains positive and significant, suggesting that, on average, countries with high levels of patent rights protection have relatively high export volumes in patent-intensive sectors.

While we see that, on average across all countries in the sample, countries with strong patent rights protection experience high export volumes in patent-intensive industries, Proposition 2 shows that if the value of β is below $\frac{\mu^\sigma - \mu}{\mu}$, the export pattern can be reverse among countries with high levels of patent rights protection. I therefore divide the sample into two samples, based on some threshold level of patent rights protection. One sample consists of all observations for which the country's level of protection is above the threshold, and the other sample consists of all observations for which the country's level of protection is below the threshold. In the context of the model, the former sample aims to capture the set of countries whose levels of protection are below $\frac{\beta\mu}{\mu^\sigma - \mu}$ and the latter sample the set of countries whose levels of protection are above $\frac{\beta\mu}{\mu^\sigma - \mu}$. This type of sample splitting is common in the literature on the relationship between financial development and economic growth, whereby the effect of financial development on growth is often absent for countries in which the level of financial development is beyond a certain threshold.[7]

In this analysis, I place threshold levels for the index of patent law at 0.25, 0.50, ... , 4.75 and run two regressions for each level of threshold. The levels for which there appears to be a significant reversal of trade patterns are those around the value of 3.75, and Chow tests confirm that the coefficients of the two regressions are statistically different from each other to warrant sample splitting. Table 5 presents the results of threshold regressions for values of 3.5, 3.75, and 4, with Columns (1), (3), and (5) representing >3.5, >3.75, and >4 samples, and Columns (2), (4), and (6) representing <3.5, <3.75, and <4 samples. I find that the coefficient estimates for the patent interaction term are significantly positive for the low-protection groups and significantly negative for the high-protection groups, implying that the effect of patent rights protection is biased positively towards patent-intensive sectors among low-protection countries and biased negatively towards patent-intensive sectors in the high-protection countries. The same procedure is also performed on

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[7] For example, see Rioja and Valev (2004).

a 15-year average sample and the results, shown in Table 6, display similar patterns.[8]

An alternative approach to determining the threshold is to place threshold levels at the 5th, 10th, ... , 90th, 95th percentiles of the distribution of the patent rights protection index in a given year. An observation of country c in year t is then put in the $>n$th group if country c's protection index is above the nth percentile of the distribution in year t or put in the $<n$th group if it is below. The levels at which a significant sign reversal takes place are those around the 90th percentile[9], and Table 7 shows the results of threshold regressions for the 85th, 90th, and 95th percentiles. The coefficient estimates imply that the effect of patent rights protection is biased positively towards patent-intensive sectors in the low-protection groups and biased negatively towards patent-intensive sectors in the high-protection groups.

7 Endogeneity

There may be problems, however, regarding the endogeneity of the estimation of equation (4). First, it is plausible that the causation runs in the opposite direction, from high export volumes to the development of patent rights protection. In such scenario, a prosperous exporting sector that is intensive in research and innovation prompts the government to enforce patent rights protection in order to sustain the growth of the sector and not lose the competitive edge to other countries. Another complication that may arise is that the development of patent rights protection may occur simply because the government anticipates a growth potential in certain exporting sectors, so that patent rights protection would only be an indicator rather than a cause of export volumes.

To account for this possibility, I adopt the instrumental variable approach and use a set of legal origin variables to proxy for P_{ct} and $P_{ct}p_i$.[10] This set of instrumental variables consists of $B_c, F_c, G_c, B_cp_i, F_cp_i$, and G_cp_i, where B_c, F_c, and G_c denote British, French, and German legal origins, respectively. The motivation is that colonizing countries often imposed their own legal infrastructure on the colonized countries (e.g. common law for British colonies, civil law for French colonies) and that different legal systems are likely to have different approaches in addressing issues

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[8] Average patent rights protection and factor endowments are dropped from the regressions because they are absorbed by country fixed effects. The same holds for all other regressions using averaged data.

[9] Countries above the 90th percentile constitute more than 40% of world trade in 1995.

[10] Nunn (2007) also uses legal origin interactions to isolate the causal impact of contract enforcement on comparative advantage.

related to patent rights protection. According to Djankov et al. (2003), any legal system can be thought of as a way to achieve a balance between disorder and dictatorship. French civil law is particularly concerned with disorder and market failures and therefore exhibits a preponderance for state-issued solutions when addressing social and economic problems. In contrast, British common law displays a strong aversion of state encroachment, thus allowing for a greater scope of market-based solutions and private contracting. As Damaska (1986) remarks, civil law is "policy-implementing," while common law is "dispute resolution." In relation to issues of property rights, La Porta et al. (2008) claims that the main channels through which the legal system affects property rights protection are judicial tenure and constitutional acceptance of case law. They find that common law countries generally have higher judicial tenure and sharply higher constitutional acceptance of case law than civil law counterparts. In turn, both high judicial tenure and high constitutional acceptance of case law are associated with better protection of property rights. However, one should keep in mind that there can be other ways in which the legal system influences property rights protection. The reason is that "legal origins shape fundamental approaches to social control of business. [L]egislation in common law countries expresses the common law way of doing things."[11]

While a country's legal origin is correlated with the status of the country's current patent law, it is not affected by export volumes simply because the legal origin is predetermined as of the years covered by the dataset. Hence, the set of legal origin variables satisfies the instrumental variable requirement that the instruments are correlated with the potentially endogenous variable but not with the error term, and allows us to examine how exogenous changes in patent rights protection influence trade volumes.

One potential concern in this IV estimation is that the legal origin variables do not vary over time, while the patent law variables P_{ct} and $P_{ct}p_i$ do. I address this issue by averaging all variables over the time period and performing the IV procedure on this averaged sample.

To show that the instruments have explanatory power for patent rights protection, I regress P_c on B_c, F_c, and G_c. Presented in Table 8, the regression result shows that two of three coefficient estimates are statistically significant, with countries with French legal origin, on average, faring worst in terms of average levels of patent rights protection, followed by those with British and

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[11] La Porta et al. (2008)

German legal origins.

Table 9 shows the results of IV estimation. We can see that the signs of the IV estimates are similar to those of the OLS estimates. In the high-protection groups (>3.5, >3.75, and >4 groups), the coefficient on the patent interaction is negative and significant, as shown in Columns (1), (3), and (5), while in the low-protection groups (<3.5, <3.75, and <4 groups), the coefficient is positive and significant, as shown in Columns (2), (4), and (6). Again, the results suggest that the effect of patent rights protection is biased positively towards patent-intensive sectors in the low-protection groups and biased negatively towards patent-intensive sectors in the high-protection groups.

Note that the magnitude of the IV estimates are comparable to that of the OLS estimates for the >3.5, >3.75, and >4 groups (see Table 6). Meanwhile, the IV estimates are at least twice the size of the OLS estimates for the <3.5, <3.75, and <4 groups. There are several reasons for this finding. First, if there is measurement error in the patent rights protection variable p_i, OLS regressions will suffer from attenuation bias, in the sense that OLS estimates are underestimated. Second, there is evidence that local business interests in developing economies campaigned for stronger patent rights protection in patent-intensive industries, which were small but had high growth potential.[12] This is an instance of reverse causation, albeit not one in which two factors reinforce each other, as we often observe in the literature.[13] In our case, it is as if low exports in patent-intensive sectors "led to" (via campaigns by business interests) higher levels of patent rights protection. As a result, the coefficient estimate is underestimated in OLS regressions on low-protection countries. Lastly, according to Maskus (2000), "[p]ressure from the United States and the European Union certainly played a critical role in pushing forward a global reform agenda. Widely publicized American negotiations and threats in the 1980s and 1990s helped usher in stronger intellectual property rights legislation." The way this mechanism works is similar to the business interest mechanism, whereby developing countries, which generally had relatively low exports of patent-intensive goods, were forced to adopt higher intellectual property rights standards by developed countries.

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[12] See Sherwood (1997).

[13] Examples include studies of the effect of financial development on economic growth, which have to take into account the positive effect of economic growth on financial development.

8 Patent Reforms

Another way of examining the impact of patent rights protection on export patterns is to look at the series of patent reforms that took place from the late 1980s onwards. In this paper I focus on 10 reform episodes that occurred during the 1980-1995 period and were considered to be significant in scope, according to Branstetter et al. (2006). These include Spain (1986), Japan (1987), Republic of Korea (1987), Indonesia (1991), Chile (1991), Mexico (1991), Portugal (1992), Thailand (1992), Colombia (1994), and Venezuela (1994). Each of these reforms encompassed at least four out of five broad attributes of patent reform: (1) expansion of eligible inventions (2) expansion of patent scope (3) expansion of patent length (4) improvement in patent enforcement (5) improvement in patent administration.

To estimate the effect of patent reforms on trade patterns, I run regressions of equation (4), replacing $P_{ct}p_i$ with $ref_{ct}p_i$ where $ref_{ct} = 1$ if country c has undergone a patent reform as of year t and $ref_{ct} = 0$ if not. Column (1) of Table 10 presents the regression results for the sample of all 10 countries that experienced a reform episode. The positive and significant coefficient estimate of the patent reform interaction suggests that, on average, the effect of a patent reform is more pronounced positively in patent-intensive industries. However, not all countries were equal regarding their pre-existing levels of patent rights protection when a reform episode took place. Japan was the country with the highest level of patent rights protection at the time of reform (the only country with the Ginarte-Park index above 3), followed by Spain and South Korea (between 2.5 and 3). I therefore perform two instances of sample-splitting. Columns (2) and (3) show the regression results performed on, respectively, a sample with only Japan and Spain and a sample without these two countries. Column (4) and (5) show the results performed on, respectively, a sample with only Japan, Spain, and South Korea, and a sample without these three countries. The rationale for the selection of these three countries is that Japan, Spain, and South Korea underwent patent reforms in the late 1980s and had relatively high levels of patent rights protection at the time of reform (above 2.5), while other countries in the sample experienced reforms only after 1990 and had relatively low levels of patent rights protection at the time of reform (below 2.5).

For countries that started out with low levels of patent rights protection at the time of reform, the coefficient is positive and significant, as shown in Columns (3) and (5), suggesting that the effect of a reform is biased positively towards patent-intensive industries. On the contrary, for countries with high levels of patent rights protection at the time of reform, the coefficient is insignificantly negative for the sample with Japan, Spain, and Korea and significantly negative for the sample with only Japan and Spain, implying that the bias is negative towards patent-intensive industries. This finding is again consistent with other results.

9 Robustness

The first robustness check I perform is to use a different measure of patent rights protection, one developed by Rapp and Rozek (1990). This index is based on a 1984 evaluation of conformity with the U.S. Chamber of Commerce guidelines on patent rights. Often used in studies before the development of the Ginarte-Park index, the Rapp-Rozek index is cruder, taking a value of either 1, 2, 3, 4, or 5, with 1 corresponding to countries with inadequate protection laws and no law prohibiting piracy and 5 to countries with protection and enforcement laws fully consistent with minimum standards proposed by the U.S. Chamber of Commerce.

Table 11 shows the results of threshold regressions using the Rapp-Rozek index, with the threshold value of 4. Since the index is based on a cross-country evaluation in 1984, I use data averaged over the 1985-1995 period. Columns (1) and (2) correspond to high-protection and low-protection groups, respectively. Unsurprisingly, the coefficients on the patent interaction are negative and significant for the high-protection group, and positive and significant for the low-protection group, mirroring the results obtained when the Ginarte-Park index is used.

In the second robustness check, I use a different variable to instrument for the patent interaction term. Because the Ginarte-Park index is available from 1960 onwards, I use the interaction between the 1960 protection level and patent intensity, $P_{c,1960}p_i$, as a proxy for $P_{ct}p_i$, under the assumption that the only way in which the 1960 level of patent rights protection affects export patterns in the 1980-1995 period is through the 1980-1995 level of protection. The results of IV estimation using the 1960 level of protection as the instrument are displayed in Table 12, with Columns (1), (3), and (5) representing >3.5, >3.75, and >4 samples, and Columns (2), (4), and (6) representing <3.5, <3.75, and <4 samples. In the high-protection groups, the estimates for the patent interaction coefficient are negative, statistically significant, and similar in magnitude to those of the IV estimation using legal origin interactions as instruments. On the other hand, the estimates for the low-protection groups have the expected sign (positive) but are not significant in two of three groups.

I also test whether the results are robust to a different measure of patent intensity. Throughout the study, I have used the number of citation-weighted patents granted as a proxy for patent intensity of a given industry. In this robustness check I use, instead, the non-weighted number of patents granted. The reason is that a significant percentage of a given patent's citations is self-citations, which may overstate the value of the patent, as the owner of a patent has an incentive to exaggerate the value for his patent.[14] Table 13 presents the results of OLS estimation using this alternative proxy for patent intensity and shows that the coefficients on the patent interaction variable are negative and significant for the high-protection groups, and positive and significant for the low-protection groups.

10 Conclusion

I construct a theoretical model to explain how patterns of comparative advantage emerge from differences in the level of patent rights protection and find that, in general, countries with high levels of protection specialize in innovation-intensive industries, i.e. industries in which invention is crucial, while countries with low levels of protection specialize in non-innovation-intensive industries. It is possible, however, to obtain the reverse pattern of specialization among countries whose levels of patent rights protection exceed a certain threshold.

I then test empirically whether there is any pattern of specialization with respect to patent rights protection and whether there is a threshold level of protection beyond which the pattern is reversed. Using the USPTO database of patents in conjunction with cross-country data on the quality of patent rights protection, I find evidence for a general pattern of specialization as well as a reversal of such pattern among countries with superior protection. To correct for potential endogeneity, I use the instrumental variable approach, using legal origins as proxies for quality of patent rights protection. I also examine the effect of patent reform episodes that several countries underwent and find that the effect on different industries depends on the country's level of protection at the time of reform. For countries with relatively low pre-reform protection, the reform's effect is biased positively towards patent-intensive industries, whereas for countries with relatively high pre-reform protection, the effect is biased negatively towards patent-intensive industries.

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[14] See Beling et al. (2003).

I find the results to be robust to different measures of patent intensity and countries' levels of patent rights protection, as well as an alternative instrumental variable. By and large, the empirical finding points to the non-monotonicity of the effect of patent rights protection on trade patterns.

11 Appendix

11.1 Proof of Proposition 1

From the final equilibrium equating savings and investment, we can express E_c as

$$\begin{aligned} E_c &= w_c \int_{z \in Z_c} (L_c(z) - L_{c,r}(z))dz + \int_{z \in Z_c} \omega_c n_c(z)\pi_c(z)dz \\ &= w_c \left(\int_{z \in Z_c} (L_c(z) - L_{c,r}(z) + \omega_c n_c(z)\frac{\mu - 1}{a} x_c(z))dz \right) \end{aligned}$$

Denote world expenditure as $E = E_H + E_F \equiv \widehat{E}_H + w\widehat{E}_F$. Perfect competition in the final goods market means that total spending on good z is

$$b(z)E = w_c L_{c,f}(z) + P_c(z)X_c(z)$$

where $w_c L_{c,f}(z)$ is the income of workers in the final good production stage. $P_c(z)X_c(z)$ is the expenditure on the aggregate intermediate good, which equals

$$P_c(z)X_c(z) = \omega_c n_c(z)\mu \frac{w_c}{a} x_{c,enf}(z) + (1 - \omega_c)n_c(z)\frac{w_c}{a} x_{c,compet}(z)$$

where

$$\omega_c n_c(z)(\mu - 1)\frac{w_c}{a} x_{c,enf}(z) = \omega_c n_c(z)\pi_c(z),$$

$$\omega_c n_c(z)\frac{w_c}{a} x_{c,enf}(z) = w_c L_{c,m,enf}(z),$$

and

$$(1 - \omega_c)n_c(z)\frac{w_c}{a} x_{c,compet}(z) = w_c L_{c,m,compet}(z).$$

We can then express total spending on good z as

$$b(z)E = w_c\left(L_{c,f}(z) + L_{c,m,enf}(z) + L_{c,m,compet}(z)\right) + \omega_c n_c(z)\pi_c(z).$$

Without loss of generality, consider the case where H specializes in low-z goods. Denote $\upsilon(z^*) = \int_0^{z^*} b(z)dz$. Balanced budget means H's income (from goods production, which excludes investment) is equal to world expenditure on H's produced goods:

$$\begin{aligned}
\int_0^{z^*}\left(L_{H,f}(z) + L_{H,m,enf}(z) + L_{H,m,compet}(z) + \omega_H n_H(z)\pi_H(z)\right)dz &= \upsilon(z^*)(\widehat{E}_H(z^*) + w\widehat{E}_F(z^*)) \\
\int_0^{z^*}\left(L_H(z) - L_{H,r}(z) + \omega_H n_H(z)\pi_H(z)\right)dz &= \upsilon(z^*)(\widehat{E}_H(z^*) + w\widehat{E}_F(z^*)) \\
\widehat{E}_H(z^*) &= \upsilon(z^*)(\widehat{E}_H(z^*) + w\widehat{E}_F(z^*))
\end{aligned}$$

or

$$w = \left(\frac{\widehat{E}_H(z^*)}{\upsilon(z^*)} - \widehat{E}_H(z^*)\right)\frac{1}{\widehat{E}_F(z^*)} = \frac{1-\upsilon(z^*)}{\upsilon(z^*)}\frac{\widehat{E}_H(z^*)}{\widehat{E}_F(z^*)}.$$

Note that

$$\begin{aligned}
\widehat{E}_H(z^*) &= \int_0^{z^*}(L_H(z) - L_{H,r}(z) + \omega_H n_H(z)\frac{\mu-1}{a}x_H(z))dz \\
&= L_H + \int_0^{z^*}(-L_{H,r}(z) + \omega_H n_H(z)\frac{\mu-1}{a}x_H(z))dz \\
&= L_H + \int_0^{z^*}\left[\left(-\omega_H\frac{1-e^{-r\tau}}{r}\frac{\mu-1}{a}x_H(z)\beta K(z)^{1-\beta}\right)^{\frac{1}{1-\beta}} + \omega_H\tau(\psi(z)\omega_c x_c(z))^{\frac{\beta}{1-\beta}}\frac{\mu-1}{a}x_H(z)\right]dz \\
&= L_H + \int_0^{z^*}\left[(-\psi(z)\omega_H x_H(z))^{\frac{1}{1-\beta}} + \omega_H\tau(\psi(z)\omega_c x_c(z))^{\frac{\beta}{1-\beta}}\frac{\mu-1}{a}x_H(z)\right]dz \\
&= L_H + \int_0^{z^*}(\psi(z)\omega_H x_H(z))^{\frac{1}{1-\beta}}\left[-1 + \frac{\tau}{\psi(z)}\frac{\mu-1}{a}\right]dz
\end{aligned}$$

and, similarly,

$$\widehat{E}_F(z^*) = L_F + \int_{z^*}^{\infty}(\psi(z)\omega_F x_F(z))^{\frac{1}{1-\beta}}\left[-1 + \frac{\tau}{\psi(z)}\frac{\mu-1}{a}\right]dz.$$

As long as $\frac{\tau}{\psi(z)}\frac{\mu-1}{a} = \tau\frac{r}{1-e^{-r\tau}}\frac{1}{\beta K(z)^{1-\beta}} < 1$, we have that $\widehat{E}_H(z^*)$ is decreasing in $z^*$and $\widehat{E}_F(z^*)$ is increasing in z^*, implying that $\frac{\widehat{E}_H(z^*)}{\widehat{E}_F(z^*)}$ is decreasing in z^*. Since $\frac{1-\upsilon(z^*)}{\upsilon(z^*)}$ is also decreasing in z^*, it follows that $B(z^*) = \frac{1-v(z^*)}{v(z^*)} \frac{\widehat{E}_H(z^*)}{\widehat{E}_F(z^*)}$ is decreasing in z^*, and is equal to ∞ when $z^* = 0$ and is equal to 0 when $z^* = 1$.

We now need to show that the A curve crosses the B curve only once. To see that the A curve is monotonic, positive, and finite-valued for all $z^* \in [0,1]$, note that

$$\begin{aligned}
\left[\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}}\right]^{1-\alpha(z^*)} \frac{1}{w} &= 1 \\
\left[\frac{m(\omega_H)}{m(\omega_F)}\right]^{1-\alpha(z^*)} w^{\frac{\beta}{1-\sigma}(1-\alpha(z^*))-1} &= 1 \\
w &= \left[\frac{m(\omega_H)}{m(\omega_F)}\right]^{-(1-\alpha(z^*))\frac{1}{\frac{\beta}{1-\sigma}(1-\alpha(z^*))-1}}.
\end{aligned}$$

Let $f(z^*) \equiv -(1-\alpha(z^*))\frac{1}{\frac{\beta}{1-\sigma}(1-\alpha(z^*))-1} < 0$. Note that $f(z^*)$ is well-defined and it is straightforward to show that $f'(z^*) = -\frac{(-1+\sigma)^2\alpha'(z^*)}{(-1+\sigma+\beta-\beta\alpha(z^*))^2} < 0$, so the A curve is monotonic.

11.2 Proof of Proposition 2

First, note that if $\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}} < 1$, then $\left[\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}}\right]^{1-\alpha(z)}$ is increasing in z and H specializes in low-z goods. Similarly, if $\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}} > 1$, then $\left[\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}}\right]^{1-\alpha(z)}$ is decreasing in z and H specializes in high-z goods. Also, it is clear that if $\frac{m(\omega_H)}{m(\omega_F)} < 1$, then $\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}} < 1$, too. If not, then $\frac{\widetilde{P}_H(z)}{\widetilde{P}_F(z)} = \left[\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}}\right]^{1-\alpha(z)} \frac{1}{w} > 1$ for all z, which cannot be an equilibrium. Similarly, if if $\frac{m(\omega_H)}{m(\omega_F)} > 1$, then $\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}} > 1$, too.

Differentiating $m(\omega)$ with respect to ω yields

$$\begin{aligned}
\frac{\partial m(\omega)}{\partial \omega} &= \frac{\omega^{-\frac{-1+\sigma+\beta}{-1+\sigma}} \left(1 + (-1+\mu^{1-\sigma})\omega\right)^{\frac{-1+\beta}{-1+\sigma}} [\beta\mu^\sigma + (\mu - \mu^\sigma)\omega]}{(-1+\sigma)[\mu^\sigma(-1+\omega) - \mu\omega]} \\
&= \frac{\gamma[(\beta-\omega)\mu^\sigma + \omega\mu]}{(\sigma-1)[\mu^\sigma(-1+\omega) - \mu\omega]} < 0
\end{aligned}$$

where $\gamma = \omega^{-\frac{-1+\sigma+\beta}{-1+\sigma}} \left(1 + (-1+\mu^{1-\sigma})\omega\right)^{\frac{-1+\beta}{-1+\sigma}} > 0$ and $\mu^\sigma(-1+\omega) - \mu\omega < 0$. Hence, $\frac{\gamma}{(\sigma-1)[\mu^\sigma(-1+\omega)-\mu\omega]} < 0$.

For $\frac{\partial m(\omega)}{\partial \omega}$ to be negative for all ω, we need $(\beta-\omega)\mu^\sigma + \omega\mu$ to be positive for all ω. Since $(\beta-\omega)\mu^\sigma + \omega\mu = \beta\mu^\sigma - \omega(\mu^\sigma - \mu)$, where $\mu^\sigma - \mu > 1$, the expression is smallest when $\omega = 1$. In that case,

$$\begin{aligned} \beta\mu^\sigma - (\mu^\sigma - \mu) &= 0 \\ \beta &= \frac{\mu^\sigma - \mu}{\mu^\sigma}, \end{aligned}$$

which means that $\beta > \frac{\mu^\sigma - \mu}{\mu^\sigma}$ implies:

- $\frac{\partial m(\omega)}{\partial \omega}$ is negative for all ω
- $\frac{m(\omega_H)}{m(\omega_F)} < 1$
- $\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}} < 1$
- $\left[\frac{m(\omega_H)}{m(\omega_F)} w^{\frac{\beta}{1-\sigma}}\right]^{1-\alpha(z)}$ is increasing in z
- H specializes in low-z goods

If $\beta < \frac{\mu^\sigma - \mu}{\mu^\sigma}$, then $\frac{\partial m(\omega)}{\partial \omega}$ is not negative for all ω; for high values of ω, $\frac{\partial m(\omega)}{\partial \omega}$ is not negative for all ω. Denote ω^* the level of enforcement such that $\frac{\partial m(\omega)}{\partial \omega} = 0$. It's clear to show that $\omega^* = \frac{\beta\mu}{\mu^\sigma - \mu}$. If $\omega_H, \omega_F < \omega^*$, then $\frac{m(\omega_H)}{m(\omega_F)} < 1$ and H specializes in low-z goods. If $\omega_H, \omega_F > \omega^*$, then $\frac{m(\omega_H)}{m(\omega_F)} > 1$ and H specializes in high-z goods. Otherwise, we need to see whether $\frac{m(\omega_H)}{m(\omega_F)} < 1$ or $\frac{m(\omega_H)}{m(\omega_F)} > 1$ and draw conclusions accordingly.

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Figure 1: $m(\omega)$ when $\beta > \frac{\mu^{\sigma}-\mu}{\mu}$

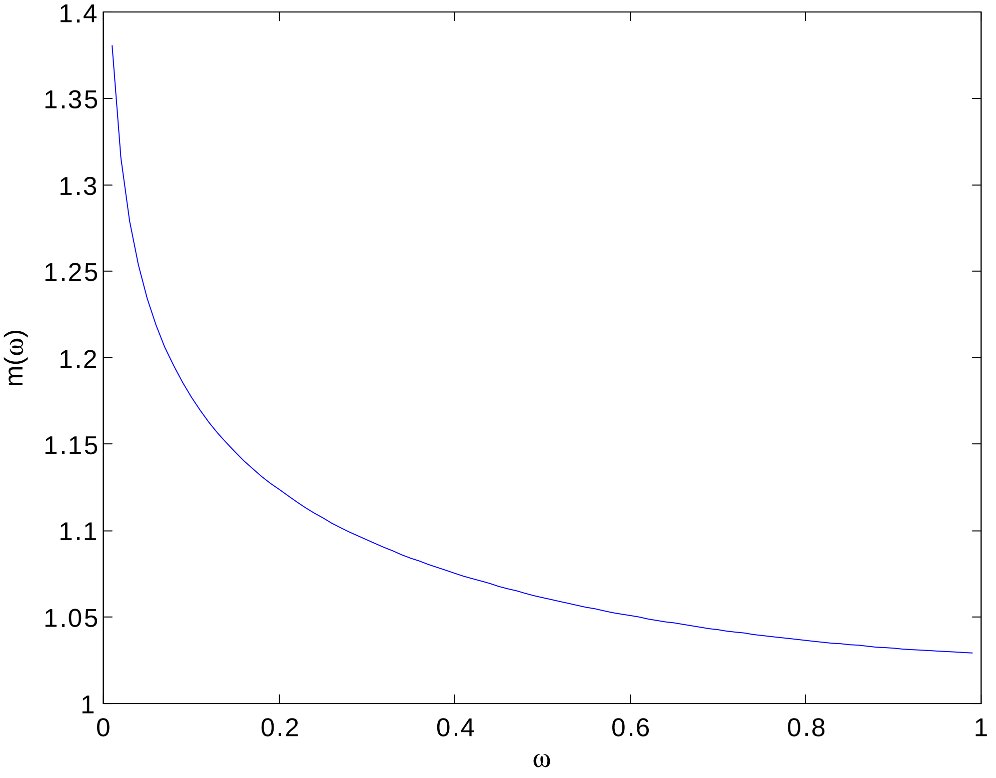

Figure 2: $m(\omega)$ when $\beta < \frac{\mu^{\sigma}-\mu}{\mu}$

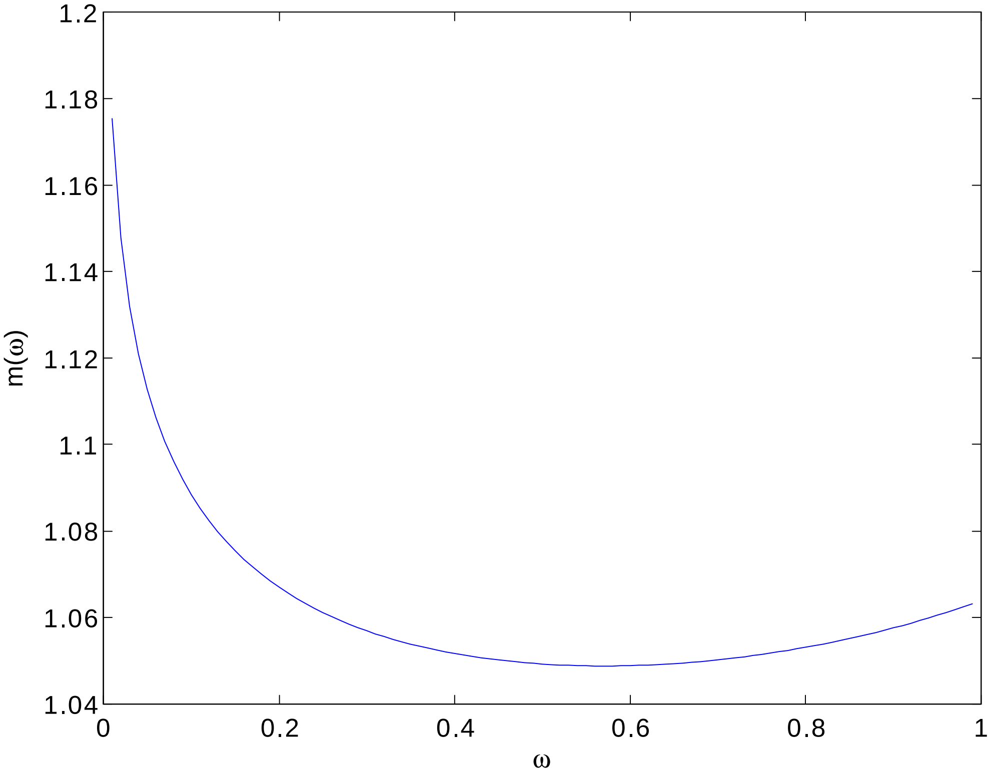

Table 1: Patent intensity

ISIC	Industry	Patent intensity
311	Food products	11.58
353	Petroleum refineries	12.24
341	Paper and products	12.24
313	Beverages	13.04
331	Wood products, except furniture	13.73
371	Iron and steel	14.02
372	Non-ferrous metals	14.03
361	Pottery, china, earthenware	14.17
354	Miscellaneous petroleum and coal products	14.24
351	Industrial chemicals	14.32
323	Leather products	14.52
352	Other chemicals	14.57
321	Textiles	14.59
362	Glass and products	14.67
332	Furniture, except metal	14.72
369	Other non-metallic products	14.73
355	Rubber products	14.75
356	Plastic products	14.82
381	Fabricated metal products	14.83
384	Transport equipment	14.83
383	Electric machinery	14.85
390	Other manufactured products	14.85
382	Non-electrical machinery	14.86
385	Professional and scientific equipment	14.89

Table 2: Countries with the highest levels of patent rights protection

Country	Level of patent rights protection
United States	4.66
United Kingdom	4.13
Netherlands	4.06
France	3.92
Germany	3.91
Italy	3.85
Switzerland	3.80
Denmark	3.79
Japan	3.76
Sweden	3.74

Table 3: Countries with the lowest levels of patent rights protection

Country	Level of patent rights protection
Jordan	0.80
Guatemala	0.85
Guyana	0.90
Nicaragua	0.96
Peru	0.99
India	1.07
Pakistan	1.19
Paraguay	1.21
Costa Rica	1.21
Venezuela	1.23

Table 4: Baseline estimates

	(1)	(2)	(3)	(4)
Patent law * patent intensity	0.590***	0.309**	0.447***	0.413***
	(5.26)	(2.50)	(3.63)	(3.30)
Patent law	0.105	0.159*	0.0252	0.0446
	(1.36)	(1.90)	(0.29)	(0.50)
GDP * patent intensity		0.318***	0.246***	0.229***
		(5.08)	(3.40)	(3.11)
GDP		0.795***	0.821***	0.833***
		(6.92)	(5.87)	(5.92)
Skill * skill intensity			1.492***	1.492***
			(5.95)	(5.96)
Capital * capital intensity			0.0116	-0.0411
			(0.01)	(-0.05)
Resource * resource intensity			0.123***	0.126***
			(2.59)	(2.65)
Fin. lib. * fin. intensity				0.376*
				(1.78)
Observations	30266	29789	24569	24569
Adjusted R^2	0.797	0.803	0.813	0.813

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of exports of industry i in country c in year t. The independent variable is the interaction of country c's level of patent protection in year t and industry i's patent intensity. Skill, capital, and natural resource endowments, as well as financial liberalization measures, are included in (3) and (4). Country, industry, and year fixed effects are included in all regressions. Standard errors are clustered by country-industry.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5: Threshold regression estimates

	>3.5	<3.5	>3.75	<3.75	>4	<4
Patent law * patent intens.	-0.873***	0.382**	-0.794**	0.452***	-1.825***	0.466***
	(-3.11)	(2.15)	(-2.48)	(2.80)	(-3.57)	(3.24)
Patent law	0.632***	0.0529	0.617**	-0.0214	1.411***	-0.0521
	(2.76)	(0.34)	(2.43)	(-0.15)	(3.38)	(-0.40)
GDP * patent intens.	0.286*	0.267***	0.280*	0.269***	0.326**	0.265***
	(1.93)	(3.32)	(1.95)	(3.43)	(2.30)	(3.44)
GDP	0.434	0.635***	0.386	0.687***	-0.124	0.714***
	(1.21)	(3.88)	(1.32)	(4.31)	(-0.37)	(4.59)
Skill * skill intensity	0.712*	1.006***	0.793**	1.102***	0.834**	1.300***
	(1.89)	(3.20)	(2.24)	(3.72)	(2.27)	(4.67)
Capital * capital intensity	-8.313	1.342	-10.35*	0.998	-10.43*	0.580
	(-1.56)	(1.39)	(-1.86)	(1.07)	(-1.74)	(0.64)
Resource * resource intensity	0.158***	0.113**	0.146**	0.119**	0.0962	0.123**
	(2.86)	(2.14)	(2.57)	(2.32)	(1.58)	(2.48)
Fin. lib. * fin. intensity	0.213	0.126	0.0798	0.208	1.902	0.258
	(0.36)	(0.46)	(0.14)	(0.84)	(1.40)	(1.14)
Observations	4031	20538	3071	21498	1728	22841
Adjusted R^2	0.795	0.749	0.800	0.765	0.827	0.786

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of exports of industry i in country c in year t. The independent variable is the interaction of country c's level of patent protection in year t and industry i's patent intensity. Skill, capital, and natural resource endowments, financial liberalization measures, as well as country, industry, and year fixed effects are included in all regressions. Standard errors are clustered by country-industry.

${}^{*}p < 0.10$, ${}^{**}p < 0.05$, ${}^{***}p < 0.01$

Table 6: Threshold regression estimates - 15-year averages

	>3.5	<3.5	>3.75	<3.75	>4	<4
Patent law * patent intens.	-2.760***	0.253	-2.853***	0.374**	-5.463**	0.511***
	(-3.69)	(1.30)	(-3.74)	(2.09)	(-2.60)	(3.32)
GDP * patent intens.	0.604***	0.213**	0.727***	0.207**	1.393***	0.228***
	(3.61)	(2.44)	(4.35)	(2.39)	(3.16)	(2.85)
GDP	0.390**	0.882***	0.300*	0.912***	0.216	1.033***
	(2.54)	(7.84)	(1.80)	(8.23)	(1.18)	(10.41)
Skill * skill intensity	0.878	1.293***	0.706	1.368***	-0.622	1.556***
	(1.61)	(3.70)	(1.31)	(4.12)	(-1.11)	(5.14)
Capital * capital intensity	-24.14***	0.933	-20.71***	0.655	2.857	-0.00348
	(-3.47)	(0.90)	(-2.99)	(0.66)	(0.25)	(-0.00)
Resource * resource intensity	0.112*	0.0992**	-0.0731	0.111**	0.0868	0.112**
	(1.72)	(1.98)	(-0.94)	(2.24)	(0.53)	(2.47)
Fin. lib. * fin. intensity	-3.185	-0.0103	-5.751	0.104	-1.030	0.229
	(-0.38)	(-0.03)	(-0.70)	(0.30)	(-0.12)	(0.78)
Observations	240	1416	192	1464	72	1584
Adjusted R^2	0.811	0.833	0.826	0.840	0.924	0.860

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of exports of industry i in country c. The independent variable is the interaction of country c's level of patent protection and industry i's patent intensity. Country and industry fixed effects are included in all regressions. Standard errors are clustered by country-industry.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 7: Threshold regression estimates - percentile

	>95th	<95th	>90th	<90th	>85th	<85th
Patent law * patent intens.	-0.877***	0.487***	-1.101***	0.450***	-0.899***	0.287*
	(-3.13)	(3.52)	(-3.33)	(2.92)	(-3.02)	(1.73)
Patent law	0.235	-0.0965	0.941**	-0.0640	0.701**	0.0706
	(0.57)	(-0.78)	(2.59)	(-0.47)	(2.54)	(0.49)
GDP * patent intens.	0.521***	0.259***	0.375**	0.262***	0.348**	0.240***
	(3.29)	(3.34)	(2.36)	(3.28)	(2.08)	(2.90)
GDP	-0.812	0.754***	0.0468	0.710***	0.0471	0.669***
	(-1.60)	(4.98)	(0.10)	(4.51)	(0.13)	(4.09)
Skill * skill intensity	0.649	1.296***	0.806*	1.148***	0.806*	0.988***
	(1.45)	(4.68)	(1.85)	(3.90)	(1.86)	(3.10)
Capital * capital intensity	-3.979	0.330	-19.80**	0.853	-13.39**	1.263
	(-0.77)	(0.36)	(-2.53)	(0.90)	(-2.42)	(1.28)
Resource * resource intensity	0.259*	0.125**	0.0944	0.123**	0.223***	0.103*
	(1.88)	(2.56)	(1.25)	(2.41)	(3.37)	(1.90)
Fin. lib. * fin. intensity	-6.535	0.332	-9.229	0.220	-0.119	0.0666
	(-1.57)	(1.45)	(-1.05)	(0.87)	(-0.16)	(0.22)
Observations	1272	23297	2808	21761	4248	20321
Adjusted R^2	0.902	0.793	0.834	0.769	0.816	0.747

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of exports of industry i in country c in year t. The independent variable is the interaction of country c's level of patent protection in year t and industry i's patent intensity. Skill, capital, and natural resource endowments, financial liberalization measures, as well as country, industry, and year fixed effects are included in all regressions. Standard errors are clustered by country-industry.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 8: First-stage check

	Patent law
British legal origin	-0.943**
	(-2.49)
French legal origin	-1.374***
	(-3.74)
German legal origin	0.401
	(0.81)
Observations	84
Adjusted R^2	0.277

t statistics in parentheses

This table presents the result of the regression of average level of patent protection on legal origins. The dependent variable is country c's average level of patent protection. The independent variables are country c's legal origin dummies.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 9: Instrumental variables

	>3.5	<3.5	>3.75	<3.75	>4	<4
Patent law * patent intens.	-2.991***	0.877**	-2.819***	0.971***	-5.463***	1.160***
	(-3.40)	(2.44)	(-3.15)	(3.41)	(-3.45)	(4.49)
GDP * patent intens.	0.639***	0.187**	0.722***	0.171**	1.393***	0.137*
	(3.66)	(2.18)	(4.30)	(2.02)	(4.18)	(1.65)
GDP	0.406***	1.018***	0.297*	1.050***	0.216	1.186***
	(2.79)	(8.04)	(1.88)	(8.86)	(1.56)	(11.01)
Skill * skill intensity	0.849*	1.305***	0.711	1.369***	-0.622	1.534***
	(1.69)	(3.86)	(1.45)	(4.26)	(-1.47)	(5.23)
Capital * capital intensity	-23.81***	1.265	-20.78***	1.052	2.857	0.553
	(-3.71)	(1.24)	(-3.29)	(1.07)	(0.33)	(0.62)
Resource * resource intensity	0.111*	0.123**	-0.0726	0.136***	0.0868	0.138***
	(1.85)	(2.51)	(-1.03)	(2.82)	(0.70)	(3.10)
Fin. lib. * fin. intensity	-2.602	-0.221	-5.833	-0.118	-1.030	-0.0267
	(-0.33)	(-0.57)	(-0.78)	(-0.33)	(-0.15)	(-0.09)
Observations	240	1392	192	1440	72	1560
Adjusted R^2	0.811	0.835	0.826	0.842	0.924	0.861

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of average exports of industry i in country c. The potentially endogenous variable is the interaction of country c's average level of patent protection and industry i's patent intensity, which is instrumented by interactions of legal origin dummies and patent intensity. Country and industry fixed effects are included in all regressions. Standard errors are clustered by country-industry.

${}^{*}p < 0.10$, ${}^{**}p < 0.05$, ${}^{***}p < 0.01$

Table 10: Patent reforms

	(1)	(2)	(3)	(4)	(5)
Patent reform * patent intens.	1.085***	-0.446***	1.469***	-0.296**	1.024***
	(6.48)	(-3.41)	(6.70)	(-1.99)	(3.69)
Patent reform	-0.730***	0.251	-0.980***	0.172	-0.547**
	(-4.73)	(1.39)	(-4.84)	(0.82)	(-2.17)
GDP * patent intens.	1.118***	1.369***	0.692***	1.064***	0.681***
	(11.66)	(13.70)	(5.10)	(10.48)	(4.83)
GDP	-0.350*	-0.564	0.167	-1.496**	0.398
	(-1.67)	(-0.30)	(0.62)	(-2.31)	(1.39)
Skill * skill intensity	0.440**	2.640***	-0.351	0.311	0.204
	(2.21)	(9.35)	(-1.49)	(1.26)	(0.64)
Capital * capital intensity	1.872**	-9.580***	5.018***	5.657***	6.035***
	(1.99)	(-4.23)	(3.68)	(4.28)	(4.01)
Resource * resource intensity	0.292***	0.0855*	0.352***	0.315***	0.302***
	(8.61)	(1.92)	(8.49)	(5.76)	(6.81)
Fin. lib. * fin. intensity	-0.283	4.751***	-1.646***	-0.962***	-0.429
	(-1.24)	(8.27)	(-4.37)	(-5.41)	(-0.93)
Observations	4389	766	3623	1143	3246
Adjusted R^2	0.740	0.888	0.674	0.810	0.639

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of exports of industry i in country c. The independent variable is the interaction of country c's reform dummy variable in year t and industry i's patent intensity. Skill, capital, and natural resource endowments, financial liberalization measures, as well as country, industry, and year fixed effects are included in all regressions. Standard errors are clustered by country-industry.

${}^{*}p < 0.10$, ${}^{**}p < 0.05$, ${}^{***}p < 0.01$

Table 11: Rapp-Rozek index

	(1)	(2)
Patent law * patent intens.	-4.649***	0.984***
	(-3.44)	(4.63)
GDP * patent intens.	0.269**	0.574***
	(2.01)	(4.63)
GDP	0.0476	1.162***
	(0.28)	(8.71)
Skill * skill intensity	1.353***	1.176*
	(2.70)	(1.87)
Capital * capital intensity	-48.78***	3.089*
	(-2.77)	(1.81)
Resource * resource intensity	0.162**	0.0943
	(2.02)	(1.35)
Fin. lib. * fin. intensity	39.30***	-0.892
	(2.84)	(-1.12)
Observations	144	792
Adjusted R^2	0.842	0.806

t statistics in parentheses

This table presents the results of the regression of average export value on the patent interaction variable. The dependent variable is the natural log of average exports of industry i in country c. The independent variable is the interaction of country c's Rapp-Rozek index of patent protection and industry i's patent intensity. Country and industry fixed effects are included in both regressions. Standard errors are clustered by country-industry.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 12: Instrument: 1960 protection level

	>3.5	<3.5	>3.75	<3.75	>4	<4
Patent law * patent intens.	-2.533**	0.0830	-3.333***	0.211	-5.463***	0.332*
	(-2.51)	(0.37)	(-4.37)	(1.02)	(-3.45)	(1.84)
GDP * patent intens.	0.569***	0.152	0.790***	0.147	1.393***	0.222**
	(2.99)	(1.38)	(5.04)	(1.35)	(4.18)	(2.23)
GDP	0.374**	1.094***	0.342**	1.137***	0.216	1.130***
	(2.51)	(7.64)	(2.24)	(8.10)	(1.56)	(8.68)
Skill * skill intensity	0.906*	1.494***	0.640	1.566***	-0.622	1.743***
	(1.79)	(3.65)	(1.31)	(4.05)	(-1.47)	(4.99)
Capital * capital intensity	-24.47***	2.076*	-19.79***	1.625	2.857	0.693
	(-3.79)	(1.65)	(-3.16)	(1.35)	(0.33)	(0.65)
Resource * resource intensity	0.114*	0.0692	-0.0797	0.0844	0.0868	0.0943*
	(1.90)	(1.18)	(-1.13)	(1.47)	(0.70)	(1.85)
Fin. lib. * fin. intensity	-3.757	0.126	-4.585	0.242	-1.030	0.358
	(-0.48)	(0.31)	(-0.62)	(0.65)	(-0.15)	(1.15)
Observations	240	1080	192	1128	72	1248
Adjusted R^2	0.811	0.782	0.825	0.793	0.924	0.825

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of average exports of industry i in country c. The potentially endogenous variable is the interaction of country c's average level of patent protection in year t and industry i's patent intensity, which is instrumented by the interaction of country c's 1960 level of patent protection and industry i's patent intensity. Country and industry fixed effects are included in all regressions. Standard errors are clustered by country-industry.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 13: Non-weighted patent intensity

	>3.5	<3.5	>3.75	<3.75	>4	<4
Patent law * patent intens.	-0.873***	0.382**	-0.794**	0.452***	-1.825***	0.466***
	(-3.11)	(2.15)	(-2.48)	(2.80)	(-3.57)	(3.24)
Patent law	0.632***	0.0529	0.617**	-0.0214	1.411***	-0.0521
	(2.76)	(0.34)	(2.43)	(-0.15)	(3.38)	(-0.40)
GDP * patent intens.	0.286*	0.267***	0.280*	0.269***	0.326**	0.265***
	(1.93)	(3.32)	(1.95)	(3.43)	(2.30)	(3.44)
GDP	0.434	0.635***	0.386	0.687***	-0.124	0.714***
	(1.21)	(3.88)	(1.32)	(4.31)	(-0.37)	(4.59)
Skill * skill intensity	0.712*	1.006***	0.793**	1.102***	0.834**	1.300***
	(1.89)	(3.20)	(2.24)	(3.72)	(2.27)	(4.67)
Capital * capital intensity	-8.313	1.342	-10.35*	0.998	-10.43*	0.580
	(-1.56)	(1.39)	(-1.86)	(1.07)	(-1.74)	(0.64)
Resource * resource intensity	0.158***	0.113**	0.146**	0.119**	0.0962	0.123**
	(2.86)	(2.14)	(2.57)	(2.32)	(1.58)	(2.48)
Fin. lib. * fin. intensity	0.213	0.126	0.0798	0.208	1.902	0.258
	(0.36)	(0.46)	(0.14)	(0.84)	(1.40)	(1.14)
Observations	4031	20538	3071	21498	1728	22841
Adjusted R^2	0.795	0.749	0.800	0.765	0.827	0.786

t statistics in parentheses

This table presents the results of the regression of export value on the patent interaction variable. The dependent variable is the natural log of exports of industry i in country c in year t. The independent variable is the interaction of country c's level of patent protection in year t and industry i's patent intensity. Skill, capital, and natural resource endowments, financial liberalization measures, as well as country, industry, and year fixed effects are included in all regressions. Standard errors are clustered by country-industry.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$