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Falvey, Rod; Foster, Neil; Greenaway, David

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ORIGINAL PAPER

Trade, imitative ability and intellectual property rights

Rod Falvey · Neil Foster · David Greenaway

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Abstract Economic theory suggests some ambiguity concerning the effects of strengthening intellectual property rights (IPRs) on international trade. Here we extend the empirical literature that attempts to resolve this ambiguity. We use panel data to estimate a gravity equation for manufacturing exports, in aggregate and by industry, from five advanced countries to 69 developed and developing countries over the period 1970–1999. In particular, we use threshold regression techniques to determine whether the impact of IPR protection on trade depends upon the level of development, imitative ability and market size of the importing country. We confirm the importance of the importers' imitative ability, and also find some evidence of a role for market size in this relationship. The individual industries present different patterns of thresholds and coefficients, with Total Manufacturing closely reflecting that of Fabricated Metal Products.

Keywords Intellectual property rights · International trade · Gravity equation · Imitative ability

JEL Classification F10 · F13 · O34

R. Falvey · D. Greenaway (✉)
School of Economics, University of Nottingham,
University Park, Nottingham NG7 2RD, UK
e-mail: david.greenaway@nottingham.ac.uk

R. Falvey
e-mail: rod.falvey@nottingham.ac.uk

N. Foster
Department of Economics, University of Vienna,
Hohenstaufengasse 9, 1010 Vienna, Austria
e-mail: neil.foster@univie.ac.at

1 Introduction

The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), a product of the Uruguay Round (1986–1994) of trade negotiations, reflects a growing trend of linking trade policy and intellectual property rights (IPRs) regimes. The stated aims of TRIPS, which sets minimum standards of IPR protection to be provided by each World Trade Organisation (WTO) member, include encouraging both innovation and international technology diffusion. The argument relating IPR protection to innovation is clear. IPR protection provides innovators with the legally enforceable power to prevent others from using an intellectual creation or to set the terms on which it can be used. In the absence of such protection new technology or knowledge is likely to be copied or imitated, thus lowering the potential profits of the innovator and reducing the incentive for individuals to undertake innovative activities. To the extent that innovation encourages economic growth, as suggested by many endogenous growth models, we would also expect stronger IPR protection to impact positively upon economic growth. Empirical evidence supporting a relationship between IPRs and innovation has been found by Kanwar and Evenson (2003); other evidence supports the existence of a positive relationship between IPRs and economic growth (Gould and Gruben 1996; Falvey et al. 2004, 2006a).

The relationship between IPR protection and international technology diffusion on the other hand is less straightforward. Technology may be diffused across borders through a variety of formal and informal channels, including international patenting, trade in goods, foreign direct investment (FDI), technology licensing, the (temporary and permanent) migration of skilled workers and product imitation. In addition to stronger IPR protection possibly affecting these potential channels in opposing ways, often the relationship between IPR protection and a single channel is not unambiguous, depending upon the level of development of the receiving country and whether it is able to carry out significant technical innovation or imitate existing technology. Several empirical studies have considered the relationship between IPR protection and a particular channel of diffusion. Maskus and Penubarti (1995) and Smith (1999) for example consider the relationship between IPRs and trade, while Smarzynska (2004) and Eaton and Kortum (1996) consider the importance of IPR protection for FDI and patenting respectively. Others (for example, Maskus 1998; Smith 2001; Nicholson 2007) consider the impact of IPR protection on multiple channels of diffusion simultaneously. The outcomes of these studies are mixed, though stronger evidence is found for the importance of IPR protection for trade and patenting than for FDI.[1]

A now large empirical literature supports the role of international trade in transferring technology both among developed countries (for example, Coe and Helpman 1995) and from developed to developing countries (for example, Coe et al. 1997). While issues remain to be resolved (Keller 2004) the evidence concerning trade as a channel of technology diffusion is perhaps the most consistent of all of the

[1] Even where the evidence indicates a relationship between IPR protection and a specific channel of diffusion, it is often the case that there is little evidence of effective technology transfer. This is particularly the case for FDI. See Falvey et al. (2006b) for a review of the impact of IPRs on the channels of diffusion.

potential channels. In this paper we concentrate on the importance of IPR protection for international trade. Specifically, we examine the importance of IPR protection for manufacturing exports from the G5 countries, in which the bulk of world innovative activity [as measured by research and development (R&D) expenditure] is conducted, to a sample of 69 developed and developing countries. To do this we estimate a gravity equation using panel data grouped into six 5-year averages over the period 1970–1999. Results are reported for both Total Manufacturing trade and nine-two-digit ISIC industries. In addition to estimating a linear relationship between IPR protection and trade, we examine whether this relationship depends upon the level of development, imitative ability and market size of the importing country using threshold regression techniques which allow us to estimate both the number of regimes and their position.

Two opposing effects of stronger IPRs on a country's imports have been identified in the literature. Imports may expand with the curtailment of domestic imitation, but may contract if exporters choose to exercise their increased market power. The empirical literature to date has found evidence of both effects, depending on the imitative ability of the importing country. Our results confirm the prevalence of market expansion effects. We also find some evidence of market power effects, but these are scattered and much less prevalent than previously thought. Our investigation also highlights the importance of one industry (Fabricated Metal Products) in determining the link between strengthened IPRs and aggregate imports from these countries. The other industries behave in different ways, implying that stronger IPRs will affect both the volume and composition of these imports, although no clear link with industry R&D intensity is evident.

The remainder of the paper is as follows. Section 2 summarises the theory and evidence linking IPR protection to international trade. Section 3 describes our empirical approach, while Sect. 4 discusses the data. Section 5 describes the results and Sect. 6 summarises our results and offers some conclusions.

2 Background

Increased IPR protection in a country can directly impact on its imports in two alternative ways. On the one hand, firms should be encouraged to export their goods into foreign markets with strong IPR protection, since such protection reduces the risk of piracy that can diminish the profitability of the firm's activity in that country. In this respect, stronger IPR protection would be expected to raise imports. On the other hand, because stronger IPR protection reduces the ability of domestic firms to imitate, it increases the market power of the exporter, which may encourage the latter to act in a monopolistic manner by reducing sales. Maskus and Penubarti (1995, p. 229) thus argue that there is a "trade-off between the enhanced market power for the firm created by stronger patents and the larger effective market size generated by reduced abilities of local firms to imitate the product". The 'market power' effect would induce the foreign firm to export less to the domestic market, while the 'market expansion' effect would shift the demand curve facing the firm and encourage larger sales. Taylor (1993) also suggests that a third factor may be important for larger markets with significant imitative abilities, with stronger IPR protection encouraging imports by reducing the need for firms to modify their products to try to deter local imitation, thus reducing costs for exporting firms.

Maskus and Penubarti argue that the 'market expansion' effect is likely to dominate in larger countries with strong imitative abilities, while the 'market power' effect would dominate in smaller countries with weak imitative abilities. Naturally the relative importance of these effects is also likely to depend on product and market characteristics. Some products are easier to imitate than others, and some products have closer substitutes than others. An insignificant effect of stronger IPR protection on aggregated trade volumes could mask significant effects for some individual industries. Hence our interest in also considering disaggregated trade flows below. The impact of IPR protection on trade will also depend on the exporter. If the latter is not an innovator, then imports from this country are less likely to embody new technology and IPR protection should be relatively unimportant for trade, hence our decision to concentrate on exports from those countries that are important producers of new knowledge.

A further complication concerns a firm's decision on its mode of serving a foreign market. In general it faces three possibilities: it may export the good, undertake FDI or license its intellectual asset to a foreign firm. The level of IPR protection may affect the firm's choice, and thus strong IPR protection might diminish trade if it induces firms to choose to serve a foreign market by FDI or licensing rather than exporting (Ferrantino 1993). But in the absence of reliable panel data on FDI and licensing at a sufficiently disaggregated level for a large enough group of countries we can do little about this.[2]

The observation that theory indicates the relationship between stronger IPR protection and trade could have either sign, depending on product and market characteristics, has lead to attempts to resolve this ambiguity empirically. In one of the earliest explorations, Maskus and Penubarti (1995) use an augmented version of the Helpman–Krugman model of monopolistic competition to estimate the effects of patent protection on exports from 22 OECD countries to a sample of 71 countries in 1984. Their explanatory variables include the importers' per capita GNP, a measure of patent protection developed by Rapp and Rozek (1990), and the interaction between this IPR index and dummies indicating whether the importing developing country has a small or a large market, the latter accounting for market size effects and technological capacity. Their results indicate that higher levels of IPR protection have a positive impact on bilateral manufacturing imports into both small and large developing economies, though the effects were statistically weaker in the smaller economies. Whilst suggestive of the importance of technological capacity or imitative ability for the relationship between IPR protection and trade, their results find little support for a positive impact of IPR protection in the most patent sensitive industries.

[2] Nicholson (2007) uses data on the numbers of US firms undertaking FDI and licensing to investigate how these activities are linked to IPRs and industry characteristics. He finds that firms in industries with high capital costs are more likely to choose FDI where IPRs are weak, and firms in R&D intensive industries are more likely to choose licensing when IPRs are strong.

This approach is extended by Fink and Primo-Braga (2005) who estimate gravity equations with either total non-fuel trade or 'high-tech' trade (a classification based on Primo-Braga and Yeats 1992) as the dependent variable for a cross-section of 89 × 88 countries in 1989. High-tech trade is isolated in the expectation that the effects of IPR protection should be stronger for knowledge-intensive trade. The explanatory variables include standard gravity factors (the GDP and populations of both trade partners, distance between trade partners and dummies for common border, common language and membership of preferential trading arrangements) plus a measure of IPR protection for the destination country developed by Ginarte and Park (1997). They deal with the problem of zero trade flows by estimating two equations, one for the probability of zero observations and the other for the magnitude of positive trade flows. They find that stronger IPR protection has a small but significantly positive impact on the probability that countries trade with each other and a significantly positive impact on bilateral trade flows for both total non-fuel imports and exports. But, contrary to expectations, stronger IPR protection is found to have a significantly negative impact on the probability that two countries trade in high-tech goods and no significant impact on bilateral high-tech trade flows. This suggests the presence of a combination of strong market power effects and a tendency for stronger IPR protection to induce producers of high-tech goods to serve foreign markets by licensing or FDI rather than exports (see Greenaway and Kneller 2007).

Considering exports from a large sample of innovating countries has the advantage of allowing for the inclusion of exporter fixed effects. Concentrating on exports from a single country, however, means that we need not be concerned that the distribution of exports will also depend upon the trade stance of the exporting country (Maskus 2000). Smith (1999) takes advantage of this feature by estimating a gravity equation of exports in 1992 from each of the 50 US states plus the District of Colombia to 96 countries for which the necessary data are available. Both the Rapp and Rozek and Ginarte and Park indices of IPR protection are employed and yield similar results. Smith begins by including interactions between the IPR measure and four dummies based on the per capita income of the importer (high, upper-middle, lower-middle, low). The results show that US exporters respond positively to the strength of IPR protection in countries with lower-middle incomes, but negatively to the strength of IPR protection in other countries. These results suggest that market power effects dominate across countries where IPR protection approximates US standards (high and upper-middle incomes) and across countries with weak imitative abilities (low income countries). In contrast, strengthened IPR protection in countries with weak IPR protection and strong imitative abilities (lower-middle income countries) result in increased imports from the United States.

The importing countries are then divided into four groups depending on the threat of imitation (defined according to the level of patent rights and R&D spending as a percentage of GNP). Dummies for these four groups were then interacted with the IPR variable. Smith finds a negative relationship between IPR protection and imports from the United States for those countries with the weakest threat of imitation, and a positive relationship for those with the strongest threat of imitation. Overall, she concludes that US exports depend upon IPR protection in importing countries, but that the direction of the relationship depends on the threat of imitation. Weak IPRs are a barrier to US exports, but only for countries that pose a strong threat of imitation.

Rafiquzzaman (2002) carries out a similar analysis on Canadian manufactured exports. Market expansion effects are found for countries with the strongest threat of imitation, and some evidence of market power effects is found where the threat of imitation is weakest. While the outcomes are broadly similar to those that Smith found for the United States, the indications of market power effects are generally weaker for Canadian exports.

Recently Co (2004) has extended this approach to a panel framework for a sample of 71 countries over the period 1970–1992. Panel data allows one to take account of changes in patent regimes and imitative ability over time, and better controls for unmeasured heterogeneity. Once again the ratio of R&D to GNP is used as a measure of imitative ability, here being interacted with the Ginarte and Park IPR variable. She finds that IPR protection has a negative and significant impact on US exports of non-R&D intensive goods, suggesting that market power effects dominate for this trade, but no significant impact on R&D intensive goods, an outcome similar to that found by Fink and Primo-Braga (2005) for high-tech trade. The coefficients on the interaction between IPR protection and imitative ability are found to be positive and significant for both types of goods, suggesting that the impact of IPR protection depends upon the level of imitative ability, with increased IPR protection having a positive impact on trade in all goods above a certain level of imitative ability.[3]

In summary, the evidence from this small empirical literature supports the following hypotheses (see also Fink and Maskus 2005). First, the level of IPR protection does matter for at least some trade flows in manufactured goods. Second, strengthening IPRs can lead to market power effects for some trade flows, particularly for importing markets where the threat of imitation is small (due to a small market, limited capacity for imitation or an existing high level of IPRs). Third, strengthening IPRs can lead to market expansion effects for other trade flows, particularly in importing markets with a significant threat of imitation. Finally, the responsiveness of trade in R&D intensive products to increased IPR protection may be difficult to predict, given that these products may be particularly hard to imitate anyway, and that their producers can choose to serve foreign markets through FDI and licensing. These hypotheses are among those explored further below. Our particular point of departure is the observation that to date the tests of hypotheses concerning the levels of IPR protection, market size and imitative ability have relied on the division of the sample into groups based

[3] Liu and Lin (2005) consider exports by Taiwan in three knowledge-intensive industries (semi-conductor, information and communications equipment). For importing countries with a lower imitative (R&D) ability than Taiwan, the results are analogous to those in the literature (i.e. market power effects in countries with relatively low imitative ability and market expansion effects in the others). For importing countries whose imitative ability exceeds Taiwan's, there are market expansion effects but no market power effects. In an interesting recent contribution, Ivus (2008) uses developing countries' previous colonial status and industry IPR-sensitivity to argue that the IPR strengthening under the TRIPS agreement has led to increased high-tech imports by developing countries.

on exogenous criteria with respect to both the number of groups and the location of the thresholds that divide them. Recently developed threshold regression techniques allow both the number and location of these thresholds to be determined from the data rather than imposed. They also allow the number and location of the thresholds to differ across industries.

3 Empirical analysis

We follow the literature in estimating a gravity equation to determine the impact of IPR protection on the manufacturing imports of our sample of countries. While the exact specification of the gravity equation can vary, our equation includes the GDPs and populations of the importer and exporter, the distance between them and other variables that may enhance or restrict trade. The starting point for our analysis is the following equation

$$\begin{aligned}\ln TRADE_{ijt} = {} & \beta_1 \ln DIST_{ij} + \beta_2 \ln GDPM_{it} + \beta_3 \ln GDPX_{jt} + \beta_4 \ln POPM_{it} \\ & + \beta_5 \ln POPX_{jt} + \beta_7 COMLAN_{ij} + \beta_8 COMBOR_{ij} + \beta_9 LOCK_i \\ & + \delta IPR_{it} + \mu_i + \theta_j + v_t + \varepsilon_{ijt} \qquad (1)\end{aligned}$$

where i and j denote the importing and exporting country respectively, and t denotes the time period, *TRADE* is exports from j to i in a particular category; *DIST* is the great circle distance between the capitals; *GDPM* and *POPM* are the GDP and population of the importing country; *GDPX* and *POPX* are the GDP and population of the exporting country; *COMLAN* takes the value one if trading partners share a common language; *COMBOR* takes the value one if the trading partners share a common border; *LOCK* takes the value one if the importing country is landlocked; *IPR* is our index of IPR protection in the importing country; μ_i, θ_j and v_t are importer, exporter and time fixed effects; and ε_{ijt} is a normally distributed error term.

We expect that, in line with existing literature (see Greenaway and Milner 2002) distance will have a negative impact on trade flows by increasing transport costs. The GDP's of the importing and exporting country are expected to have a positive impact on trade flows. In the former this is due to a higher GDP indicating a larger market size, which should increase imports, while in the latter higher levels of GDP represent higher productive capacity. There is some ambiguity over the expected sign of the coefficients on population. In general, a larger population is usually associated with a larger country size, which is likely to lead to more diversified production and higher levels of self-sufficiency, and should lower trade flows and imports in particular. A larger population also allows a country to take fuller advantage of economies of scale leading to increased intra-industry trade (Prewo 1978). For an exporting country therefore, a larger population by encouraging economies of scale would seem to imply larger manufacturing exports. A common language should facilitate communication between trade partners and reduce the search costs of international trade. A common language may reflect former colonial ties, which for historical reasons may also lead to greater trade flows. A common border facilitates trade, but being landlocked is generally considered to reduce international trade due to the relatively high cost of overland transportation. Finally, while these are the expected coefficients for data on total trade we may expect deviations from this when we consider industry data.

While the majority of studies using the gravity equation to predict trade flows employ cross-section data, the use of panel data allows us to capture the relationship between IPRs and trade over a longer period of time; to account for changing IPR regimes and imitative ability; to control for the overall business cycle and to disentangle the time-invariant country-specific effects (Egger 2000); and to control for unmeasured country and time-specific heterogeneity (Co 2004). When using panel data we need to make a choice between the fixed and the random effects estimator. Co (2004) largely relies on a random effects model since with only one exporter a fixed effects model would preclude the inclusion of time-invariant variables such as distance and the common border dummy. Mátyás (1997) and Egger (2000) argue that where possible a three way fixed effects model (including importer, exporter and time-specific fixed effects) should be estimated. Egger for example argues that since the effects we seek to capture are trade policy and other export driving and impeding 'environmental' factors, including historical and geographical determinants which tend not to be random, a fixed effects estimator is more appropriate. These fixed effects are represented by μ_i, θ_j and v_t in the estimating equation above.[4]

The estimate of coefficient δ gives us a simple linear estimate of the impact that IPR protection has on a country's imports from our five developed countries. But, as discussed above, there are reasons to believe that the relationship between IPR protection and trade is non-linear, and in particular that it may depend upon the level of development, imitative ability and the market size of the importing country. To test these hypotheses we follow the general approach of Smith (1999) and Rafiquzzaman (2002) of allocating countries into groups based on the relevant characteristic. But rather than using a predetermined allocation as they do, we employ the threshold techniques of Hansen (1996, 1999, 2000),[5] which allow us to estimate rather than impose both the number of regimes and the positioning of the splits.[6]

The Hansen method (see Appendix 1 for details) is based on a threshold regression where observations fall into regimes that depend on an estimated value of an observed variable (e.g. a measure of imitative ability). In the two-regime model, for example, we have

[4] A further issue is how to deal with zero trade flows. Using five-year averages did alleviate this problem somewhat, but there were still a few cases where zero trade flows were reported. Several options are available (Frankel 1997, chapter 6), but given that the threshold techniques that we employ below have been developed for OLS we adopt the most straightforward "solution" of adding a small number to the zero observations (equal to \$100), which allows us to estimate the log-linear model.

[5] Hansen (1999) in particular describes the threshold regression technique for panel data with fixed effects.

[6] The alternative hypothesis, tested by Co (2004), is that the marginal effect of IPR protection on trade is a continuous (in fact linear) function of, say imitative ability, which is tested by including the appropriate interactive term. The threshold and interactive approaches are not nested hypotheses, however, and it is possible that each is valid for some industries. Where thresholds are estimated, but an interactive term is more appropriate, we would expect to find a large number of significant thresholds with the coefficient on IPR rising for higher regimes. If however we were to find only one or two significant thresholds, or coefficients that change sign across regimes then the results would not support the interaction hypothesis.

$$\delta IPR(TH_{it}) = \delta_1 IPR_{it} I(TH_{it} \leq \lambda) + \delta_2 IPR_{it} I(TH_{it} > \lambda) \quad (2)$$

where λ is the estimated breakpoint or threshold. Here the observations are separated into two regimes depending on whether the threshold variable, TH_{it}, is smaller or larger than the value λ. The impact of IPR protection on trade will be given by δ_1 for countries in the low regime (i.e. $TH_{it} \leq \lambda$) and by δ_2 for countries in the high regime (i.e. $TH_{it} > \lambda$). We estimate the threshold (λ) as the value that minimises the concentrated sum of squared errors from the least squares regression. In practice this involves searching over distinct values of the threshold variable (TH_{it}) for the value of λ that minimises the sum of squared errors. After obtaining a value of λ, we can estimate the parameters of our gravity equation. Having found the threshold we identify whether it is statistically significant by testing the null hypothesis that $\delta_1 = \delta_2$. Rejecting the null hypothesis allows us to conclude that a threshold exists in the relationship between IPR and Trade. One complication is that the threshold λ is not identified under the null hypothesis, implying that classical tests do not have standard distributions and critical values cannot be read off standard distribution tables. We follow Hansen (1996) and bootstrap to obtain the *p*-value for the test of a significant threshold.[7]

This technique can be extended to consider the possibility of more than one threshold (i.e. more than two regimes). We decide upon the optimal number of thresholds by first estimating a single threshold. If this is found to be significant, we search for a second threshold using sequential estimation (see Appendix 1). If this second estimated threshold is significant we search for a third threshold and so on. As is common in the literature, we impose the restriction that at least 20% of observations must lie in each regime to maintain a reasonable sample size in each. This implies that the maximum number of regimes we can consider is five.

The data that we use and its sources are described in Appendix 2. We examine manufacturing exports from the five largest developed countries to a sample of 69 other developed and developing countries.[8] World R&D is concentrated in the OECD countries,[9] and within the OECD heavily concentrated in these five countries.[10] Table 1 (column 2) shows that in all industries the leading five countries

[7] The bootstrap distribution of the test statistic was computed using 1,000 replications of the procedure proposed in Hansen (1996).

[8] The five exporting countries are France, Germany, Japan, the United Kingdom and the United States. The importing countries are Algeria, Argentina, Australia, Austria, Bangladesh, Belgium-Luxemburg, Bolivia, Brazil, Cameroon, Canada, Central African Republic, Chile, Colombia, Costa Rica, Denmark, the Dominican Republic, Ecuador, Egypt, El Salvador, Finland, Ghana, Greece, Guatemala, Guyana, Haiti, Honduras, Iceland, India, Indonesia, Ireland, Israel, Italy, Jamaica, Kenya, Korea (Republic of), Malawi, Malaysia, Mexico, the Netherlands, New Zealand, Nicaragua, Niger, Norway, Pakistan, Paraguay, Peru, the Philippines, Portugal, Senegal, Sierra Leone, South Africa, Spain, Sri Lanka, the Sudan, Sweden, Switzerland, Syria, Tanzania, Thailand, Togo, Trinidad and Tobago, Turkey, Uganda, Uruguay, Venezuela, Zaire, Zambia, Zimbabwe.

[9] UNIDO (2002) notes that the share of R&D financed by enterprises in advanced countries was 98% in the 1980s and 94% in the 1990s.

[10] The ANBERD database reports total manufacturing R&D expenditure for 15 OECD countries for 1973–1998, and the average share of R&D expenditure by these five economies over that period was 91.4%. There has been a slight decline in this share over the sample period from 92.8% in 1973 to 89.4% in 1998.

Table 1 Descriptive data on the significance of R&D and patents (percent)

	Share of G5 in total OECD R&D expenditure (1973–1998)[a]	Share of industry R&D in total manufacturing R&D for G5 (1973–1998)[b]	Ratio of industry R&D to production in G5 (1978–1996)[c]	Effectiveness of patents for product innovations (%)[d]	Industry share of manufacturing exports (%)[e]
3—Total Manufacturing	91.4	100	2.23	32.70	100
31—Food, Beverages and Tobacco (Food)	84.6	1.76	0.29	28.96	5.99
32—Textiles, Apparel and Leather (Textiles)	90.1	0.55	0.24	27.69	5.10
33—Wood Products and Furniture (Wood)	89.4	0.29	0.19	26.91	1.17
34—Paper, Paper Products and Printing (Paper)	83.9	0.94	0.28	24.51	2.85
35—Chemical Products (Chemicals)	89.5	20.04	2.53	37.79	17.97
36—Non-Metallic Mineral Products (Non-Metallic)	93.1	1.25	0.98	28.83	1.58
37—Basic Metal Industries (Basic)	86.9	2.22	0.63	27.14	6.33
38—Fabricated Metal Products (Fabricated)	92.3	72.30	4.07	33.02	57.08
39—Other Manufacturing (Other)	88.9	0.63	0.65	25.71	1.84

[a] The figures in this column report the percentage of R&D expenditure in each industry carried out by the leading five economies. Data is available over the period 1973–1998 for 15 OECD countries

[b] The figures in this column report the share of total manufacturing R&D expenditure that is spent in each of the industries. The shares reported are the average shares over the period 1973–1998

[c] This column reports the ratio of industry R&D expenditure to industry production. The figures are averages over the period 1978–1996 for the G5 countries. R&D data are expressed in current PPP US dollars. Production data is expressed in current prices and in national currency. The production data was converted to US dollars, using the PPP exchange rates provided in the STAN database. These PPP's are based on a comparison of consumer goods prices, and are neither industry-specific nor do they reflect relative producer prices. The conversion of these industry-level production data to a common currency should be interpreted with caution therefore

[d] This column reports results based on Table 1 of Cohen et al. (2000). Cohen et al. (2000) report results using SITC rev. 3 at the four-digit level whereas we use SITC rev. 2 at the two-digit level. To calculate the figures at the two-digit level we use the unweighted average of the four-digit results. Where a four-digit industry according to SITC rev. 3 is allocated to two or more two-digit industries according to SITC rev. 2 we include the industry in all of the two-digit industries

[e] The figures in this column refer to the average shares of exports from the G5 in each industry out of total exports to our sample of importing countries over the period 1970–1999

make up over 80% of total R&D spending by the 15 OECD countries for which we have data. Also reported in Table 1 are the average industry shares in Total Manufacturing R&D for the G5 countries over the period 1973–1998. It is clear from these figures that R&D is heavily concentrated in two of the two-digit industries, Chemicals and, particularly, Fabricated Metal. Column 4 of Table 1 reports the ratio of industry R&D to industry production in our five exporting countries, with data averaged over the period 1978–1996, to give an indication of their relative R&D intensities. Once again Chemicals and Fabricated Metal tend to be the most R&D intensive, with much smaller intensities found in the other industries. Since our IPR index is a measure of patent strength, column 5 is a measure of the effectiveness of patent protection for product innovations in the relevant industry.[11] While the dispersion in outcomes is much smaller than for the other indicators, we again see that Chemicals and Fabricated Metal are the industries for which patent protection is relatively important. The final column gives the share of each industry's exports in Total Manufacturing exports. Not unexpectedly given the figures in the previous columns, exports from the G5 to our sample of importing countries are concentrated in Fabricated Metals and, to a lesser extent, Chemicals. The predominance of the former is reflected in the results that follow.

Finally, we explain our choices for threshold variables. As discussed above, the literature points to the relationship between IPR protection and trade depending upon an importer's level of development, imitative ability and market size. We measure an importer's level of development by its GDP per capita. Imitative ability refers to a country's capacity to copy and produce technology and goods produced elsewhere, and is likely to depend upon a range of factors. Smith (1999) employs data on R&D expenditures as a percentage of GNP and the level of IPR protection to split her sample into four groups. But this variable has important limitations for our purposes. First, data is unavailable for many of our countries and time periods, which is quite constraining in a panel context.[12] Second, the reliability of the data that is available for developing countries has been questioned.[13] Third, even where it is accurately measured, R&D expenditures are more likely to capture innovative than imitative activity. We therefore turned to education level indicators, which are more widely available and were also suggested by Smith, which gives us another check on the robustness of her results. Here two alternatives are available—average years of secondary schooling (SYR) and higher education (HYR) in the population over 15. We use both below, but SYR is our preferred measure of imitative ability because we expect that in general copying the embodied outcome of an innovation requires lower skill levels than the innovation itself. HYR is likely to be a better indicator

[11] This measure is derived from Cohen et al. (2000). The underlying data is from a survey questionnaire administered to 1,478 R&D labs in US manufacturing in 1994. The question asked respondents to report the percentage of their product innovations for which patents had been effective in protecting the firm's competitive advantage from those innovations.

[12] Our observations fall from 2,021 to 1,360.

[13] Maskus (2000, p. 118) observes that "in the developing economies R&D data are highly suspect and not comparable to those in developed countries". He also notes that Smith's designations of countries into the four groups based on R&D data led to a number of anomalies.

of innovative ability.[14] The final threshold variable that we consider is the level of GDP, as a measure of market size. We expect that the incentive to imitate will be greater in larger markets, other things equal, but that firms in advanced countries may take advantage of market power in smaller markets.

4 Results

4.1 A linear relationship

The results of estimating each regression separately using OLS with the IPR variable included linearly are reported in Table 2.[15] All variables are expressed in natural logarithms (except for the dummies and the IPR variable). To ease interpretation we report the results for the two-digit industries listed in descending order of their R&D intensity. The results for the 'core' gravity variables are broadly as anticipated, taking into account our small number of exporters and that trade flows are more heavily influenced by the comparative advantage factors picked up by the (unreported) country dummies as we consider narrower industry definitions. We find a negative and significant coefficient on distance. The coefficient on importer GDP is consistently positive and significant, while the coefficient on the population of the importer is negative and significant. Rather unexpectedly the exporter's GDP often has a negative coefficient when it is significant, but this seems to be largely a consequence of the inclusion of fixed effects.[16] The exporter's population usually has a positive coefficient when it is significant. While a common language appears to consistently raise the level of imports across industries, the coefficient on the common border dummy is found to vary in both sign and significance. Again this seems to be a consequence of the inclusion of fixed effects.[17] The coefficient on landlocked sometimes shows 'perverse' signs for the same reason.

Turning to the IPR variable, we have significant positive coefficients for all industries, with the exception of Textiles for which an insignificant positive coefficient

[14] The view that secondary education is the broad key to development (shifting countries towards the frontier) is supported by Meier (1995, p. 315) "the most critical manpower requirement tends to be for people with a secondary education who can be managers, administrators, professional technicians or sub-professional technical personnel". Similarly, Ramcharan (2004, p. 320) conjectures that "it may well be that developing economies need only invest in secondary schooling, importing high-skilled education embodied in the foreign goods".

[15] We also estimated these equations as a system using seemingly unrelated regression (SURE) methods. The SURE results are very similar to the OLS results and are available upon request, but for consistency with the threshold results that we report later which rely on OLS estimates, we report the OLS estimates in the text.

[16] If we re-estimate excluding importer, exporter and time dummies, the size of the negative coefficients on exporter GDP tends to fall significantly, and in many cases becomes significant and positive.

[17] When fixed effects are excluded, the common border is more likely to be positive and significant for the industries, but still negative for the most R&D intensive products. It should be remembered that while we expect a common border to lead to greater trade flows in aggregate, this will not necessarily be the case for each individual product. The negative coefficients may be an idiosyncrasy of the sample since the number of common borders is limited and, with the exception of the US-Mexico border, involve trade between advanced countries.

Table 2 OLS estimates of the impact of IPR protection on trade

Industry	*DIST*	*GDPM*	*POPM*	*GDPX*	*POPX*	*LOCK*	*COMLAN*	*COMBOR*	*IPR*	*F*-Stat	R^2
Total Manufacturing	−1.0	1.43	−1.31(−5.86)***	0.43	1.28	−20.8	0.67	0.11	0.18	15,443.1***	0.99
	(−32.95)***	(16.22)***		(0.82)	(1.50)	(−1.66)*	(8.80)***	(1.18)	(2.60)***		
Fabricated Metal Products	−0.88	1.47	−1.47	1.75	0.90	−52.40	0.75	0.17	0.19	15,699.0***	0.99
	(−31.42)***	(15.14)***	(−6.05)***	(3.40)***	(1.04)	(−4.07)***	(10.90)***	(1.92)*	(2.56)**		
Chemical Products	−1.21	1.37	−0.99	−0.11	1.33	−10.09	0.80	−0.35	0.23	7,821.7***	0.99
	(−30.46)***	(11.91)***	(−3.63)***	(−0.17)	(1.31)	(−0.62)	(8.36)***	(−2.89)***	(2.86)***		
Non-Metallic Minerals	−1.29	1.86	−1.45	−0.40	1.55	−11.96	1.11	−0.14	0.19	5,965.4***	0.99
	(−33.43)***	(14.06)***	(−4.86)***	(−0.60)	(1.33)	(−0.71)	(13.05)***	(−1.17)	(2.07)**		
Other Manufacturing	−1.13	2.10	−1.38	−2.49	5.34	−30.94	1.21	−0.71	0.20	3,951.5***	0.99
	(−25.24)***	(12.13)***	(−3.95)***	(−3.15)***	(3.85)***	(−1.54)	(12.41)***	(−4.23)***	(1.80)*		
Basic Metal Industries	−1.36	1.43	−0.69	−3.54	2.21	65.99	0.66	0.04	0.28	4,958.8***	0.99
	(−34.43)***	(10.08)***	(−1.86)*	(−4.35)***	(1.62)	(3.30)***	(6.55)***	(0.30)	(2.38)**		
Food, Beverages, Tobacco	−1.08	1.24	−0.95	−5.38	4.08	91.72	0.37	0.30	0.37	5,070.4***	0.99
	(−23.46)***	(6.78)***	(−2.77)***	(−5.36)***	(2.94)***	(4.51)***	(4.07)***	(1.96)**	(3.58)***		
Paper, Paper Products, Printing	−1.35	1.37	−1.18	−4.19	2.57	89.25	1.44	−0.10	0.20	5,411.4***	0.99
	(−29.54)***	(8.84)***	(−3.80)***	(−5.65)***	(2.08)**	(4.90)***	(16.12)***	(−0.68)	(2.08)**		
Textiles, Apparel, Leather	−1.62	2.25	−1.80	−7.91	10.25	45.15	0.67	0.08	0.16	4,473.5***	0.99
	(−31.54)***	(13.79)***	(−4.91)***	(−9.10)***	(6.97)***	(2.06)**	(7.15)***	(0.51)	(1.33)		
Wood Products, Furniture	−1.57	2.33	−1.49	−8.20	10.95	30.02	1.23	0.12	0.29	2,400.6***	0.99
	(−29.93)***	(12.74)***	(−3.75)***	(−8.57)***	(6.77)***	(1.39)	(10.73)***	(0.73)	(2.28)**		

All regressions include a full set of importer, exporter and time effects that are not reported for brevity

*, ** and *** indicate significance at the 10, 5 and 1% level respectively. *t*-statistics in parentheses are based on White's heteroscedasticity consistent standard errors

is found. While we do not wish to make too much of these results, since this is not our preferred specification, we note that there is no obvious relationship between the size of the coefficient on IPRs and R&D intensity at the industry level, with the largest coefficient on IPRs being found in Food. This illustrates an important point. Our IPR index is that constructed by Ginarte and Park (1997) and is specifically based on the strength of patent protection in the country concerned (see Appendix 2 for details). While patent protection is particularly significant for R&D intensive industries, a country with a strong patent regime is very likely to provide strong protection for all forms of intellectual property. Certainly TRIPS defines rights across a wide spectrum.[18] As a result we interpret the Ginarte and Park index as a general IPR index, and expect that it may prove significant in industries where IPRs other than patents are important.

Were our investigations to cease at this point, we would conclude that strengthening IPRs would raise exports to all countries, for all manufacturing industries (except one) and would reduce exports in none. But our discussion of the relevant theory and empirical literature indicated that the relationship between IPRs and trade was very likely non-linear in form, with the impact of strengthening IPRs likely to depend on product and importing country characteristics. The coefficients estimated in the linear equation would then represent an ‘average’ effect, whose literal interpretation could be quite misleading. Our threshold regression analysis will demonstrate this.

4.2 Single variable thresholds

Our initial approach to examining the importance of third variables in the relationship between IPR protection and trade is to estimate the optimal number of thresholds for each of our three threshold variables in turn. For each threshold variable we report the location of the significant thresholds (both the value and its percentile location) and the coefficient and *t*-value on IPR protection for each of the corresponding regimes, for each industry.[19]

4.2.1 Thresholds on the level of development

The results reported in Table 3 use the level of development of the importer (specifically the natural log of GDP per capita) as the threshold variable.[20] Our major interest in these results lies in their implications for the impact of strengthened IPR protection on the imports of developing countries. In recent

[18] TRIPs includes agreements on the following forms of intellectual property; copyrights and related rights, trademarks, geographical indications, industrial designs, patents, layout-designs of integrated circuits, and protection of undisclosed secrets.

[19] For brevity and ease of presentation we choose not to report the coefficients on the other gravity variables. These results are available upon request. The coefficients on the other gravity variables are found to be remarkably consistent across the remaining tables, and are quite robust in terms of size, sign and significance to the choice of threshold variable and the number of thresholds.

[20] Note that in this table there are occasions in which the last estimated threshold was significant. In these cases it was not possible to search for a further threshold whilst maintaining the restriction that 20% of observations must lie in each regime. In these cases we report the results in Tables 4 and 5 based on the last significant estimated threshold.

Table 3 Development thresholds (threshold variable: GDP per capita)

	Percentile	0		50	100
Total Manufacturing	Thres GDP/cap	6.41*** (26^{th})	7.36** (47^{th})	9.41*** (79^{th})	
	Coeff IPR	–0.12 (–1.18)	0.10 (1.19)	0.20 (2.89)***	0.31 (4.03)***
Fabricated Metal Products	Thres GDP/cap	6.41*** (26^{th})	7.36** (47^{th})	9.41** (79^{th})	
	Coeff IPR	–0.13 (–1.13)	0.12 (1.30)	0.21 (2.83)***	0.33 (3.90)***
Chemical Products	Thres GDP/cap	6.41*** (26^{th})	9.41** (79^{th})		
	Coeff IPR	0.03 (0.31)	0.23 (2.81)***	0.36 (4.08)***	
Non-Metallic Minerals	Thres GDP/cap	6.41*** (26^{th})	7.96** (60^{th})		
	Coeff IPR	–0.1 (–0.77)	0.15 (1.57)	0.29 (2.93)***	
Other Manufacturing	Thres GDP/cap	6.41*** (26^{th})	8.57* (71^{st})		
	Coeff IPR	–0.17 (–1.09)	0.16 (1.34)	0.32 (2.60)***	
Basic Metal Industries	Thres GDP/cap	6.41*** (26^{th})	7.92*** (58^{th})		
	Coeff IPR	–0.26 (–1.63)	0.22 (1.80)*	0.42 (3.50)***	
Food, Beverages, Tobacco	Thres GDP/cap	6.41*** (26^{th})	7.44* (48^{th})	8.56*** (71^{st})	
	Coeff IPR	–0.07 (–0.47)	0.18 (1.41)	0.30 (2.73)***	0.58 (4.85)***
Paper, Paper Products, Printing	Thres GDP/cap	6.41*** (26^{th})	7.96** (60^{th})		
	Coeff IPR	–0.06 (–0.47)	0.16 (1.56)	0.30 (2.99)***	
Textiles, Apparel, Leather	Thres GDP/cap	6.41*** (26^{th})	7.68** (53^{rd})		
	Coeff IPR	–0.43 (–2.40)**	0.06 (0.42)	0.25 (2.17)**	
Wood Products, Furniture	Thres GDP/cap	6.41*** (26^{th})	7.73*** (54^{th})		
	Coeff IPR	–0.15 (–0.80)	0.12 (0.81)	0.37 (2.94)***	

For each industry group, this table reports the position of the estimated thresholds and their significance (first row) and the estimated coefficient on the IPR variable for each regime and its significance (second row). The coefficients on the remaining variables from the gravity model (including importer, exporter and time effects) are not reported for brevity

*, ** and *** indicate significance at the 10, 5 and 1% level respectively. *t*-statistics in parentheses are based on White's heteroscedasticity consistent standard errors. The significance of the estimated thresholds is found using the bootstrap procedure of Hansen (1996) with 1,000 replications

years the latter have shown increased interest in WTO membership as a means of gaining improved access to export markets. At the same time they have expressed concern over the power to advanced country exporters they may concede in their own markets through the accompanying TRIPS obligations. The estimation of thresholds on GDP per capita should indicate the degree to which the existence and strength of market power and market expansion effects are related to importers' levels of development.

The first row in Table 3 shows that there are three significant thresholds for Total Manufacturing, occurring at the 26th, 47th and 79th percentiles of GDP per capita in the sample. This implies that there are four IPR regimes with similar numbers of observations in each, and with IPR coefficients and *t*-statistics as shown in the second row.[21] The coefficient on the IPR index rises as one moves up the regimes, but is only significantly positive in the upper two regimes. As

[21] The thresholds are marked in italics and are located horizontally in this and the following two tables so as to give a rough indication of their relative location across industries.

Table 4 Imitative ability thresholds (threshold variable: average years of secondary schooling)

Percentile		0	50		100
Total Manufacturing	Thres SYR	*1.56*** (65th)*			
	Coeff IPR	0.13 (1.98)**	0.20 (2.89)***		
Fabricated Metal Products	Thres SYR	*1.56**** (65th)*			
	Coeff IPR	0.14 (1.85)*	0.23 (2.92)***		
Chemical Products	Thres SYR	*1.96* (75th)*			
	Coeff IPR	0.20 (2.47)**	0.27 (3.32)***		
Non-Metallic Minerals	Thres SYR	*0.56* (26th)*	*1.56**** (65th)*		
	Coeff IPR	0.08 (0.83)	0.14 (1.53)	0.26 (2.69)***	
Other Manufacturing	Thres SYR	*1.56**** (65th)*			
	Coeff IPR	0.11 (0.97)	0.26 (2.26)**		
Basic Metal Industries	Thres SYR	*0.5*** (21st)*	*0.97* (44th)*	*1.56* (65th)*	
	Coeff IPR	0.13 (1.07)	0.27 (2.30)**	0.20 (1.60)	0.29 (2.37)**
Food, Beverages, Tobacco	Thres SYR	*0.59*** (28th)*	*1.2* (52nd)*	*1.95* (75th)*	
	Coeff IPR	0.26 (2.27)**	0.35 (3.33)***	0.42 (3.87)***	0.49 (4.55)***
Paper, Paper Products, Printing	Thres SYR	*0.7*** (34th)*	*1.56*** (65th)*		
	Coeff IPR	0.11 (1.09)	0.19 (1.96)*	0.28 (2.84)***	
Textiles, Apparel, Leather	Thres SYR	*0.5* (25th)*	*1.21**** (52nd)*	*1.95* (75th)*	
	Coeff IPR	–0.01 (–0.08)	0.09 (0.70)	0.26 (2.09)**	0.35 (2.77)***
Wood Products, Furniture	Thres SYR	*1.56*** (65th)*			
	Coeff IPR	0.13 (1.04)	0.39 (3.05)***		

See Table 3

expected the significant coefficient in the linear case is contained within the range of these coefficients, and is larger than the two smaller (and insignificant) coefficients, and smaller than the two larger (and significant) coefficients. These results indicate that it is only in more developed countries that strengthening IPRs will raise manufacturing imports in aggregate. The results for Fabricated are almost an exact reflection of those for Manufacturing, a pattern that we will see repeated below. The only other industry with three significant thresholds is Food, which has a similar pattern of significance of coefficients, though these are all larger. The remaining industries have two significant thresholds. In all cases the IPR coefficient increases as we move to higher income regimes, and the coefficients are always positive and significant in the highest regimes. All industries have a significant threshold at the 26th percentile of GDP per capita (corresponding to the GDP per capita of Senegal in 1975). All bar one (Chemicals) have a negative coefficient in the lowest regime, but only for Textiles is this coefficient significant. Recall that this industry was the only industry for which the coefficient on IPRs was not significant in the linear regression. Here this is explained as the average of significant market power effects in countries with the lowest levels of development and significant market expansion effects in countries with the highest levels of development.

Table 5 Imitative ability thresholds (threshold variable: average years of higher schooling)

Percentile		0	50	100
Total Manufacturing	Thres HYR	*0.098*** *(47th)*		
	Coeff IPR	0.14 (2.11)**	0.21 (2.99)***	
Fabricated Metal Products	Thres HYR	*0.099**** *(47th)*		
	Coeff IPR	0.16 (2.14)*	0.23 (2.89)***	
Chemical Products	Thres HYR			
	Coeff IPR	0.23 (2.86)***		
Non-Metallic Minerals	Thres HYR	*0.099** *(47th)*		
	Coeff IPR	0.16 (1.73)*	0.22 (2.35)**	
Other Manufacturing	Thres HYR	*0.175**** *(62nd)*		
	Coeff IPR	0.16 (1.35)	0.22 (1.95)*	
Basic Metal Industries	Thres HYR	*0.027** *(22nd)*		
	Coeff IPR	0.20 (1.69)*	0.31 (2.62)***	
Food, Beverages, Tobacco	Thres HYR	*0.076** *(42nd)*	*0.175**** *(62nd)*	
	Coeff IPR	0.25 (2.38)**	0.32 (2.95)***	0.43 (4.06)***
Paper, Paper Products, Printing	Thres HYR			
	Coeff IPR	0.20 (2.08)**		
Textiles, Apparel, Leather	Thres HYR	*0.099**** *(47th)*		
	Coeff IPR	0.10 (0.81)	0.22 (1.82)*	
Wood Products, Furniture	Thres HYR	*0.036** *(25th)*	0.175*** (62nd)	
	Coeff IPR	0.24 (1.75)*	0.13 (0.98)	0.29 (2.26)**

See Table 3

Smith (1999) and Rafiquzzaman (2002) also examine the links between the impact of a stronger IPR regime and the importer's level of development. They do this by dividing the importing countries into groups based on income per capita and including dummy variables for each group interacted with the IPR variable. Smith finds market expansion effects for the lower middle income group and market power effects for the other three in Manufacturing. The industries exhibit a similar pattern. Rafiquzzaman finds market expansion effects at all income levels for Manufacturing, but some evidence of market power effects, mainly in the low income group, for some industries. Interestingly, our threshold analysis indicates the same number of regimes (four) as Smith for Manufacturing, though in different locations. But as Tables 4 and 5 indicate, four is not the appropriate number of regimes for the majority of industries. Once this is taken into account significant market power effects are much less in evidence.

What do our results imply about TRIPS and the imports of developing countries? For the relatively more advanced developing countries—those countries above the 47th percentile of income per capita in our sample—strengthening their IPR regimes will increase Total Manufacturing imports from our five advanced exporters. Table 3 shows that similar thresholds exist for the two-digit manufacturing industries. For these countries there is the prospect of increased technology diffusion through commodity trade. But for the least developed countries, specifically those below the 26th percentile, strengthening their intellectual property regimes will not increase imports from advanced countries, and indeed will likely reduce them in Textiles. For these countries the prospect of assuming the full TRIPS obligations would appear unattractive. Fortunately many of them can obtain access for their exports under alternative schemes [e.g. through the generalized system of preferences (GSP)].

4.2.2 Thresholds on imitative ability

Table 4 performs the same analysis using our preferred measure of imitative ability (SYR) as the threshold variable. In this case we expect to observe market expansion effects for countries with high levels of imitative ability, with the possibility of market power effects for those countries with little ability to imitate advanced technology. Manufacturing has one significant threshold and IPRs have a significant positive coefficient in each regime, but larger in the higher regime. This outcome matches that for Fabricated and Chemicals, though the latter's threshold is at a higher level. The other industries show a variety of outcomes, with one to three thresholds. There is only one negative coefficient, and that is insignificant, so there is no evidence of market power effects associated with imitative ability. With one exception (Basic) all coefficients are increasing, positive if significant and either always significant or significant in the higher regimes. There is thus clear evidence that strengthening IPRs increases trade, at least above some level of imitative ability, and that this effect is stronger at higher levels of imitative ability.

Table 5 reports the equivalent outcomes using HYR as a measure of imitative ability. These are very similar to those for SYR. Manufacturing has one significant threshold and IPR has a significant positive coefficient in each regime, but larger in the higher regime. Again this outcome mirrors that for Fabricated. Industries have the same number or fewer significant thresholds as for SYR, with one exception (Wood), and all have at least one significant coefficient on IPR. Again higher regimes have higher coefficients, with the exception of Wood, providing clear evidence that strengthening IPRs increases trade, at least above some threshold, and that this effect is stronger at higher levels of HYR. Given the similarity in results between SYR and HYR, we report only results for our preferred measure (SYR) when we consider dual thresholds in the next section.

4.2.3 Thresholds on market size

Table 6 reports the results for market size (GDP) thresholds. Here our interest is in whether we find a pattern of market power effects in small markets and market expansion effects in large markets. Again this is a case where the results for Manufacturing exports and Fabricated exports are very similar. Both show two thresholds and similar coefficients in the three regimes they generate. The market power effect shown for Manufacturing at small market sizes primarily reflects that for Fabricated. While other industries have negative coefficients over this range they

Table 6 Market size thresholds (threshold variable: GDP)

	Percentile	0	50		100
Total Manufacturing	Thres GDP	*22.18*** (21st)*	*24.91** (65th)*		
	Coeff IPR	-0.17 (-3.02)***	0.14 (1.93)*	0.22 (3.20)***	
Fabricated Metal Products	Thres GDP	*22.18*** (21st)*	*24.91** (65th)*		
	Coeff IPR	-0.22 (-3.48)***	0.15 (1.91)*	0.24 (3.20)***	
Chemical Products	Thres GDP	*22.82** (38th)*			
	Coeff IPR	0.36 (3.64)***	0.22 (2.76)		
Non-Metallic Minerals	Thres GDP	*22.18*** (21st)*	*25.79** (79th)*		
	Coeff IPR	-0.12 (-1.11)	0.14 (1.49)	0.25 (2.73)***	
Other Manufacturing	Thres GDP	*24.37*** (53rd)*			
	Coeff IPR	0.31 (2.52)**	0.12 (1.06)		
Basic Metal Industries	Thres GDP	22.15*** (20th)	25.81** (79th)		
	Coeff IPR	-0.05 (-0.36)	0.21 (1.81)*	0.37 (3.22)***	
Food, Beverages, Tobacco	Thres GDP	*22.15*** (20th)*	*23.44* (46th)*	*25.37*** (72nd)*	
	Coeff IPR	-0.19 (-1.16)	-0.03 (-0.21)	0.35 (3.13)***	0.54 (5.15)***
Paper, Paper Products, Printing	Thres GDP	*22.48* (29th)*			
	Coeff IPR	0.27 (2.53)**	0.19 (1.98)**		
Textiles, Apparel, Leather	Thres GDP	*23.02*** (41st)*			
	Coeff IPR	-0.01 (-0.06)	0.23 (1.96)*		
Wood Products, Furniture	Thres GDP	*22.8*** (38th)*	*25.11** (66th)*		
	Coeff IPR	0.43 (2.78)***	0.19 (1.45)	0.36 (2.71)***	

See Table 3

are not significant. Three other industries have two significant thresholds, Food has three and the others one. For Manufacturing and Fabricated all coefficients are significant in all regimes and positive and increasing for the larger market sizes. This pattern of increasing coefficients, significant for the larger market sizes is present in four other industries. For two of the remainder there is a significant positive effect only for larger market sizes. A third is positive and significant throughout, but declining, and the last is positive and significant only for the largest and smallest market sizes.

In summary, the results in Tables 4, 5 and 6 confirm that the strength of importer's IPRs is a significant determinant of its manufacturing imports from our five advanced countries. This is evident in Manufacturing exports, and to a greater or lesser degree in the exports of individual Manufacturing industries, though it seems that Fabricated most closely matches the aggregate behaviour. We find no significant market power effects associated with imitative ability, and those associated with a small market size at the aggregate level reflect those in Fabricated only. Market expansion effects are pervasive at higher levels of imitative ability, and are also evident when we consider market sizes, tending to be stronger in larger markets in most industries.

4.3 Dual variable thresholds

In this section we explore the possibility of interactions between different threshold variables. Specifically, we examine whether the relationship between strengthening IPRs and trade depends upon the interaction between imitative ability (as measured by SYR) and both the level of IPR protection and market size. The approach we adopt involves three steps. First we take the highest significant threshold on secondary schooling from Table 4 to distinguish between low and high imitative ability.[22] We then search for a second threshold based on either GDP or the level of IPRs in the high imitative ability regime, and finally we search for a third threshold based on the level of GDP or IPRs in the low imitative ability regime. When estimating the third threshold we include the second threshold if it was found to be significant (see Appendix 1 for details). The final equation (where all thresholds are significant) is therefore

$$\begin{aligned}\ln TRADE_{ijt} = {} & \beta_k X_{ikt} + \delta_1 IPR_{it} I(SYR_{it} \le \lambda_1; Z_{it} \le \lambda_2) + \delta_2 IPR_{it} I(SYR \le \lambda_1; Z_{it} > \lambda_2) \\ & + \delta_3 IPR_{it} I(SYR_{it} > \lambda_1; Z_{it} \le \lambda_2) + \delta_4 IPR_{it} I(SYR_{it} > \lambda_1; Z_{it} > \lambda_2) \\ & + \mu_i + \theta_j + v_t + \varepsilon_{ijt} \qquad (3)\end{aligned}$$

where Z_{it} is either the level of IPR protection or the natural log of the level of GDP.

4.3.1 Thresholds on imitative ability and market size

Intellectual property rights should matter more in countries where imitation is likely, and both high imitative ability (as measured by an educated workforce) and a large market size (as measured by the level of GDP) make imitation more likely, in the latter case due to a large market making successful imitation more profitable. Is it the case, as Maskus and Penubarti (1995) suggest, that market expansion effects dominate in larger countries with stronger imitative abilities, while market power effects dominate in smaller countries with weaker imitative abilities? Table 7 reports our results. In the high imitative ability regime the coefficients are positive and significant for all market sizes (except the small market size for Wood). The coefficients are increasing in market size for Manufacturing exports and for six of the industries, and the coefficients are independent of market size for the other three. There is thus clear evidence of market expansion effects, increasing in market size, in countries with high imitative ability. In contrast, the results in the low imitative ability regime are less clear cut. There are no significant effects for Manufacturing exports. The only evidence of market power effects is in other in small markets. Elsewhere there is evidence of market expansion effects for both small and large market sizes for one industry (Food), for small markets only for three (Chemicals, Paper and Textiles) and for large markets only for another three (Fabricated, Basic and Wood). The coefficients are greater in larger markets in five industries, and lower in four. Clearly there is little evidence of market power effects, and while market

[22] We can only deal with one threshold for imitative ability, and the highest thresholds take just two values, 1.56 for total manufacturing and 6 of the industries, and 1.95/6 for the other three industries.

Table 7 Imitative ability and market size

	Low imitative ability		High imitative ability	
	Small market δ_1	Large market δ_2	Small market δ_3	Large market δ_4
Total Manufacturing				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 22.11$	$GDP > 22.11$	$GDP \leq 26.25$	$GDP > 26.25$
Coeff IPR	−0.05 (−0.63)	0.11 (1.52)	0.15 (2.00)**	0.26 (3.52)***
Fabricated Metal Products				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 22.11$	$GDP > 22.11$	$GDP \leq 26.3$	$GDP > 26.3$
Coeff IPR	−0.07 (−0.77)	0.14 (1.84)*	0.20 (2.69)***	0.25 (3.24)***
Chemical Products				
Thres	$SYR \leq 1.96$	$SYR \leq 1.96$	$SYR > 1.96$	$SYR > 1.96$
	$GDP \leq 22.82$	$GDP > 22.82$	$GDP \leq 26.42$	$GDP > 26.42$
Coeff IPR	0.27 (2.90)***	0.12 (1.51)	0.18 (2.24)**	0.33 (3.72)***
Non-Metallic Minerals				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 22.17$	$GDP > 22.17$	$GDP \leq 25.88$	$GDP > 25.88$
Coeff IPR	−0.12 (−1.15)	0.10 (1.09)	0.17 (1.85)*	0.29 (3.04)***
Other Manufacturing				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 21.20$	$GDP > 21.20$	$GDP \leq 25.82$	$GDP > 25.82$
Coeff IPR	−0.59 (−1.66)*	0.12 (1.07)	0.27 (2.33)**	0.27 (2.33)**
Basic Metal Industries				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 22.11$	$GDP > 22.11$	$GDP \leq 26.20$	$GDP > 26.20$
Coeff IPR	−0.08 (−0.64)	0.20 (1.74)*	0.24 (2.06)**	0.34 (2.91)***
Food, Beverages, Tobacco				
Thres	$SYR \leq 1.95$	$SYR \leq 1.95$	$SYR > 1.95$	$SYR > 1.95$
	$GDP \leq 21.14$	$GDP > 21.14$	$GDP \leq 24.69$	$GDP > 24.69$
Coeff IPR	1.01 (2.81)***	0.27 (2.54)***	0.21 (1.84)***	0.39 (3.73)***
Paper, Paper Products, Printing				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 22.48$	$GDP > 22.48$	$GDP \leq 24.29$	$GDP > 24.29$
Coeff IPR	0.22 (2.09)**	0.10 (0.98)	0.22 (2.21)**	0.22 (2.21)**
Textiles, Apparel, Leather				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 22.00$	$GDP > 22.00$	$GDP \leq 25.88$	$GDP > 25.88$
Coeff IPR	0.27 (1.89)*	0.03 (0.26)	0.22 (1.81)*	0.22 (1.81)*

Table 7 continued

	Low imitative ability		High imitative ability	
	Small market δ_1	Large market δ_2	Small market δ_3	Large market δ_4
Wood Products, Furniture				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$GDP \leq 25.74$	$GDP > 25.74$	$GDP \leq 23.53$	$GDP > 23.53$
Coeff IPR	0.02 (0.12)	0.32 (2.21)**	0.21 (1.28)	0.44 (3.42)***

The results in this table are for the interactions between two threshold variables. Observations are split into a low and high imitative ability regime based on the highest SYR threshold from Table 6. Thresholds are then calculated based on the level of GDP in both the low and the high imitative ability regimes, giving a possible number of four regimes. In some cases no significant threshold on GDP is found for the high imitative ability regime, with the coefficient reported being that from assuming no threshold in the high imitative ability regime. The first row for each industry reports the estimated thresholds on both SYR and GDP, while the second reports the estimated coefficients on the IPR variable and their significance. The coefficients on the remaining variables from the gravity model (including importer, exporter and time effects) are not reported for brevity

*, ** and *** indicate significance at the 10, 5, and 1% level respectively. *t*-statistics in parentheses are based on White's heteroscedasticity consistent standard errors. The significance of the estimated thresholds is found using the bootstrap procedure of Hansen (1996) with 1,000 replications

expansion effects are common, they are almost equally split between large and small markets. In general, it seems that market size has an ambiguous impact on the relationship between IPR and trade for countries with low imitative ability, but that for countries with high levels of imitative ability market expansion effects tend to be larger in countries with large markets.

4.3.2 Thresholds on imitative ability and IPR protection

Here we follow the standard approach in the literature, originating with Smith (1999), of splitting the sample into four groups based on both the level of IPR protection and imitative ability. This reflects the view that, although high imitative ability will make imitation more likely, this can be countered by high levels of IPR protection that reduces the threat of imitation. We re-examine this hypothesis using an alternative measure of imitative ability (schooling rather than R&D spending) and a broader sample of exporting countries, as well as allowing the thresholds on both variables to be determined endogenously and to vary across industries.

We have evidence that stronger IPRs are more important when imitative ability is high from Sect. 4.2.2. We now consider discontinuities in this relationship. Our results are presented in Table 8. Consider first the regimes where imitative ability is low. Here there is clear evidence that strengthening IPRs beyond a threshold (which is industry specific) will not affect imports from these advanced countries. For all industries (except Food) the coefficient on IPRs is not statistically significant in the higher IPR range. This is largely as expected; countries in the high IPR regime have a lower threat of imitation, suggesting that market expansion effects may be limited.

Table 8 Imitative ability and intellectual property rights

	Low imitative ability		High imitative ability	
	Low IPRs δ_1	High IPRs δ_2	Low IPRs δ_3	High IPRs δ_4
Total Manufacturing				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 3.27$	$IPR > 3.27$	$IPR \leq 2.95$	$IPR > 2.95$
Coeff IPR	0.30 (3.70)***	0.09 (1.18)	0.37 (4.25)***	0.23 (3.20)***
Fabricated Metal Products				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 3.27$	$IPR > 3.27$	$IPR \leq 2.95$	$IPR > 2.95$
Coeff IPR	0.28 (3.12)***	0.09 (1.08)	0.36 (3.87)***	0.25 (3.12)***
Chemical Products				
Thres	$SYR \leq 1.96$	$SYR \leq 1.96$	$SYR > 1.96$	$SYR > 1.96$
	$IPR \leq 2.41$	$IPR > 2.41$	$IPR \leq 3.31$	$IPR > 3.31$
Coeff IPR	−0.29 (−2.25)**	−0.07 (−0.78)	−0.06 (−0.59)	0.08 (0.95)
Non-metallic minerals				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 3.18$	$IPR > 3.18$	$IPR \leq 2.95$	$IPR > 2.95$
Coeff IPR	0.29 (2.74)***	0.07 (0.63)	0.39 (3.52)***	0.28 (2.91)***
Other Manufacturing				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 2.67$	$IPR > 2.67$	$IPR \leq 2.56$	$IPR > 2.56$
Coeff IPR	−0.06 (−0.49)	0.08 (0.74)	0.18 (1.52)	0.18 (1.52)
Basic Metal Industries				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 2.41$	$IPR > 2.41$	$IPR \leq 3.35$	$IPR > 3.35$
Coeff IPR	−0.17 (−1.22)	0.03 (0.24)	0.05 (0.46)	0.16 (1.43)
Food, Beverages, Tobacco				
Thres	$SYR \leq 1.95$	$SYR \leq 1.95$	$SYR > 1.95$	$SYR > 1.95$
	$IPR \leq 3.24$	$IPR > 3.24$	$IPR \leq 2.89$	$IPR > 2.89$
Coeff IPR	0.53 (4.66)***	0.29 (2.64)***	0.68 (5.50)***	0.45 (4.24)***
Paper, Paper Products, Printing				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 3.36$	$IPR > 3.36$	$IPR \leq 2.91$	$IPR > 2.91$
Coeff IPR	0.19 (1.98)**	−0.07 (−0.53)	0.26 (2.73)***	0.26 (2.73)***
Textiles, Apparel, Leather				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 3.36$	$IPR > 3.36$	$IPR \leq 2.93$	$IPR > 2.93$
Coeff IPR	0.24 (1.90)*	−0.12 (−0.77)	0.44 (3.24)***	0.27 (2.26)**

Table 8 continued

	Low imitative ability		High imitative ability	
	Low IPRs δ_1	High IPRs δ_2	Low IPRs δ_3	High IPRs δ_4
Wood Products, Furniture				
Thres	$SYR \leq 1.56$	$SYR \leq 1.56$	$SYR > 1.56$	$SYR > 1.56$
	$IPR \leq 2.70$	$IPR > 2.70$	$IPR \leq 2.54$	$IPR > 2.54$
Coeff IPR	−0.43 (−2.64)***	−0.06 (−0.48)	−0.21 (−1.15)	0.09 (0.66)

The results in this table are for the interactions between two threshold variables. Observations are split into a low and high imitative ability regime based on the highest SYR threshold from Table 6. Thresholds are then calculated based on the level of IPRs in both the low and the high imitative ability regimes, giving a possible number of four regimes. In some cases no significant threshold on IPRs is found for the high imitative ability regime, with the coefficient reported being that from assuming no threshold in the high imitative ability regime. The first row for each industry reports the estimated thresholds on both SYR and IPRs, while the second reports the estimated coefficients on the IPR variable and their significance. The coefficients on the remaining variables from the gravity model (including importer, exporter and time effects) are not reported for brevity

*, ** and *** indicate significance at the 10, 5 and 1% level respectively. *t*-statistics in parentheses are based on White's heteroscedasticity consistent standard errors. The significance of the estimated thresholds is found using the bootstrap procedure of Hansen (1996) with 1,000 replications

Unlike Smith (1999) however, we find little evidence of market power effects for this regime. In the low IPR regime we find the coefficient on IPRs to be significant in all industries (except other and Basic). For Manufacturing and five industries there is evidence of market expansion effects in this regime. For two industries there is evidence of significant market power effects. We conclude that countries with limited imitative ability will find that strengthening their IPR regimes will initially increase manufacturing imports from these five countries, but that this will be accompanied by a shift in the composition of these imports, away from those industries with significant market power effects towards those with significant market expansion effects. Once the IPR regime becomes sufficiently strong, however, further strengthening will leave imports unaffected (except for Food).

A clear pattern also emerges for countries with high imitative abilities. For those industries exhibiting market power effects when imitative ability is low, strengthening IPRs generally has no significant effect when imitative ability is high. For those industries exhibiting market expansion effects when imitative ability is low, strengthening IPRs also has market expansion effects when imitative ability is high, though this effect is invariably weaker in the higher IPR regime (except for Paper where the effects are the same), reflecting the smaller threat of imitation. In general, countries with high imitative ability will find that strengthening their IPR regime leads to increased Manufacturing imports, with similar shifts in the broad composition of these imports occurring as for countries with low imitative ability, since the same industries expand for both low and high imitative ability.

These outcomes broadly support previous results, except that there is far less evidence of market power effects. There are two other noteworthy aspects of these outcomes. The first is the separation of the two-digit industries into two groups—those exhibiting market power effects and those exhibiting market expansion effects. The second is that this separation bears no obvious relationship to an industry's R&D intensity.

Finally, are these results consistent with the argument that the coefficients on IPRs should decline as we move away from regimes with the greatest threat of imitation? Intuitively, countries with high imitative ability and low IPR protection provide the greatest threat of imitation, and those with low imitative ability and high IPR protection offer the least. Countries with high imitative ability and high IPR protection and countries with low imitative ability and low IPR protection are somewhere in between. Do our estimated IPR coefficients decline in this way? The answer is yes for those industries that exhibit market expansion effects, but there is no consistent pattern for those that exhibit market power effects.

5 Summary and conclusions

The theoretical ambiguity concerning the effects of strengthening IPRs on imports has been much emphasised in the literature and has led to several attempts at its empirical resolution. The general conclusions that have emerged are that imitative ability and, to a lesser extent, market size are important in this relationship, with strong evidence of market expansion effects in countries with high imitative ability and larger markets, and rather weaker evidence of market power effects in countries with low imitative ability and small markets. But establishing these outcomes has often relied on classifying countries into imitative ability or market size cohorts on a subjective basis, without being able to determine the sensitivity of the outcomes to the classification.

As has become standard, we use a variant of the gravity equation to examine the impact of IPR protection on trade, but otherwise our approach differs from most previous examinations in several respects. First, we employ panel data rather than the more usual cross-section data, thus allowing us to control for unobserved heterogeneity both across countries and time. We also consider a wider range of advanced exporters than is usual in the literature. Second, we use an alternative measure of imitative ability (schooling) and explicitly consider the interactions between imitative ability and market size. Third, and most significantly, rather than splitting our observations into different regimes in a subjective manner or making certain assumptions about the form of such interactions (i.e. a linear interaction term), we use threshold regression techniques to estimate both the number of regimes and their positioning.

Our empirical outcomes are summarised in Table 9, and from these we draw the following general conclusions. First, we find statistically significant thresholds for all threshold variables and all industries, indicating that there is a non-linear relationship between trade flows and IPRs. Second the results for Total Manufacturing mirror the characteristics of one industry in particular—Fabricated Metal Products. Since these products form nearly 60% of manufactured exports from these five countries this is perhaps unsurprising, but certainly it would be well to keep in

Table 9 Summary of threshold regression results

	Number of thresholds			Market power effects							Market expansion effects						
				Single threshold			Dual thresholds				Single threshold			Dual thresholds			
							Market size		IPR					Market size		IPR	
	Y	S (H)	M	Y	S (H)	M	Sm	Lge	Low	Hi	Y	S (H)	M	Sm	Lge	Low	Hi
Man	3	1 (1)	2			B					A	E (E)	A	A	A	E	A
Fab	3	1 (1)	2			B					A	E (E)	A	A	E	E	A
Chem	2	1 (0)	1						B		A	E (E)	B	E	A		
Non-Met	2	2 (1)	2								A	A (E)	A	A	A	E	A
Other	2	1 (1)	1				B				A	A (A)	B	A	A		
Basic	2	3 (1)	2								A	A, B (E)	A	A	E		
Food	3	3 (2)	3								A	E (E)	A	E	E	E	E
Paper	2	2 (0)	1								A	A (E)	E	E	A	E	A
Text	2	3 (1)	1	B							A	A (A)	A	E	A	E	A
Wood	2	1 (2)	2						B		A	A (A, B)	A,B		E		

Thresholds: *Y* GDP per capita; *S*, *H* secondary and tertiary schooling, respectively; *M* market size. Effects: *A* Blank entry indicates no significant effect (market power or market expansion as appropriate) found. Single thresholds: *A*, *B* effects found only above or below a threshold, respectively; *E* effects found in all cases. Dual thresholds: *A*, *B* effects found only when imitative ability is above or below its threshold, respectively; *E* effects found at both imitative ability levels

mind that the aggregate is not representative of the individual industries. Third, while there is only limited evidence of market power effects, where they do occur it is below the relevant threshold. So although market power effects are far from pervasive, they should not be totally discounted for the least developed, small countries with low imitative ability and weak IPRs. Finally, market expansion effects are prevalent and, with few exceptions, either occur in all regimes or above a relevant threshold.

The examination of combined thresholds on imitative ability and the level of IPRs was directly comparable to the results based on subjective thresholds in the literature. Allowing thresholds to vary across industries brought the patterns previously identified into sharper focus. For countries with low imitative abilities, strengthening low IPRs will lead to market expansion effects for most industries, but market power effects for some. But for each industry (except Food) there is a ceiling beyond which strengthening IPRs will have no significant effect on trade flows. For countries with high imitative abilities we found a clear separation of industries. Those which exhibit market power effects when imitative ability is low show no significant effects from strengthening IPRs when imitative ability is high. Those which exhibit market expansion effects when imitative ability is low, exhibit market expansion effects when imitative ability is high.

The latter results draw attention to the different behaviour of industries and illustrate why it is useful to look beyond Total Manufacturing exports. The two-digit industries present a range of outcomes, and strengthening IPRs is likely to change not only the volume but also the composition of imports from these advanced countries, although not necessarily in favour of the more R&D intensive industries. The broad shifts in the composition are largely independent of the level of imitative ability.

If, as the literature suggests, increased Manufacturing trade with advanced countries brings technology diffusion, then our results indicate that most developing countries can anticipate increased technology flows as their IPRs are strengthened. The small and least developed may see little such benefits, however. For them technology diffusion may have to depend on other channels. Consideration of how IPRs affect these other channels and, in particular, how they affect exporting firms' choice of market access is an important element of future research in this area.

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Appendix 1: threshold regressions

Threshold regression addresses the issue of whether regression functions are identical across observations or whether there exists evidence of non-linearity with observations split into discrete classes. Hansen (1996, 2000) developed a method of estimating such thresholds and testing for their significance as well as constructing confidence intervals. Hansen (1999) extended this approach to fixed effects panel data. In this appendix we briefly describe the methods used in this paper.

The method can be described using the following two variable panel regression model

$$y_{it} = \mu_i + \delta_1 x_{it} I(q_{it} \leq \lambda) + \delta_2 x_{it} I(q_{it} > \lambda) + \varepsilon_{it} \qquad \text{(A1)}$$

where $I(\cdot)$ is the indicator function and q_{it} is the threshold variable.[23] Here the observations are divided into two regimes depending upon whether the threshold variable, q_{it}, is smaller or larger than the threshold, λ. The coefficient on x_{it} is given by δ_1 for observations with q_{it} less than or equal to λ and by δ_2 for q_{it} greater than λ. Chan (1993) and Hansen (1999, 2000) recommend estimation of λ by least squares, which involves finding the value of λ that minimises the concentrated sum of squared errors, S_1, that is $\hat{\lambda} = \arg\min_\lambda S_1(\lambda)$. In practice this involves searching over distinct values of q_{it} for the value of λ at which the concentrated sum of squares is smallest. Hansen (1999) notes that it is undesirable to have two few observations in a particular regime, a possibility that can be excluded by constraining the possible values of λ to those for which a minimum percentage of observations are in each regime. In our analysis we impose the restriction that at least 20% of observations must lie in each regime.

Hansen (1999) suggests the following steps to estimate the threshold value: first, sort the distinct values of the observations on the threshold variable, q_{it}. Second,

[23] To estimate this equation by least squares Hansen (1999) recommends a fixed effects transformation to remove the individual-specific mean.

eliminate the smallest and largest η percent. For each of the remaining values of q_{it} estimate Eq. A1 and save the sum of squared residuals. Third, choose the estimate of $\hat{\lambda}$ as the value of q_{it} with the minimum sum of squared errors.

Having found a threshold it is important to determine whether it is statistically significant or not, that is, it is necessary to test the null hypothesis H_0: $\delta_1 = \delta_2$. Given that the threshold is not identified under the null hypothesis this test has a non-standard distribution and critical values cannot be read off standard distribution tables. Hansen (1999) proposes a bootstrap procedure to simulate the asymptotic distribution of the likelihood ratio test. This involves the following steps: first, estimate the linear model where no threshold is assumed and save the sum of squared residuals, S_0. Second, calculate the likelihood ratio test of the null hypothesis, H_0, given by $F_1 - [S_0 - S_1(\lambda)]/\hat{\sigma}^2$, where $\hat{\sigma}^2 = \{1/n[t-1]\}S_1(\hat{\lambda})$, with n the number of cross-sectional units and t the number of time periods. Third, construct a bootstrapped sample under the null hypothesis by drawing from the normal distribution of the residuals from the linear model.[24] Fourth, using the bootstrap sample estimate the model under the null (linearity) and the alternative (threshold at $\hat{\lambda}$) and calculate the bootstrap likelihood ratio statistic, F_1. Finally, repeat this procedure a large number of times (in our case 1,000) and calculate the percentage of draws for which the simulated statistic exceeds the actual one. This is the bootstrap estimate of the p-value for F_1 under H_0.

In the dual-threshold model we have

$$y_{it} = \mu_i + \delta_1 x_{it} I(q_{it} \le \lambda_1) + \delta_2 x_{it} I(\lambda_1 < q_{it} \le \lambda_2) + \delta_3 x_{it} I(q_{it} > \lambda_2) + \varepsilon_{it} \quad \text{(A2)}$$

where the two thresholds are ordered such that $\lambda_1 < \lambda_2$. It is a straightforward extension to search for the values of λ_1 and λ_2 that minimise the sum of squared errors. At the same time it can be expensive in terms of computation time to search for both thresholds simultaneously. Chong (1994), Bai (1997) and Bai and Perron (1998) have shown however that sequential estimation is consistent. This involves fixing the first threshold at $\hat{\lambda}_1$ and searching for a second threshold assuming that the first is fixed. The search takes place for values of q_{it} both above and below the first threshold, though the method can be adapted to ensure that a minimum of η per cent of observations are in each of the three regimes. It can be shown that the estimate of the second threshold, $\hat{\lambda}_2$, is asymptotically efficient using this method. This is not the case for $\hat{\lambda}_1$ however, because it was estimated from a sum of squared errors function that was contaminated by the presence of a neglected regime. To overcome this problem Bai (1997) recommends a refinement estimator for $\hat{\lambda}_1$ that involves fixing the second threshold at $\hat{\lambda}_2$ and searching for the first threshold again, now including the second threshold. This approach can be extended to consider the possibility of more than two thresholds.

In Sect. 4.3 we investigate the possibility of thresholds on more than one variable. Specifically, we examine interactions between the level of imitative ability and both the level of IPRs and market size. To allow such a possibility we adopt an approach similar to that described in the previous paragraph. We begin by fixing the

[24] Given the panel nature of the problem Hansen (1999) recommends grouping the residuals by individual and drawing (with replacement) a sample of size n in order to construct the bootstrap series.

threshold on our measure of imitative ability. In particular, we fix the threshold at the highest significant threshold on imitative ability and then search for a threshold on the other variable in the high imitative ability regime (i.e. for observations for which the measure of imitative ability is above the estimated threshold). Finally we consider the possibility of a threshold on these variables in the low imitative ability regime. Where the second threshold, that is the threshold in the high imitative ability regime, is significant we include it when searching for a third threshold. But then the estimated thresholds in the high imitative ability regime are not asymptotically efficient, since they were estimated from a sum of squared errors function contaminated by the presence of a neglected regime. To deal with this we follow Bai (1997) and re-estimate the high imitative ability threshold now including the estimated threshold in the low imitative ability regime.

Appendix 2: data

Our data is averaged over six 5-year periods, 1970–1974, 1975–1979, 1980–1984, 1985–1989, 1990–1994 and 1995–1999. Due to missing data for various variables the maximum number of observations is 2021. The data for population, GDP and GDP per capita came from the World Bank's World Development Indicators (2001) database. Data on distance, common language and borders and landlockedness came from a website maintained by Jon Haveman. Trade data came from the OECD's International Trade by Commodity Statistic (Historical Series, 1961–1990) and International Trade by Commodity Statistic (1990–1999). The trade data from 1961 to 1990 was in SITC rev. 2 and was converted to ISIC rev. 2 using a concordance supplied by the OECD. The data for the period 1990–1999 was in SITC rev. 3 and was converted to SITC rev. 2 and then ISIC rev. 2 again using a concordance supplied by the OECD. The education data was taken from the Barro and Lee (2001) database. The index of IPR protection is provided in Ginarte and Park (1997) and is the most commonly used indicator of IPR protection. This index was

Table 10 Summary statistics

Variable	Mean	Standard deviation	Minimum	Maximum
3—Total Manufacturing	19.10	2.13	4.61	25.58
31—Food, Beverages and Tobacco	16.73	2.52	4.61	22.28
32—Textiles, Apparel and Leather	15.46	2.48	4.61	22.18
33—Wood Products and Furniture	12.78	3.05	4.61	21.68
34—Paper, Paper Products and Printing	14.79	2.65	4.61	22.38
35—Chemical Products	17.20	2.33	4.61	23.64
36—Non-Metallic Mineral Products	14.50	2.43	4.61	21.28
37—Basic Metal Industries	15.81	2.56	4.61	22.30
38—Fabricated Metal Products	18.51	2.18	9.36	25.19
39—Other Manufacturing	14.21	2.62	4.61	21.57

Table 10 continued

Variable	Mean	Standard deviation	Minimum	Maximum
DIST	8.70	0.86	5.27	9.85
GDPM	23.90	1.90	20.00	27.76
POPM	16.22	1.35	12.25	20.69
GDPX	28.40	0.71	27.28	29.71
POPX	18.35	0.55	17.76	19.42
LOCK	0.16	0.37	0	1
COMLAN	0.16	0.37	0	1
COMBOR	0.03	0.18	0	1
IPR	2.55	0.81	0.33	4.57
GDPPC	7.69	1.60	4.74	11.25
HYR	0.18	0.20	0.001	1.192
SYR	1.40	1.07	0.039	5.037
GDP	23.89	1.90	20.00	27.76

The table reports the mean, standard deviation, minimum and maximum for the gravity determinants along with the same statistics for imports from the five exporters to the 69 importers in total manufacturing and the nine industries. All variables are in natural logs with the exception of the IPR index, dummy variables (i.e. *COMBORD*, *COMLANG*, *LOCK*) and the education index (*SYR)*. The industry identification numbers refer to ISIC rev. 2 code

constructed for 110 countries quinquennially for the period 1960–1990. Five characteristics of patent laws are included: extent of coverage; membership in international patent agreements; provisions for loss of protection; enforcement mechanisms and duration of protection. Each was assigned a value ranging from zero to one and their unweighted sums formed the index, with a higher number signalling stronger IPR protection. This data has been updated to 1995 by Park who kindly supplied us with the full set of data. Table 10 provides summary statistics for all the variables.

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