How Stronger Protection of Intellectual Property Rights Affects International Trade Flows

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Introduction

Intellectual property rights (IPRs) affect international trade flows when knowledge-intensive goods move across national boundaries. The importance of IPRs for trade has gained more significance as the share of knowledge-intensive or high technology products in total world trade has doubled between 1980 and 1994 from 12% to 24%.[1] At the international level, IPRs have traditionally been governed by several conventions – most prominently the Paris Convention for patents and trademarks and the Berne Convention for copyright – which are administered by the World Intellectual Property Organization (WIPO). In the 1980s, mounting disputes over IPRs lead to the inclusion of trade-related IPRs on the agenda of the GATT/WTO Uruguay round and the resulting "Trade Related Intellectual Property Rights Agreement, including Trade in Counterfeit Goods" (TRIPs) of 1994 represents the most far-reaching multilateral agreement towards global harmonization of IPRs.[2]

Several studies have attempted to estimate the extent to which IPRs are trade-related. Maskus and Penubarti (1995) use an augmented version of the Helpman-Krugman model of monopolistic competition to estimate the effects of patent protection on international trade flows. Their results indicate that higher levels of protection have a positive impact on bilateral manufacturing imports into both small and large developing economies. These results are confirmed by Primo Braga and Fink (1997) where we estimated a similar model and found the same positive link between patent protection and trade flows.

This study provides new evidence regarding the effects of patent protection on international trade. It employs a gravity model of bilateral trade flows and estimates the effects of increased protection on a cross-section of 89x88 countries. It improves on previous studies in two respects. First, we estimate the gravity model for two different kind of aggregates: total non-fuel trade and high technology trade. Second, it addresses the problem of zero trade flows between countries by adopting a bivariate distributed probit regression model. Second, to measure the strength of IPRs regimes, we make use of a fine tuned index on national IPRs systems developed by Park and Ginarte (1996). Our results confirm previous findings suggesting a positive link between IPRs protection and trade flows for the total non-fuel trade aggregate. However, IPRs are not found to be significant for high technology trade flows.

[1] These estimates are based on trade data from the UN Comtrade database. For the definition of high technology products, see Table 1.

[2] For a detailed review of the TRIPs Agreement and its economic implications, see Primo Braga (1996).

The next section provides a summary of theoretical considerations involved. Section III presents the estimation set-up. Section IV reports the results obtained. Section V compares our results to related studies. Section VI concludes the paper.

II. A review of the economics of trade-related intellectual property rights

The conventional economic rationale for the protection of IPRs in closed economies can be found in Arrow (1962). Since knowledge is non-rival in nature, it should be freely available (apart from the cost of transmitting knowledge). If this were the case, however, the market would underinvest in the production of new knowledge, because innovators would not be able to recover their costs. By granting innovators the exclusive rights to commercialize their intellectual assets over a certain period of time, IPRs offer an incentive for the production of knowledge. In short, IPRs introduce a static distortion (i.e., access to proprietary knowledge is sold above its marginal cost), which is rationalized as an effective way to foster the dynamic benefits associated with innovative activities.

IPRs are territorial in character, that is, they are created by national laws and differ across countries. If intellectual property embedded in goods and services originating in country A crosses the border to country B, two questions arise. First, how will IPRs protection in country B affect the magnitude of the bilateral trade flow from country A to B; and second what are the implications of such protection on economic welfare of both countries A and B.

Bilateral trade flows and differences in IPRs protection

IPRs affect international trade flows in several ways. A firm, for example, may be deterred to export its patented good into a foreign market, if potential "pirates" can diminish the profitability of the firm's activity in that market because of a weak IPRs regime. Accordingly, a strengthening of a country's patent regime would tend to increase imports as foreign firms would face increasing net demand for their products reflecting the displacement of pirates. On the other hand, a firm may choose to reduce its sales in a foreign market as a response to stronger IPRs protection because of its greater market power in an imitation safe environment. These opposing market-expansion and market-power effects imply that the overall effect of IPRs protection on bilateral trade flows is theoretically ambiguous (Maskus and Penubarti 1995).

A further source of ambiguity stems from the fact that differing levels of IPRs protection may affect a firm's decision on its preferred mode of serving a foreign market. A firm may choose to serve a foreign market by foreign direct investment (FDI) or by licensing its intellectual asset to a foreign firm instead of exporting the product in an environment characterized by strong IPRs (Ferrantino 1993).[3] Thus, strengthened IPRs protection may have a further negative effect on trade flows in this respect.

Welfare implications

The implications of tighter IPRs on economic welfare are highly complex. The simple fact that trade flows rise or fall in response to tighter IPRs is not sufficient for drawing conclusions regarding economic welfare. Both static and dynamic effects need to be considered. Moreover, in this paper, we are primarily concerned with the effects of IPRs on international trade flows. In a different paper (Primo Braga and Fink 1997), we discuss how tighter IPRs affect economic welfare through FDI, the transfer of technology, and domestic R&D. The following paragraphs give a brief summary of the associated static and dynamic costs and benefits for two trading economies that may arise only in response to changes in trade flows fostered by stronger IPRs.

From a **static**, partial-equilibrium point of view, the source country of the trade flow is likely to gain from tighter protection, because it can capture increased monopoly profits from the sale of its goods abroad. In contrast, the static effects on the welfare of the destination country are likely to be negative: increased market power by foreign title holders leading to deadweight losses.[4] In this view, many small, innovation-consuming countries fear that increased patent protection will only lead to a rent transfer to developed, innovation-producing countries.[5]

From a static, general-equilibrium point of view, tighter IPRs tend to be further detrimental to the destination country of the trade flow because the reallocation of production, i.e. the shift of product lines

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[3] FDI as a mode of serving a foreign country is of special relevance because the existence of intangible assets such as intellectual property is a major rationale for the existence of (horizontally integrated) TNCs (Caves 1996). The importance of FDI is also highlighted by the fact that in 1992 world wide sales of foreign affiliates (US$ 5,325 billion) exceeded global exports of goods and services (US$ 4,570 billion). See The World Bank (1996) for further details.

[4] See, for example, Deardorff (1992). Nogués (1993), Maskus and Konan (1994) and Subramanian (1995) try to estimate these deadweight losses for the pharmaceutical industry in several developing countries.

[5] This scenario assumes that the destination country is able to imitate the source countries' products in the absence of IPRs. If this is not the case, i.e. if technology is not freely available, the introduction of IPRs creates consumer surplus in the form of newly available products which may partly offset the deadweight loss. In this view, tighter IPRs are beneficial in that they transfer technology.

from the destination country to the source country, worsens the terms of trade in favor of the source country. In addition, the reallocation of production may reduce welfare in both countries as efficiency considerations call for an allocation of manufacturing to the region with lower costs.[6] This effect may be of particular relevance if one recalls that most countries with weak IPRs are low-wage, developing countries.[7]

From a **dynamic** point of view, the introduction of IPRs stimulates innovation in the source country and thus increase future trade flows. This will be beneficial for both trading economies assuming that social returns on these innovations exceed private returns.[8] The international recognition of IPRs also can be seen as an adjustment mechanism which guarantees the functioning of dynamic competition between countries. Through IPRs, innovation producing countries have an incentive to develop new technologies which in their next generation are manufactured by follower countries. This mechanism thus leads to continued technological progress and economic growth and from a dynamic point of view is beneficial for both leaders and followers (Fisch and Speyer 1995).

To sum up, the overall effect of IPRs protection on levels of bilateral trade flows is ambiguous. From a static welfare point of view, IPRs can be viewed as a rent transfer mechanism which deteriorates the international allocation of production. Most studies conclude that the destination country looses from tighter protection whereas the source country is usually better off.[9] However, benefits of a dynamic nature can be identified for both trading partners. On average, it is not clear whether these dynamic benefits can compensate for the static losses in the countries strengthening their IPRs systems and whether tighter IPRs improve world economic welfare via their impact on trade flows. It is worth pointing out that these theoretical considerations may be moot in a world economy in which political economy considerations are clearly in favor of higher standards of protection.[10]

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[6] See Helpman (1993), who develops these conclusions from a dynamic general equilibrium model with two regions, one product, and one factor.

[7] The welfare implications resulting from the reallocation of production may be partly offset by increased production via foreign subsidiaries (FDI).

[8] Diwan and Rodrik (1991), for example, show that a Southern, innovation-consuming country may have an incentive to protect patent rights, if it has a different distribution of preferences over the range of exploitable technologies and R&D resources in Northern, innovation-producing countries are scarce.

[9] See, for example, Chin and Grossman (1988), Deardorff (1991), and Helpman (1993).

[10] See, for example, Primo Braga (1996) for a discussion of the political economy in the context of the TRIPS negotiations.

III. Empirical analysis: the estimation set-up

To empirically estimate the effects of increased patent protection on bilateral trade flows we use a conventional gravity model. Gravity models have been applied successfully to explain different types of international flows, such as migration, commuting, recreational traffic, and trade. Typically, they specify that a flow from country *i* to country *j* can be explained by supply conditions in country *i*, by demand conditions in country *j*, and by forces either assisting or resisting the flow's movement.[11]

Our depend variables are bilateral trade flows for 89x88 countries which were extracted from the United Nations Comtrade database. The data refer to 1989 total non-fuel and high technology trade. The rationale for using high technology trade flows besides total non-fuel trade is based on the a priori expectation that the effects of IPRs protection are stronger for knowledge-intensive trade. For a definition of our high technology aggregate, see Table 1.

Following earlier specifications of gravity models, our explanatory variables are GDP and population of both countries *i* and *j*, geographical distance between the two countries, a dummy variable which is one if the two countries share a common border and zero otherwise, and a dummy variable which is one if the two countries share the same language and zero otherwise.[12] The coefficients on GDP are expected to be positive and around unity (Anderson 1979); the coefficients on population are expected to be small and negative, representing economies of scales (Linneman 1966). Positive geographic and cultural distance are expected to have a negative influence on bilateral trade flows; that is the coefficient on geographical distance is expected to be negative, the coefficients on common border and language are expected to be positive. The data appendix gives more information on the countries included and the sources of all variables.

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[11] Gravity models were developed based on intuitive reasoning rather than economic modeling. Due to their empirical success, there have been numerous attempts to shed some light on the economic underpinnings of the gravity equation. Linneman (1966) showed how the standard gravity equation can be derived from a quasi-Walrasian general equilibrium model of export supply and import demand. Leamer and Stern (1970) showed how a gravity model can be derived from a probability model of trade patterns. Anderson (1979) suggested a theoretical foundation in terms of an expenditure system with goods differentiated by countries of origin. Bergstrand (1985 and 1989) used a general equilibrium world trade model assuming utility- and profit-maximizing agent behavior and showed that the gravity model "fits in" with the Heckscher-Ohlin model of inter-industry trade and the Helpman-Krugman-Markusen models of intra-industry trade.

[12] See, for example, Tinbergen (1962), Linneman (1966), Aitken (1973), Pelzman (1977), and Primo Braga, Safadi, and Yeats (1994).

To capture the effects of preferential trading agreements, we also include separate dummy variables for the European Community (EC), the European Free Trade Agreement (EFTA), the Latin American Integration Association/Latin American Free Trade Association (LAIA/LAFTA), the Association of South East Asian Nations (ASEAN), and the Central American Common Market (CACM). We expect positive coefficient on these five dummy variables.

Finally, to capture the effect of intellectual property rights on bilateral trade flows we use the IPRs index developed by Park and Ginarte (1996).[13] This index grades national IPRs regimes of 110 countries on a scale from zero to five. To compute a country's ranking, Park and Ginarte (1996) create five different categories – extent of coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms, and duration of protection. For each category, they use several benchmark criteria (e.g. patentability of pharmaceuticals for extent of coverage) and compute the share of "fulfilled" criteria. A country's score is the unweigthed sum of these shares over all categories.[14] The United States receives the highest score with 4.52; several countries without patent laws (e.g., Angola, Burma, Ethiopia, Papua New Guinea) receive a score of 0.

A common problem regarding the estimation of bilateral trade flows is that some flows are reported as zero because countries do not trade with each other. For example, in our data set on average about 26% of the total non fuel trade flows and 53% of high technology trade flows are zero. A standard log-linear model with a log-normally distributed error term cannot, by definition, explain these zero trade flows. Simple exclusion of zero trade flows would lead to a potential sample selection bias. There are several ways how to address this problem. We follow Bikker and de Vos (1992), who propose a bivariate normally distributed probit regression.[15] The model consists of an equation for the probability of zero observations and an equation for the magnitude of a positive action:

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[13] For a short review of alternative indices see Primo Braga and Fink (1997). The Park and Ginarte index is most attractive in the present context because it has the broadest country coverage and refers to the state of protection as of 1990 which is consistent with our trade data. Moreover, compared to the index developed by Rapp and Rozek (1990), it allows for a much more fine tuned ranking of national IPRs regimes.

[14] Park and Ginarte (1996) recognize the possibility that different weights for each category may significantly alter a country's ranking. They examine how sensitive their index is to changes in the weights of the categories and conclude that "...the ordering of IPR values by country is not sensitive to the application of equal weighting (or unweighting) of categories".

[15] An alternative approach to deal with the problem of zero trade flows is to use a log-linear specification with an additive normally distributed error term, which can explain non-positive flows, and a Tobit limited dependent variable model (see Rohweder, 1988). We obtained reasonable estimates with this approach for the total non-fuel aggregate, but could not obtain a maximum likelihood for the high technology aggregate. We attributed this to the non-linear nature of the model and the corresponding undesirable features of the likelihood function.

$$(1)\quad I_{ij} = \begin{cases} 0 & \text{if} \quad z_{ij}\, g + v_{ij} \leq 0 \\ y_{ij} & \text{if} \quad z_{ij}\, g + v_{ij} > 0 \end{cases},$$

$$(2)\quad y_{ij} = x_{ij}\, b + u_{ij}\ .$$

I_{ij} is the observed phenomenon which is 0 if the bilateral trade flow between country *i* and *j* is zero and y_{ij} – the log of bilateral trade – if the trade flow is positive; z_{ij} is the log of the variables explaining the probability of a positive observation (the gravity variables without the preferential trading dummies and the Park and Ginarte index), and g the corresponding vector of coefficients for these variables.[16] v_{ij} is a normally distributed error term with mean zero; the variance of v_{ij} is normalized to one as all parameters g are determined apart from a constant. x_{ij} is the logarithm of the explanatory variables for positive trade flows (the gravity variables and the Park and Ginarte index), b the corresponding vector of coefficients to be estimated, and u_{ij} a normally distributed error term with mean zero and variance s^2. The error terms v_{ij} and u_{ij} are correlated with each other and drawn from a bivariate normal distribution with a correlation coefficient equal to r. Equations (1) and (2) can be estimated by maximum likelihood technique. Appendix A derives the likelihood function.

Besides addressing the problem of sample selectivity, the bivariate probit regression model is attractive because it also estimates the effects of explanatory variables (such as IPRs) on the probability that two countries trade with each other.

Two alternative specifications are estimated: Model (I) estimates the probit and gravity equations without the Park and Ginarte index whereas Model (II) includes the Park and Ginarte index. The rationale for this exercise is to evaluate what impact inclusion of IPRs have on the other explanatory variables. Moreover, to evaluate the robustness of the results, we estimate these two model specifications for both exports – bilateral trade flows from country *i* to country *j* as reported by country *i* – and imports – bilateral trade flows from country *j* to country *i* as reported by country *i*. Since we are primarily interested in the

[16] The reason for excluding the preferential trading dummies is that zero trade flows do not occur in (most) preferential trading agreements. Inclusion of these variables in the probit regression would then lead to perfect colinearity.

role of IPRs in attracting trade flows and not in creating trade flows, we only use the Park and Ginarte index of the destination country of the trade flow as explanatory variable (that is country *j* in the case of exports and country *i* in the case of imports).

IV. Empirical Estimates

Our estimation results are presented in Tables 2 through 5. The overall performance of the models is quite good. Most gravity variables have the expected signs and are statistically significant. Exceptions are for total non-fuel trade (Tables 2 and 3) the coefficient on the border dummy which has the wrong sign in the probit equation and is not statistically significant in the gravity equation; and the wrong signs of the coefficients on the dummies indicating EC and EFTA membership in the gravity equation, which are, however, never significant. For the high technology aggregate (Table 4 and 5), the exceptions are similar: the coefficients on the border dummy in the probit equation and on EC and EFTA membership in the gravity equation are never statistically significant and sometimes have the wrong sign. Likelihood ratio tests indicate that for all alternative specifications estimated the explanatory variables are jointly significantly different from zero.

The estimated correlation coefficients between the probit and gravity equations ρ are always close to zero and not statistically significant based on a likelihood ratio test for both total non-fuel and high technology trade. This suggests that for our data it would have been possible to estimate the equations independently and that the exclusion of zero observations in the gravity equation does not lead to a bias stemming from a non-random sample selection.

Recalling the theoretical ambiguity of the effect of IPRs on bilateral trade described in Section II, we had no prior expectations regarding the sign of the coefficient on the Park and Ginarte index. For both total non-fuel imports and exports, the Park and Ginarte index has only a small effect on the probability of positive trade flows between countries, although the effect is positive and statistically significant at the 5% level for total non-fuel exports. Turning to the gravity equation, IPRs have a significantly positive impact on bilateral trade flows for both total non-fuel imports and exports. Comparisons of models (I) and (II) in Tables 2 and 3 suggests that inclusion of IPRs leads to relatively small changes in the coefficients of most gravity variables. The biggest changes occur in the coefficients on GDP and population of the destination country of the trade flow. These changes can be explained by the strong correlation between the strength of

IPRs protection and the level of economic development as measured by per capita GDP.[17] To what extent we pick up development related effects related to bilateral trade with the Park and Ginarte index remains open to discussion.

For high technology trade in Tables 4 and 5 the evolving pattern is different. For both exports and imports, the Park and Ginarte index has a significantly negative impact on the probability that countries trade with each other. The impact of IPRs on positive trade flows, in turn, is slightly negative but not statistically significant. This result is somewhat surprising. If IPRs influence trade flows, we would expect this influence to be most visible for trade in knowledge-intensive goods. Several explanations can be brought forward. First, strong market power effects in the case of high technology goods may offset positive market expansion effects caused by stronger IPRs regimes. Second, stronger IPRs regimes may cause high technology firms to serve foreign markets by FDI, in-part substituting for trade flows. Third, it may be that the Park and Ginarte index does not correctly capture the IPRs effect (see below for a discussion) or that development related effects interplay with stronger IPRs protection. Fourth, our high technology aggregate may include many knowledge-intensive goods which are insensitive to the destination country's IPRs regime; for these goods other than legal means may be more important in appropriating investment in R&D (e.g., first mover advantage or rapid movement down the learning curve). Finally, we omitted important explanatory variables in our gravity equation such as tariff and non-tariff trade barriers; this type of specification error may bias our estimated results.

V. Comparisons to related studies

There are several related studies which also try to estimate the effects of intellectual property rights on bilateral trade flows.[18] Maskus and Konan (1994) also use a gravity model to estimate the effect of IPRs protection on bilateral trade. They regress the index developed by Rapp and Rozek (1990) along with several other development-related variables on the residual of the gravity flow estimation. This approach, however, produces only valid estimates if these variables were uncorrelated with the independent variables of the gravity estimation. This is clearly not the case as both GDP and population are included in the

[17] In our data, the Personian correlation coefficient between GNP per capita and the Park and Ginarte index lies around 65%.

[18] In addition to the studies survey in this section, Primo Braga and Fink (1997) and Ferrantino (1993) also provide econometric evidence regarding the IPRs-trade link.

gravity model.[19] Hence, it is not clear to what extent Makus and Konan's finding of a positive IPRs trade link is reliable.

Maskus and Penubarti (1995) estimate the effect of IPRs on bilateral trade flows in an augmented version of the Helpman-Krugman model of monopolistic competition. Imports of good *i* by country *j* from exporter *k* as a share of aggregate expenditure in country *j* are explained by the sectoral exporter output, the importer GNP per capita, trade-resistance measures for the importing country (tariff revenue as a percentage of dutiable imports, black-market exchange rate premia), and the Rapp and Rozek index of patent strength for country *j*.[20] Dummy variables indicating whether the importing developing country has a small or large market are interacted with the Rapp and Rozek index.

To address the problem of endogeneity and also potential errors of measurement in the Rapp and Rozek index, Maskus and Penubarti adopt an instrumental variable approach. Their instruments are prior indicators of the level of economic development (GDP per capita, primary exports as a share of total exports, infant mortality rate, and secondary enrollment ratios), and dummy variables for former British and French colonies, for membership in Paris and Berne Conventions, and for the existence of legislative provision for pharmaceutical and chemical product patents. Maskus and Penubarti find a positive IPRs-trade link: countries with stronger patent regimes import more than what is predicted by the Helpman-Krugman model. Moreover, the impact of patent protection on trade flows is found to be bigger in the larger developing countries.

In comparing Maskus and Penubarti's results to our findings, two things need to be pointed out. As Maskus and Penubarti, we, too, face the problem of endogeneity and measurement error. It can be argued, however, that the degree of endogeneity may not be too severe if one takes into account that most countries' IPRs regimes were established during or before the 1960s and the level of protection remained fairly constant until 1989/90 (the years of our estimation).[21] Still issues of measurement error can be quite severe. Although the Park and Ginarte index considers more aspects of an IPRs system than the Rapp and

[19] Moreover, it is not clear what lower Maskus and Konan (1994) use with regard to their Tobit estimation; since the model specification is standard log-linear, it cannot, by definition, be zero. Finally, they do not describe how they compute the predicted values for the residuals of the Tobit estimation; this requires non-standard procedures (McDonald and Moffit 1980).

[20] Sectoral exporter output is used as predicted by a first-stage regression designed to address endogeneity problems.

[21] Park and Ginarte (1996) compute their IPRs ranking quinquennially from 1960 to 1990. The average level of patent protection increased from 2.13 in 1960 to 2.46.

Rozek index (e.g. the availability of enforcement mechanisms), it only measures the level of protection as written "on the books". It is well-known, however, that *de jure* protection may be quite different from *de facto* protection. With respect to Maskus and Penubarti's instrument variable approach, it needs to be pointed out that most of their instruments tend to be strongly correlated with bilateral trade flows. Hence, it is not clear to what degree Maskus and Penubarti really reduce problems related to endogeneity and measurement error.

A potential problem in Maskus and Penubarti's estimation lies in the way they interact the Rapp and Rozek index with dummy variables for small and large developing countries. As mentioned previously, the strength of patent protection tends to be strongly correlated with the level of economic development.[22] Through interaction with the two dummies, the Rapp and Rozek index is allowed a much more flexible impact than GNP per capita. Hence, it may be that the three coefficients estimated for the Rapp and Rozek index pick up a misspecification in the functional form of GNP per capita. Their estimated coefficient on GNP per capita is not significantly different from zero for most cases, which they attribute to the notion of homothetic preferences. Unfortunately, they do not report estimation results without interacting the Rapp and Rozek index with dummies; it is thus difficult to evaluate the seriousness of this potential problem in Maskus and Penubarti's study.[23]

VI. Summary and Conclusion

With an increasing share of knowledge-intensive products in international trade and the inclusion of trade-related IPRs on the agenda of the GATT/WTO, IPRs have become an important trade issue. Political economy considerations -- as reflected in the TRIPS Agreement -- favor higher standards of IPRs protection.

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[22] Maskus and Penubarti (1995) report a correlation coefficient of 0.712 between the Rapp and Rozek index and GNP per capita.

[23] We also estimated our gravity model in a similar way as Maskus and Penubarti (1995). Instead of the Park and Ginarte index, we used the Rapp and Rozek index interacted with three dummies for high income countries, large developing countries, and small developing countries. Our estimated coefficients were similar: we find a significantly positive IPRs-trade link for large developing countries. However, inclusion of the Rapp and Rozek index interacted with the three dummies lead to large changes in the coefficients on GDP and population. We concluded that the relatively more flexible impact of IPRs in our model indeed picks up a misspecification in the functional form of per capita income and therefore abandoned this approach.

Economic analysis suggests that the effects of IPRs protection on bilateral trade flows are theoretically ambiguous. Because of the complex static and dynamic considerations related to a policy of tighter protection, it is difficult to generate normative recommendations. When estimating the effects of IPRs protection in a gravity model of bilateral trade flows, our empirical results suggest that, on average, higher levels of protection have significantly positive impact on non-fuel trade. However, this result is not confirmed when confining the estimation to high technology goods where we found IPRs to have no statistically significant impact.

More empirical research is needed to gain more insight regarding the IPRs-trade link, especially at industry and firm level. The challenge of such research will be to find 'natural experiments' to overcome the colineraty and endogeneity problems of the cross-country type of analyses like the present study. One alternative, for instance, would be to consider a country which at some point in the past significantly changed its system of IPRs and to test for structural change. A further important field of research is to examine the impact of tighter IPRs on FDI and their interplay with trade flows.

Table 1: Definition of the High Technology Aggregate

SITC Code[a]	Description
513	Inorganic Elements
514	Other Inorganic Chemicals
515	Radioactive Materials
533.1	Coloring Materials
541	Medicinal Products Excluding Pharmaceuticals
541.9	Pharmaceutical Goods
561.3	Potassic Fertilizers
571.2	Fuses and Detonators
571.4	Hunting and Sporting Ammunition
581.1	Plastics and Products of Condensation
581.2	Products of Polymerization
651.6	Synthetic Fibers
651.7	Yarn and Artificial Fibers
711.3	Steam Engines
711.4	Aircraft Engines
711.5	Internal Combustion Engines
711.6	Gas Turbines
711.8	Engines, nes
714	Office Machinery
724	Telecommunications Apparatus
729.3	Transistors, Photocell, etc.
729.7	Electron Accelerators
729.9	Electrical Machinery and Apparatus
734	Aircraft
861	Scientific Instruments
862	Photographic Supplies
891.1	Tape Recorders
891.2	Recorders of Sound
894.3	Nonmilitary Arms
899.6	Orthopedic Appliances

[a] Based on SITC Revision 1 classification.

Source: Primo Braga and Yeats (1992).

Table 2: Maximum Likelihood Estimates for Total Non-Fuel Imports[a]

Model	(I)		(II)	
Equation	Probit	Gravity	Probit	Gravity
Intercept	-7.000 (-27.40)	-10.228 (-29.02)	-6.960 (26.28)	-10.956 (-30.58)
GDP_i	0.541 (31.47)	1.109 (51.73)	0.545 (29.90)	0.949 (34.98)
GDP_j	0.567 (32.36)	1.341 (61.89)	0.566 (32.33)	1.339 (62.12)
$Population_i$	-0.194 (-9.80)	-0.233 (-8.53)	-0.198 (-9.17)	-0.082 (-2.64)
$Population_j$	-0.058 (-3.03)	-0.333 (-12.76)	-0.058 (-3.03)	-0.336 (-12.97)
Distance	-0.435 (-12.17)	-1.109 (-23.87)	-0.437 -12.15)	-1.060 (-23.20)
Border	-0.376 (-2.32)	0.179 (0.91)	-0.378 (-2.33)	0.239 (1.27)
Language	0.592 (8.67)	0.861 (9.50)	0.591 (8.66)	0.867 (9.62)
EC		-0.264 (-0.94)		-0.305 (-1.08)
EFTA		-0.393 (-0.81)		-0.415 (-0.86)
LAIA/LAFTA		0.713 (3.27)		0.951 (4.37)
ASEAN		2.269 (4.64)		2.476 (5.10)
CACM		2.133 (4.32)		2.414 (4.91)
IPRs[b]			-0.014 (-0.53)	0.369 (9.59)
$\hat{\sigma}$		2.100		2.083
obs.	7304	5492	7304	5492
$\hat{\rho}$	-0.034		-0.043	
$-2\ln l(\rho = 0)$[c]	0.853		1.346	
$-2\ln l(\{\gamma, \beta\} = 0)$[c]	8874.433		8965.677	

[a] t-statistics in parentheses

[b] Park and Ginarte index of the destination country of the trade flow, that is country *j* in the case of exports and country *i* in the case of imports.

[c] For a definition of the likelihood ratio test statistics, see Appendix A.

Table 3: Maximum Likelihood Estimates for Total Non-Fuel Exports[a]

Model	(I)		(II)	
Equation	Probit	Gravity	Probit	Gravity
Intercept	-6.631	-10.791	-6.766	-11.170
	(-27.77)	(-29.31)	(-27.10)	(-29.55)
GDP_i	0.556	1.374	0.556	1.374
	(33.86)	(60.26)	(33.85)	(60.38)
GDP_j	0.458	1.017	0.443	0.945
	(29.84)	(46.85)	(25.93)	(35.11)
$Population_i$	-0.052	-0.320	-0.052	-0.320
	(-2.84)	(-12.18)	(-2.83)	(-12.20)
$Population_j$	-0.153	-0.137	-0.137	-0.070
	(-8.15)	(-4.90)	(-6.57)	(-2.17)
Distance	-0.473	-1.114	-0.467	-1.100
	(-13.55)	(-23.69)	(-13.34)	(-23.41)
Border	-0.393	0.301	-0.381	0.328
	(-2.54)	(1.52)	(-2.47)	(1.65)
Language	0.588	0.826	0.588	0.826
	(8.96)	(8.95)	(8.97)	(8.98)
EC		-0.068		-0.096
		(-0.24)		(-0.34)
EFTA		-0.137		-0.152
		(-0.28)		(-0.31)
LAIA/LAFTA		0.822		0.944
		(3.73)		(4.26)
ASEAN		2.352		2.442
		(4.78)		(4.97)
CACM		2.127		2.267
		(4.28)		(4.56)
IPRs[b]			0.047	0.176
			(1.92)	(4.46)
$\hat{\sigma}$		2.113		2.109
obs.	7309	5294	7309	5294
$\hat{\rho}$	0.005		0.002	
$-2\ln l(\rho = 0)$[c]	0.016		0.003	
$-2\ln l(\{\gamma, \beta\} = 0)$[c]	8520.968		8544.524	

[a] t-statistics in parentheses

[b] Park and Ginarte index of the destination country of the trade flow, that is country *j* in the case of exports and country *i* in the case of imports.

[c] For a definition of the likelihood ratio test statistics, see Appendix A.

Table 4: Maximum Likelihood Estimates for High Technology Imports[a]

Model	(I)		(II)	
Equation	Probit	Gravity	Probit	Gravity
Intercept	-5.494 (-27.17)	-14.487 (-26.21)	-4.794 (-22.87)	-14.313 (-26.95)
GDP_i	0.568 (40.12)	0.911 (22.68)	0.717 (39.04)	0.960 (16.69)
GDP_j	0.495 (36.36)	1.898 (52.12)	0.512 (36.45)	1.897 (52.38)
$Population_i$	-0.324 (-18.71)	-0.086 (-2.06)	-0.474 (-22.59)	-0.132 (-2.38)
$Population_j$	-0.170 (-10.31)	-0.733 (-20.70)	-0.175 (-10.43)	-0.731 (-20.70)
Distance	-0.421 (-13.56)	-1.115 (-19.11)	-0.466 (-14.62)	-1.124 (-19.00)
Border	0.011 (0.08)	0.157 (0.64)	-0.110 (-0.78)	0.141 (0.61)
Language	0.480 (8.54)	1.154 (9.53)	0.488 (8.43)	1.146 (9.49)
EC		0.224 (0.74)		0.227 (0.76)
EFTA		-0.053 (-0.10)		-0.057 (-0.11)
LAIA/LAFTA		0.798 (3.24)		0.771 (3.08)
ASEAN		3.407 (6.53)		3.374 (6.46)
CACM		2.992 (5.63)		2.959 (5.55)
IPRs[b]			-0.340 (-14.09)	-0.093 (-1.50)
$\hat{\sigma}$		2.229		2.228
obs.	7304	3548	7304	3548
$\hat{\rho}$	0.066		0.064	
$-2\ln l(\rho=0)$[c]	1.354		1.309	
$-2\ln l(\{\gamma,\beta\}=0)$[c]	7606.860		7812.274	

[a] t-statistics in parentheses

[b] Park and Ginarte index of the destination country of the trade flow, that is country *j* in the case of exports and country *i* in the case of imports.

[c] For a definition of the likelihood ratio test statistics, see Appendix A.

Table 5: Maximum Likelihood Estimates for High Technology Exports[a]

Model	(I)		(II)	
Equation	Probit	Gravity	Probit	Gravity
Intercept	-8.300	-14.272	-8.334	-14.225
	(-32.67)	(-28.75)	(-31.67)	(-28.02)
GDP_i	0.987	1.804	0.987	1.803
	(47.17)	(44.86)	(47.15)	(44.85)
GDP_j	0.270	0.927	0.265	0.936
	(18.71)	(36.09)	(15.10)	(29.05)
$Population_i$	-0.305	-0.658	-0.305	-0.658
	(-17.00)	(-18.43)	(-17.01)	(-18.41)
$Population_j$	-0.086	-0.097	-0.081	-0.105
	(-4.28)	(-2.67)	(-3.60)	(-2.59)
Distance	-0.596	-1.062	-0.595	-1.064
	(-17.27)	(-18.78)	(17.21)	(-18.76)
Border	-0.121	0.129	-0.116	0.124
	(-0.84)	(0.58)	(-0.810)	(0.565)
Language	0.706	1.225	0.707	1.226
	(11.01)	(10.66)	(11.03)	(10.67)
EC		0.326		0.332
		(1.14)		(1.15)
EFTA		0.086		0.089
		(0.17)		(0.18)
LAIA/LAFTA		0.720		0.702
		(2.96)		(2.86)
ASEAN		3.467		3.455
		(6.97)		(6.93)
CACM		2.661		2.640
		(5.20)		(5.15)
IPRs[b]			0.0132	-0.022
			(0.50)	(-0.45)
$\hat{\sigma}$		2.121		2.121
obs.	7309	3342	7309	3342
$\hat{\rho}$	-0.027		-0.027	
$-2\ln l(\rho=0)$[c]	0.451		0.442	
$-2\ln l(\{\gamma,\beta\}=0)$[c]	8725.684		8726.127	

[a] t-statistics in parentheses

[b] Park and Ginarte index of the destination country of the trade flow, that is country *j* in the case of exports and country *i* in the case of imports.

[c] For a definition of the likelihood ratio test statistics, see Appendix A.

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Appendix A: Description of Likelihood Function and Likelihood Ratio Tests

Following Bikker and de Vos (1992), the likelihood function can be derived as follows. From (1), the likelihood of zero observations can be written as:

(A.1) $P(I_{ij} = 0) = \Phi(-z_{ij}\, g)$,

where Φ denotes the standard normal distribution function. Recalling that the conditional density of v_{ij} given u_{ij} is given by $u_{ij}\, r \,/\, s + e_{ij}$, where e_{ij} is (univariate) normally distributed with mean zero and variance $1 - r^2$, the likelihood of non-zero observations is:

$$\text{(A.2)} \quad \begin{aligned} P(I_{ij} = y_{ij}) &= P(z_{ij}\, g + v_{ij} > 0 \,|\, u_{ij}) \;\; f\left[(y_{ij} - x_{ij} b) / s\right] \\ &= \Phi\left[\left(z_{ij}\, g + r(y_{ij} - x_{ij} b) / s\right) / (1 - r^2)^{1/2}\right] \frac{1}{s}\, f\left[(y_{ij} - x_{ij} b) / s\right], \end{aligned}$$

where f denotes the standard normal distribution function. From (A.1) and (A.2) the logarithm of the complete likelihood function is:

$$\text{(A.3)} \quad \begin{aligned} \ln L(g, b, s, r) &= \sum_{I_{ij}=0} \ln \Phi(-z_{ij}\, g) \\ &+ \sum_{I_{ij}=y_{ij}} \left\{ \ln \Phi\left[\left(z_{ij}\, g + r(y_{ij} - x_{ij} b) / s\right) / (1 - r^2)^{1/2}\right] - \ln s + \ln f\left[(y_{ij} - x_{ij} b) / s\right] \right\} \end{aligned}$$

The log-likelihood function can be maximized by iterative procedures. To test whether the correlation coefficient r is statistically different from zero, we apply a likelihood ratio test. This can be done by maximizing the likelihood function in (A.3) under the restriction $r = 0$ and computing the liklihood ratio

(A.2) $l = L^{**}_{\max} \,/\, L^{*}_{\max}$,

where $L^{**}_{\max}$ denotes the maximum of the likelihood function in the restricted model and $L^{*}_{\max}$ the maximum of the likelihood function in the unrestricted model. The test statistic $-2 \ln\, l$ (as reported in Table 1) is asymptotically chi-square distributed.

Similarly, the joint statistical significance of all explanatory variables can be tested by restricting all coefficients (except the coefficients on the intercepts) to zero and computing the corresponding likelihood ratio.

Data Appendix

Data on bilateral trade flows were extracted from the United Nations Comtrade database. We collected data for the following 89 countries:

Algeria
Argentina[c]
Australia
Austria[b]
Bangladesh
Belgium-Luxembourg[a]
Benin
Bolivia[c]
Brazil[c]
Burma
Cameroon
Canada
Chile[c]
Colombia[c]
Congo
Costa Rica[e]
Cote D'Ivoire
Denmark[a]
Dominican Republic
Ecuador[c]
Egypt
El Salvador[e]
Ethiopia
Finland[b]
France[a]
Gabon
Germany[a]
Ghana
Greece[a]
Guatemala[e]
Haiti
Honduras[e]
Hong Kong
India
Indonesia[d]
Iran
Ireland[a]
Israel
Italy[a]
Jamaica
Japan
Jordan
Kenya
Korea
Kuwait
Madagascar
Malaysia[d]
Mauritania
Mauritius
Mexico[c]
Morocco
Netherlands[a]
New Zealand
Nicaragua[e]
Niger
Nigeria
Norway[b]
Oman
Pakistan
Panama
Papua New Guinea
Paraguay[c]
Peru[c]
Philippines[d]
Portugal
Saudi Arabia
Senegal
Singapore[d]
Somalia
Spain
Sri Lanka
Sweden[b]
Switzerland[b]
Syria
Tanzania
Thailand[d]
Togo
Trinidad and Tobago
Tunisia
Turkey
United Arab Emirates
United Kingdom[a]
United States
Uruguay[c]
Venezuela[c]
Yemen
Zaire
Zambia
Zimbabwe

[a] European Community (EC)
[b] European Free Trade Association (EFTA)
[c] Latin American Integration Association/Latin American Free Trade Association (LAIA/LAFTA)
[d] Association of South East Asian Nations (ASEAN)
[e] Central American Common Market (CACM)

All countries except Zambia served as reporter and partner countries of bilateral trade flows. Zambia was not listed as a reporter in the database. This sums to a maximum of [(89 x 88) - 88] = 7744 observations. In the estimation, the dataset had to be further reduced, because the Park and Ginarte index did not include rankings for Kuwait, Oman, United Arab Emirates, and Yemen. Belgium-Luxembourg also had to be excluded, because the two countries have different IPRs regimes. However, these countries could still serve as source countries of trade flows. This explains the total of 7309 observation for exports and 7304 observations for imports. Trade data refer to 1989 US$ value of total non-fuel trade (SITC 0 through 9-3) and high technology trade (see Table 1).

1989 US$ GDP (Atlas method) and population were taken from the World Bank. Geographical distance is the straight-line distance between the economic centers of the respective countries and was taken from Erzan, Holmes, and Safadi (1992). The languages included in the corresponding dummy variable are Arabic, English, Portuguese, and Spanish. We are most grateful to Raed Safadi in providing the data for the gravity variables.