Effects of Foreign Intellectual Property Rights on U.S. Bilateral Exports of Biotechnology Related Agricultural Inputs

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Abstract: This paper examines the effect of foreign intellectual property right (IPR) systems and the policies that comprise them on U.S. exports of biotechnology related agricultural input industries. Policy components include the extent of patent coverage across industry sectors, enforcement mechanisms, provisions for loss of patent protection, memberships to other international patent agreements, and duration of patent protection. Extending the empirical and theoretical work of Smith (2002), this paper uses a gravity model to analyze how IPRs affect the market power and market expansion effects of exports to countries with differing abilities to imitate technology. The findings suggest that strengthening global IPRs grant a market power effect to U.S. exporters; strong IPRs reduce U.S. exports by awarding a temporary monopoly over the protected good. However, the analysis of the individual policy components of an IPR system reveal which components inhibit trade through market power effects and which components counterbalance it through market expansion effects, increasing the flow of trade and access to biotechnology related agricultural inputs.

1. Introduction

In 2001, the Fourth Ministerial Conference in Qatar mandated World Trade Organization (WTO) negotiations to review the often-debated Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs). While developed countries favor strong intellectual property right (IPR) protection to encourage innovation, developing countries fear IPRs will increase monopoly power of firms from developed countries. This debate is particularly sensitive to IPRs related to agricultural inputs as the growth in biotechnology impacts both the amount of intellectual property embedded in agricultural inputs and the structural transformation of the input industry into multinational "life science" corporations.

The debate over the strength of IPRs prompts research in two areas. (1) What is the implication of increasing global IPR protection on the direction and volume of trade in biotechnology related agricultural inputs? (2) What policy components of an IPR system significantly affect the flows of these commodities? Policy components include the extent of sectoral patent coverage, enforcement mechanisms, provisions for loss of protection, memberships to other international patent agreements, and duration of patent protection. For example, do policies that increase IPR enforcement affect export flows in the same way that increases in patent protection duration or sectoral patent coverage affect export flows?

While the literature overlooks question (2) the limited research on question (1) presents mixed results. In an OECD-wide study of the distribution of exports across both large and small developing countries, Maskus and Penubarti (1995) find that strengthening IPRs result in an expansion of trade flows of commodities in industries characterized by significant intellectual property. Fink and Primo Braga (1999) confirm a positive link between intellectual property rights and trade flows for non-fuel aggregates, but found no significant link between intellectual property rights and high technology trade flows.

However, a new body of literature suggests that these inconclusive links between the direction of trade and IPRs is because strong IPRs simultaneously increase trade by a *market expansion effect* and decrease trade by a *market power effect*. A market expansion effect occurs when strong foreign IPRs expand export markets by ensuring exclusive rights to sell the protected export. A market power effect occurs when strong foreign IPRs reduce exports by ensuring a temporary monopoly power over the protected good. The theory predicts IPRs to cause a market expansion effect of exports to countries with strong abilities to imitate technology and a market power effect of exports to countries with weak abilities to imitate technology. Smith (1999, 2002) is one of the first to empirically find support for this theory. In particular, Smith (2002) provides initial evidence of these effects on U.S. exports of biological products, medicinals and botanicals, and pharmaceuticals.

The purpose of this paper is to answer questions (1) and (2) using the econometric and theoretical framework of Smith (2002). To answer question (1), I extend Smith (2002) to the biotechnology related agricultural input industry, including field crop seeds and agricultural chemicals. To answer question (2) I link articles of the TRIPs agreement to an index of IPRs policy components and analyze how different policies affect the trade in these commodities. This is the first piece of research that attempts to understand how different components of a country's IPR system affect the flow of traded goods. These findings could have significant policy implications for future WTO negotiations over TRIPs.

2. Theoretical framework & predictions

This paper applies the theoretical framework from a set of literature that establishes a link between IPRs and international trade (see for example Helpman 1993, Taylor 1993, Ethier and Markusen 1996, and Markusen 2001). It is also grounded in the recent literature that has produced predictions on the effect that foreign IPR policies has on the direction of trade (Maskus and Penubarti 1995, Fink and Primo Braga 1999 and Smith 1999, 2002). Since this paper is an extension of Smith (2002), the following paragraphs briefly review Smith's theory and predictions.

Smith (2002) analyzes how a foreign country's ability to imitate technology affects the relationship between strengthening IPRs and the market power or market expansion effects on U.S. exports of goods embodying a significant amount of intellectual property, biological products, medicinals and botanicals, and pharmaceuticals in particular. This research was grounded in the theory that the direction of trade depends on the relative dominance of market power or market expansion effects. Under the market expansion effect, strong IPRs reduce the threat of imitation and induce expansion of U.S. exports by assuring exclusive rights to sell protected technologies to countries with a high risk of imitation. Under the market power effect, strong foreign IPRs raise the cost of imitation and U.S. firms exercise market power by restricting the quantity of exports and raising prices to extract monopoly rents in countries safe from imitation. Smith derives two hypotheses from this theory of international trade.

Hypothesis A: The market expansion effect predicts a positive relationship between the strength of foreign property rights and U.S. bilateral exports. Strong property rights are expected to confer market expansion across countries with strong imitative abilities (where cost of deterring imitation is high).

Hypothesis B: The market power effect predicts a negative relationship between the strength of foreign property rights and U.S. bilateral exports. Strong property rights are expected to confer market power across countries with weak imitative abilities (where few imitative substitutes are available).

Smith (2002) uses the bilateral trade equations of the gravity model to test and confirm hypotheses (A) and (B). The study uses an index developed by Ginarte and Park (1997) that measures the strength of IPRs for 105 countries and constructs two dummy variables to group countries according to their ability to imitate technology. It then analyzes cross-country effects of foreign IPRs on U.S. exports pooled across the years 1972, 1977, 1982, 1987, and 1992. The analysis also considers these effects at multiple points in time and considers the relative magnitude of these effects over time. The element of time is included to capture the relationship between IPRs and trade as global trade and IPRs both increase over time and as the biological, medicinals and botanicals and pharmaceuticals industries face structural changes. These industries have become increasingly consolidated over time, in part, because different firms hold IPRs to multiple technologies needed to produce a product.

In this paper, using the same IPR index and dummy variables for imitative abilities, I test whether hypotheses (A) and (B) hold for U.S. exports of biotechnology related agricultural inputs pooled across years 1972, 1977, 1982, 1987, 1992, 1997, and 2002. I also consider these effects at multiple points in time. In particular, I expect the relationship between foreign policies on IPRs and U.S. bilateral exports of biotechnology agricultural input industries to be positive for countries with strong abilities to imitate technology (i.e., developed countries) and negative for countries with weak abilities to imitate technology (i.e. developing countries).[1] Also, I expect the magnitude of these effects to strengthen over time due to the increasing role IPRs have played in agriculture, the growing concentration of firms in the agricultural input industry, and the enactment of TRIPs calling for the harmonization of intellectual property rights to a level similar to the U.S.[2]

Further, I examine the relationship between individual policy components of a foreign IPR system and U.S. bilateral exports of these commodities. Debates between developed and developing countries over several articles of the TRIPs Agreement warrant an investigation of how individual IPR policy components affect trade in biotechnology related agricultural inputs.[3] First, Article 27.1 requires WTO members to grant patents for processes and products in all fields of technology. Many developing countries oppose the patenting of life forms, including the patenting of biological inventions and plant and animal varieties, but developed countries

[1] While this paper is interested in the effects of IPRs on trade with developing and developed countries, the theory applied relates to countries with weak and strong abilities to imitate technology. The technique used to group countries into imitative abilities yields groups that strongly correlate with level of development.

[2] See James and Krattiger (1996) and James (2001) for a review of the growth of biotechnology in agriculture. See King (2001) for a discussion on industry concentration in agricultural input industries.

tend to support it.[4] Second, Article 27.3(b) requires the protection of microorganisms and microbiological or non-biological processes and requires the protection of plant varieties either by patents or by an effective *sui generis* system, but also allows allows members to exclude granting patents to plants, animals and essentially biological processes. Developing countries are concerned about the allowance of plant breeders' rights or plant variety protection implied by Article 27.3(b) because they fear it limits access to new seed technology and reduces their ability to reuse seeds for replanting. However, others argue that improving protection for plant varieties will increases access to these varieties for developing countries. In particular, the U.S. has called for an examination of the exclusion of patents for plants and animals and for incorporating protection of plant varieties. Third, Article 31 allows for use of intellectual property without authorization of the patent right holder. Developing countries worry about the economic power of firms holding the temporary monopoly rights of patented goods. Tools such as compulsory licenses or working requirements implied by Article 31 provide a way to curb this power. However, from a developed country perspective, these allowances imply a loss of rights to patent protection and a loss of monopoly rent. Fourth, Article 33 requires patent duration of 20 years from the first date of application.

The IPR index is constructed from five policy components convenient for analyzing the effects of the four above articles: (1) extent of sectoral patent coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5)

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[3] See Watal (2002) and Hoque and Skully (2001) for a discussion on trade interests of developing countries regarding intellectual property and biotechnology.

[4] The U.S. has provided protection for biological inventions since 1980 and has used utility patents for plants and animals in 1985 and 1987 (Shoemaker, 2001). Other developed countries, including Japan, Australia, New Zealand, Korea, Singapore, and the European Union have laws similar to the U.S. (Watal, 2000).

duration of patent protection. Article 27.1 can be linked to extent of sectoral patent coverage. Article 27.3(b) can be linked to memberships in international patent agreements. While this index does not explicitly include a measure for plant breeders' rights, it includes a country's membership to the International Union for the Protection of New Varieties of Plants (UPOV – Union Internationale pour la Protection des Obtentions Végétals), formed in 1961 to internationally harmonize protection for plant breeders' rights. Article 31 can be linked to provisions for loss of protection and Article 33 can be linked to duration of patent protection. Further, an additional topic of interest to the U.S. in the review of TRIPs is implementation and dispute settlement (Watal, 2000); this can be linked to enforcement mechanisms.

Given the linkages above, this paper considers the following questions with regard to the TRIPs agreement and trade in biotechnology related agricultural inputs. First, how do strengthening different components of foreign intellectual property policies through TRIPs affect the direction of trade? Second, do these individual policy components grant market power or market expansion effects to countries with strong or weak imitative abilities, respectively (i.e. does hypotheses (A) and (B) hold for individual policy components)? Third, given that intellectual property has played an increasing role in the agricultural biotechnology industry over time and given enactment of TRIPs in 1995 calling for the harmonization of intellectual property rights to a level similar to the U.S., how have changes in intellectual property rights affected the flow of trade over time? I expect to see hypotheses (A) and (B) hold for the individual components of the IPR patent system across countries and across years. In addition, I expect the magnitude of these effects to strengthen over time.

3. Empirical specification, methods and data

I test hypotheses (A) and (B) by examining the effects of foreign IPRs and their components on U.S. bilateral exports of biotechnology related agricultural inputs to 108 countries for 1972, 1977, 1982, 1987, 1992, 1997, and 2002 for field crop seeds and 1972, 1977, 1982, 1987, 1992, 1997, and 2002 for agricultural chemicals. Following Smith (2002), I divide countries into two groups according to their ability to imitate technology and apply the gravity model to analyze the average effects of foreign IPR and individual polices on U.S. exports. I also conduct the analysis at multiple points in time and determine whether the cross-country effects are relatively larger in magnitude in 1992-2002 than in earlier years. Exports are lagged two years behind the IPR to allow time for the U.S. to respond to any change in a foreign country's IPR system.

3.1. Specification and method

Following Smith (2002) I express the general commodity version of the gravity model in log-linear form[5]:

$$\ln\left(X_{ijk}\right) = \alpha_{oi} + \alpha_{1i} \ln\left(\frac{Q_j}{N_j}\right) + \alpha_{2i} \ln\left(N_j\right) + \alpha_{3i} \ln\left(\frac{Q_k}{N_k}\right) + \alpha_{4i} \ln\left(N_k\right) + \alpha_{5i} \ln\left(D_{jk}\right) + \alpha_{6i} \ln\left(A_{jk}\right) + e_{ijk}$$

X_{ijk} is U.S. bilateral exports from country j to foreign country k in industry i, Q_j/N_j and Q_k/N_k are per capita incomes of countries j and k. N_j and N_k are populations of countries j and k. D_{jk} is geographic distance between countries j and k. A_{jk} are distortions in k that enhance or reduce bilateral exports from j and e_{ijk} is log normally distributed error term.

[5] A known problem with a log specification is that when no trade occurs between countries the log transformation generates a missing observation. To deal with this problem, a one-dollar-value was imputed for all observations with zero trade before the log transformation.

The gravity model predicts positive parameters on income per capita and population, reflecting relative endowments and market size, and a negative parameter on distance, reflecting transportation cost. It predicts that the parameters on distortions are positive (negative) when distortions increase (decrease) bilateral exports.

I estimate seven empirical specifications of the model discussed below. The first three specifications follow Smith (2002), only altering the industry of study and time span. The exporter j is the U.S. Distortions A_{jk} are defined as openness O_{jk} in country k to trade to U.S. exports and level of intellectual property right protection IPR_k in country k as evidenced by the overall IPR index. To analyze market power and market expansion effects of hypotheses (A) and (B), IPR_k is interacted with a dummy variable for the ability of country k to imitate technology: w_k for counties with weak imitative abilities and s_k for countries with strong imitative abilities.

As in Smith (2002), I make two modifications to the intercept term. First, the intercept (β_{0i}) captures the U.S. terms or (j) terms from the model such that:

$$\beta_{0i} = \alpha_{0i} + \alpha_{1i} \ln\left(\frac{Q_j}{N_j}\right) + \alpha_{2i} \ln(N_j)$$

where α_{0i} is unmeasured distortions to trade and the remaining terms are constant for the U.S. Second, I add a vector V_k to include the intercept plus a shift dummy variable for countries with strong imitative abilities (s_k). This allows for deviations in unmeasured distortions (α_{0i}) related to imitative abilities across (s_k) countries but unrelated to intellectual property rights.

The first specification pools the observations across time to estimate the average effect of increasing IPRs across countries.

$$(1)\quad \ln(X_{ik}) = \beta_{0i}{}'V_k + \beta_{1i}\ln\left(\frac{Q_k}{N_k}\right) + \beta_{2i}\ln(N_k) + \beta_{3i}\ln(D_{jk}) + \beta_{4i}\ln(O_{jk}) + \beta_{5i}w_k\ln(IPR_k) + \beta_{6i}s_k\ln(IPR_k) + e_{ik}$$

I expect a negative sign on the parameter β_{5i}, suggesting a market power effect on countries with weak imitative abilities according to hypothesis (B) and a positive sign on the parameter β_{6i}, suggesting a market expansion effect to countries with strong imitative abilities according to hypothesis (A).

The second specification considers the effects of IPR policies over multiple points in time by adding a vector of dummy variables (t) for each observation year.

$$(2)\quad \ln(X_{ik}) = \beta_{0i}{}'V_k + \beta_{1i}\ln\left(\frac{Q_k}{N_k}\right) + \beta_{2i}\ln(N_k) + \beta_{3i}\ln(D_{jk}) + \beta_{4i}\ln(O_{jk}) + \beta_{5i}w_k\ln(IPR_k)t + \beta_{6i}s_k\ln(IPR_k)t + e_{ik}$$

I expect the same parameter signs as above, except they represent effects of cross-country differences for a given year.

The third specification considers a time-shift term ($t_{92\text{-}02}$) for the years 1992-2002 to analyze whether IPRs have a larger positive or negative effect on U.S. bilateral exports in later years than earlier years.

$$(3)\quad \ln(X_{ik}) = \beta_{0i}{}'V_k + \beta_{1i}\ln\left(\frac{Q_k}{N_k}\right) + \beta_{2i}\ln(N_k) + \beta_{3i}\ln(D_{jk}) + \beta_{4i}\ln(O_{jk}) + \beta_{5i}w_k\ln(IPR_k) + \beta_{6i}s_k\ln(IPR_k) + \beta_{7i}w_k\ln(IPR_k)t_{92-02} + \beta_{8i}s_k\ln(IPR_k)t_{92-02} + e_{ik}$$

I expect a significant negative parameter on β_{7i} and a significant positive parameter on β_{8i}.

Specifications 4-7 consider distortions in trade due to specific policy components that comprise the overall IPR index: extent of sectoral patent coverage (COV), enforcement mechanisms (ENF), provision for loss of protection (LOP), membership in international patent agreements (MEM), duration of protection (DUR).

The fourth specification considers the average effects of each intellectual property component on the overall direction of U.S. bilateral trade flows, pooled across all years.

$$\begin{aligned} \ln(X_{ik}) = \beta_{0i}{}' V_k + \beta_{1i} \ln\left(\frac{Q_k}{N_k}\right) + \beta_{2i} \ln(N_k) + \beta_{3i} \ln(D_{jk}) + \beta_{4i} \ln(O_{jk}) \\ + \beta_{5i} COV_k + \beta_{6i} ENF_k + \beta_{7i} LOP_k + \beta_{8i} MEM_k + \beta_{9i} DUR_k + e_{ik} \end{aligned} \tag{4}$$

The parameters (β_{5i}, β_{6i}, β_{7i}, β_{8i}, and β_{9i},) indicate the average effect that each component has on the direction of U.S. bilateral trade flows.[6]

Specifications (5), (6) and (7) are the same as the first three, replacing the overall IPR index measuring intellectual property rights (IPR_k) with the five category indices. For these last specifications, I expect negative parameter signs on the dummy variables for weak imitative abilities (w) indicating a market power effect and positive for dummy variables for strong imitative abilities (s) indicating a market expansion effect.

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[6] Specifications with the IPR components apply a semi-log functional form, eliminating logs on IPR policy variables. This is done to eliminate the possibility of missing values when a country (k) has zero valued component of IPR protection.

3.2. Data[7]

Gravity model specifications are estimated using U.S. export data for field crop seeds and agricultural chemicals from United States Department of Agriculture, Foreign Agricultural Service.[8]

To capture the effect of foreign policies on IPRs, I use an index of patent rights developed by Ginarte and Park (1997) and updated by Park and Wagh (2002).[9] The index expresses a measure of patent rights using a coding system applied to national patent laws for 110 countries, every five years from 1960-2000. Five categories of patent laws construct this index: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection. For each country and time period, every category receives a scored value ranging from zero to one. The unweighted sum of the five categories constitutes the overall index, where the higher value of the index indicates the stronger level of protection.

A country's ability to imitate technology is captured by dummy variables constructed by Smith (2002). The data used to construct the dummies include: R&D expenditures as a percentage of

[7] A data appendix is available by the author upon request.

[8] Field crop seeds include durum wheat seed for sowing, wheat and meslin seed for showing, barely seed for sowing (except durum), oats seed for sowing, corn (maize) seed for sowing (excluding sweet corn), yellow corn seed, other corn seed, grain sorghum seed for sowing, soybean seeds for sowing, sunflower seeds for planting, sunflower seeds for oil stock for sowing, sunflower seeds (except for oil stock) for sowing, cotton seeds for sowing. Agricultural chemical exports include fungicides, herbicides, insecticides, and other pesticides.

[9] The figures for the year 2000 are preliminary since they do not incorporate TRIPs compliance reviews.

GNP, R&D scientists and engineers per million population, R&D technicians per million population, and educational obtainment.

Data for the traditional gravity model variables (per capita income, population and openness) comes from Penn World Tables 6.1 (Heston, Summers and Aten 2002).[10] Distance is the direct-line (geodisc) distance between Indianapolis and foreign country capitals (Fitzpatrick and Modlin, 1986).

4. Empirical results

4.1. Effects of overall increases in foreign IPRs on agricultural inputs

This section reports the empirical results of the first three specifications. The results are reported in Table 1. The estimates on the IPR variables describe the response of U.S. exporters to the strength of IPRs of a country relative to other countries within the same imitative abilities grouping.

First, the results for the average effects of an overall increase in IPRs, pooled across all years provide support for the market power effect of hypothesis (B): strong IPRs result in reduced exports in countries with weak imitative abilities. The results are mixed for hypothesis (A); the market expansion hypothesis is confirmed for field crop seeds, but a strong market power effect is found for agricultural chemicals suggesting that exporters of agricultural chemicals behave monopolistically regardless of imitative abilities.

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[10] 2002 data is not yet available at the time this version of the paper was written so year 2000 data was used instead.

Second, the results for the annual effects of strengthening IPRs provide more support for the market power hypothesis (B) in 1987 and 1992 for field crop seeds and in 1987, 1997, and 2002 for agricultural chemicals. There is some support for hypothesis (A) for field crop seeds in 1972 and 2002. Again, there is a strong market power effect for agricultural chemicals regardless of imitative abilities, especially for years 1987-2002 compared to 1977-1982.

Third, comparing the deviation in effects of IPRs from 1992-2002 compared to earlier years, I find increasing support for hypothesis (B). Not surprisingly, the results also indicate increasing market power effects for agricultural chemicals in more recent years, regardless of imitative abilities.

Overall, there is some support for the market expansion hypothesis (A) for field crop seeds and significant support for the market power hypothesis (B) for both commodities, the effects of which tend to increase over time. Further, the finding of market power effects for both countries with strong and weak imitative abilities suggest that U.S. exporters of agricultural chemicals behave monopolistically.

4.2. Effects of increased components of IPRs on agricultural inputs

This section reports the empirical results of the next four specifications that test hypotheses (A) and (B) for individual policy components on U.S. exports of biotechnology related agricultural inputs. The results of specifications 4-5 are reported in Table 2; the results of specifications 6-7 are not reported in a table but will be discussed below.[11]

[11] Estimates are available upon request.

The first column reports the average effect that individual IPR policies have on the overall direction of U.S. bilateral trade. It does not itself provide any evidence for or against hypotheses (A) or (B), but indicates how individual policies affect the overall direction of trade. The results show that on average, U.S. exports of biotechnology related agricultural commodities expand with increased sectoral patent coverage, increased enforcement, and increased provisions for loss of protection. Exports decrease with membership in international patent agreements and with duration of patent protection.

The results reported in the second column can be used to test hypotheses (A) and (B) by showing the average effects of IPR components on countries with weak and strong abilities to imitate technology. The only policy to show evidence of support for hypotheses (A) and (B) is sectoral patent coverage. The results show a market power effect for weak countries and a market expansion effect for strong countries especially for agricultural chemicals. This suggests that Article 27.1, requiring patent protection in all fields of technology, will have a significant effect on trade and market access to biotechnology related agricultural inputs; developing countries who grant patents to all sectors might have limited access to these commodities due to a market power effect while developed countries might increase their access.

Across all countries, strengthening enforcement mechanisms positively affects U.S. exports of both commodities. While not directly addressed in TRIPs, these results suggest regardless of the level of development, strengthening enforcement of IPRs can increase market access to agricultural biotechnologies.

Provisions for loss of protection should be interpreted as protection against losses arising from working requirements, compulsory licensing and revocation of patents. Across all countries strengthening these provisions increases U.S. exports of biotechnology related agricultural inputs, except for field crop seeds for strong countries. These results suggest that allowing for intellectual property use without authorization of the patent holder (Article 31), without these provisions for loss of protection, could reduce U.S. trade in agricultural biotechnologies.

Across all countries, holding memberships in other international patent agreements has a significant negative effect on U.S. exports of both commodities. Recall that one of three components to this policy index is a country's membership to UPOV 1961, where signors of this agreement grant plant breeders' rights, a form of protection similar to patents. The strong market power effect for both weak and strong countries suggest that Article 27.3(b), which requires the protection of plant varieties or plant breeders' rights, can inhibit market access of agricultural biotechnologies to both developing and developed countries.

Finally, duration of patent coverage induces a market power effect for field crop seeds in weak countries and for agricultural chemicals in strong countries. Thus, Article 33, requiring patent duration of 20 years, can also encourage market power among U.S. exporters of agricultural biotechnologies.

Overall, the estimates do not appear to be very sensitive to imitative abilities, rather market power and market expansion effects appear to be policy specific. There is support for the market expansion hypothesis (A) for policies that increase patent coverage, enforcement mechanisms and provide provisions for loss of protection and support for the market power hypothesis (B) for policies that encourage membership in other international patent agreements and provide patent protection for the required duration.

4.3. Other policy variable findings

The following summarizes the findings of the last two specifications of the gravity model that analyze the annual effects and deviations in effects of later years to earlier years of IPR components. For each component, I find no strong time trends; if anything the results show a strengthening of the relationship between trade and IPR components for middle years of the data set (1982, 1987, 1992) in comparison to earlier and later years. This is somewhat surprising, because one might expect stronger linkages between trade and IPRs due to increases in global trade and IPR harmonization and due to increased consolidation in the biotechnology industry after 1992. But the results continue to confirm the same market power and market expansion effects. Namely, increases in sectoral patent coverage has market power (expansion) effects for weak (strong) countries, enforcement mechanisms and provisions for loss of protection tend to induce market expansion and membership in international patent agreements and duration of protection tend to cause a market power effect.

4.4. Other results

This section reports the remaining results from Tables 1 and 2. First, the standard gravity model variables are significant and have the appropriate sign. Estimates on per capita income and population are positively related to U.S. bilateral trade, while distance is negatively related. Openness of trading partners is generally positively and significantly related to U.S. bilateral exports. Second, consider the effect of unmeasured policies (independent of IPRs) as measured by the intercept and intercept shift parameters. The intercept is generally positive and significant suggesting that unmeasured polices in foreign countries encourage U.S. exports. The intercept shift is insignificant for agricultural chemicals, suggesting that the unmeasured policies do not significantly differ for strong countries relative to weak countries. However for field crop seeds, the intercept shift is generally negative and significant, indicating that unmeasured policies tend to create barriers to trade for strong countries relative to weak countries.

5. Conclusions and policy implications

This paper contributes to the growing body of literature on the effect that increasing intellectual property rights has on the flow of traded goods. The objective was to address two questions inspired by debates between developing and developed countries over TRIPs and trade in agricultural biotechnologies. The first question asked what was the implication of increasing global IPR protection on the direction and volume of trade in biotechnology related agricultural inputs? To answer this question, I extended previous work by Smith (2002) by examining two hypotheses about how strong foreign policies on IPRs affect the market power and market expansion of U.S. bilateral exports of biotechnology related agricultural inputs. The results provide some support for the market expansion hypothesis (A) for field crop seeds and significant support for the market power hypothesis (B) for both commodities. These effects tend to increase over time. Further, the finding of market power effects for both countries with strong and weak abilities to imitate technology suggest that U.S. exporters of chemicals behave monopolistically.

The second questions asked what policy components of an IPR system significantly affect the flows of these commodities? To answer this, I considered the impact of individual IPR policies on the direction of U.S. bilateral exports and the market power and market expansion effects. I find that the relationship between IPRs and trade is not very sensitive to a country's ability to imitate technology. The results provide an initial indication that the direction of U.S. bilateral exports is positively related to increases in sectoral patent coverage for strong countries and negatively related for weak countries. Further, U.S. exports are positively related to enforcement mechanisms and provisions for loss of protection and negatively related to increases in membership in international patent agreements and duration of protection regardless of imitative abilities.

Taken together, strengthening overall IPR protection results in a dominant market power effect, however when considering the individual policies, certain policies increase trade while others decrease it regardless of imitative abilities.

Several policy implications can be derived from these results since they address some major concerns that developing and developed countries have over specific articles of TRIPs. First, the finding that increasing overall IPRs across both weak and strong countries results in a market power effect for agricultural chemicals raise general monopoly power concerns among policy makers about global implications of IPR harmonization. Second, consider concerns over Article 27.1, requiring patents in all fields of technology. Generally, less developed countries oppose the patenting of biological inventions. The findings suggest that increasing sectoral coverage awards market power to U.S. firms exporting to weak countries (developing countries) and a market expansion effect to strong countries (developed countries), raising some doubt that increasing patent coverage through Article 27.1 will improve developing country access to biotechnology related agricultural inputs. Third, in the debate over plant breeders' rights or the protection of plant varieties, many developing countries worry about the effect that this might have on the custom of saving seeds for one's own future use. In this empirical analysis, a proxy for measuring the impact of strengthening plant breeders' rights at the expense of farmers' right to reuse seed was addressed through the policy variable for the membership to international patent agreements. Across both countries with weak and strong imitative abilities, increasing membership induces a market power effect on the exportation of all agricultural input commodities. This result stresses the need for policy makers to be aware of market access implications of increasing plant breeders' rights. Fourth, consider the debate over requiring that a patent be worked within a country or that compulsory licenses be allowed. The results of this paper suggest that increasing provisions for the loss of patent protection due to such measures results in a market expansion effect across countries with weak and strong imitative abilities. This implies that increasing provisions may be a way to increase access to agricultural inputs. Finally, consider the fact that the U.S. is focusing their attention on implementation and dispute settlement or enforcement mechanisms in current TRIPs discussions. The findings imply that enforcement mechanisms have a significant positive impact on U.S. exports, suggesting increasing enforcement of IPRs can improve market access to agricultural biotechnologies.

While the results of the impact of individual IPR policy components on the direction of U.S. trade in biotechnology related agricultural inputs should not be generalized to other industries, they should inspire further research on how the Articles of TRIPs are truly trade related. A better understanding how which components increase access to agricultural biotechnologies through trade and which inhibit access through awarding market power to exporters should assist policy makers construct a compromise in the TRIPs Agreement debate between developed and developing countries.

Table 1: Estimates of specifications (1), (2) and (3).

		Average Effects		Annual Effects		Deviation Effects	
		Field Seeds	Ag. Chemicals	Field Seeds	Ag. Chemicals	Field Seeds	Ag. Chemicals
Intercept		14.80 **	-4.87	9.39 **	15.33 **	13.19 **	-11.60 **
		(3.94)	(3.74)	(4.10)	(3.83)	(4.13)	(3.83)
Income/Cap.		2.19 **	2.00 **	2.67 **	2.77 **	2.29 **	2.46 **
		(0.24)	(0.30)	(0.26)	(0.30)	(0.26)	(0.30)
Population		1.57 **	2.02 **	1.64 **	2.29 **	1.61 **	2.22 **
		(0.17)	(0.18)	(0.17)	(0.17)	(0.17)	(0.18)
Distance		-4.62 **	-2.48 **	-4.47 **	-2.47 **	-4.65 **	-2.50 **
		(0.35)	(0.32)	(0.35)	(0.32)	(0.35)	(0.32)
Openness		0.01	1.42 **	-0.05	1.72 **	0.10 **	1.70 **
		(0.42)	(0.44)	(0.41)	(0.41)	(0.43)	(0.43)
w*IPRs		-0.72	-2.42 **			0.02	-0.61
		(0.84)	(0.77)			(0.90)	(0.87)
S*IPRs		1.78 **	-1.52 **			1.52 **	-0.47
		(0.60)	(0.50)			(0.66)	(0.55)
w*IPRs*t	1972			1.21			
				(1.06)			
	1977			1.51	2.10 **		
				(1.00)	(0.97)		
	1982			-0.89	-0.26		
				(1.02)	(1.01)		
	1987			-1.66 *	-1.86 *		
				(0.97)	(1.06)		
	1992			-2.56 **	-1.37		
				(0.99)	(0.99)		
	1997			-1.55	-3.58 **		
				(0.99)	(0.92)		
	2002			-0.12	-3.13 **		
				(1.05)	(0.85)		
s*IPRs*t	1972			2.88 **			
				(0.98)			
	1977			1.57	0.53		
				(0.98)	(0.77)		
	1982			1.41	-0.71		
				(0.95)	(0.66)		
	1987			-0.30	-1.45 **		
				(1.08)	(0.68)		
	1992			1.18	-2.78 **		
				(1.01)	(0.75)		
	1997			1.02	-3.05 **		
				(0.96)	(0.70)		
	2002			1.52 *	-3.59 **		
				(0.83)	(0.67)		
w*IPRs*t92-02						-1.02 *	-2.43 **
						(0.56)	(0.58)
s*IPRs*t92-02						0.17	-2.40 **
						(0.58)	(0.38)
s(fixed effect)		-2.67 **	-1.17	-2.88 **	-1.21	-2.45 **	-1.28
		(1.01)	(0.91)	(1.05)	(0.96)	(1.02)	(0.93)
R^2		0.48	0.44	0.50	0.50	0.48	0.47
Count		637	545	637	545	637S	545

Notes: ** Significant at the 5% level. * Significant at the 10% level. Heteroscedasticty corrected standard errors in the parentheses. Endogenous variable is U.S. Bilateral Exports to country k in industry i. Average effects data is pooled: Field Crop Seeds (1972, 1977, 1982, 1987, 1992, 1997, 2002) and Agricultural Chemicals (1997, 1982, 1987, 1992, 1997, 2002). w = dummy variable for countries with weak imitative abilities s = dummy variable for countries with strong imitative abilities. t = dummy variables for years. t92-02 = dummy variable for 1992, 1997, 2002.

Table 2: Estimates of specifications (4) and (5).

	Average Directional Effects		Average Effects	
	Field Seeds	Ag. Chemicals	Field Seeds	Ag. Chemicals
Intercept	19.04 **	0.06	20.09 **	1.94
	(4.48)	(3.69)	(4.57)	(4.05)
Income/Cap.	2.20 **	1.94 **	2.08 **	1.84 *
	(0.20)	(0.24)	(0.24)	(0.31)
Population	1.41 **	1.92 **	1.43 **	1.89 *
	(0.17)	(0.16)	(0.17)	(0.17)
Distance	-4.96 **	-2.72 **	-4.94 **	-2.84 *
	(0.38)	(0.32)	(0.37)	(0.32)
Openness	-0.29	1.03 **	-0.20	1.01 *
	(0.41)	(0.40)	(0.41)	(0.40)
COV	3.68 **	-0.73		
	(0.91)	(0.75)		
ENF	4.22 **	2.01 **		
	(0.87)	(0.74)		
LOP	-0.12	1.64 **		
	(0.61)	(0.64)		
MEM	-2.76 **	-3.32 **		
	(0.74)	(0.71)		
DUR	-2.63 **	-2.12 **		
	(0.90)	(0.85)		
w*COV			1.07	-2.39 *
			(1.10)	(1.15)
w*ENF			3.03 **	2.81 *
			(1.18)	(1.17)
w*LOP			1.52 *	2.27 *
			(0.80)	(0.90)
w*MEM			-2.11 **	-2.69 *
			(0.92)	(1.14)
w*DUR			-2.09 **	-1.36
			(0.98)	(1.05)
s*COV			8.17 **	3.71 *
			(1.82)	(0.86)
s*ENF			5.11 **	1.70 *
			(1.28)	(0.85)
s*LOP			-1.32	3.08 *
			(1.21)	(0.91)
s*MEM			-4.14 **	-4.92 *
			(1.33)	(0.83)
s*DUR			-0.77	-5.47 *
			(2.11)	(1.36)
s(fixed effect)			-3.79 **	1.58
			(1.52)	(1.32)
R^2	0.51	0.45	0.52	0.47
Count	661	565	661	565

Notes: ** Significant at the 5% level. * Significant at the 10% level. Heteroscedasticty corrected standard errors in the parentheses. Endogenous variable is U.S. Bilateral Exports to country k in industry i. Average effects data is pooled: Field Crop Seeds (1972, 1977, 1982, 1987, 1992, 1997, 2002) and Agricultural Chemicals (1997, 1982, 1987, 1992, 1997, 2002). w = dummy variable for countries with weak imitative abilities s = dummy variable for countries with strong imitative abilities.

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