Forthcoming in Land Economics

INTELLECTUAL PROPERTY RIGHTS, ENVIRONMENTAL REGULATIONS, AND FOREIGN DIRECT INVESTMENT

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October 16, 2003

* Corresponding author. We would like to thank Kasama and Wallapa Chupawa for valuable research assistance and Ira Gang, M. Scott Taylor, Per Fredriksson, two anonymous referees, and participants at the International Economics and Finance Society Session at the 2000 Southern Economic Association Meetings in Washington D.C. for helpful comments. We are indebted to Robert Deacon for providing the lead data. Qiu is grateful for financial support by Hong Kong Government RGC research grant (HKUST6412/00H).

ABSTRACT

Sustainable development has been a popular buzzword amongst policymakers and economists for over a decade. Although a key tenet of maintaining a sustainable development path for many economies rests on attracting mobile capital, theoretical and empirical evidence into the institutional policies that attract factors remains largely unresolved. This paper takes a positive look at the determinants of attracting capital with particular attention paid to intellectual property rights and environmental regulations.

JEL Classification: F23, O34, Q28

Key Words: Foreign direct investment, Intellectual property rights protection, Environmental policy

I. INTRODUCTION

Inducing economies to follow a sustainable development trajectory has been an important global policy objective since delegations from 178 countries met in Rio de Janeiro during the first two weeks of June 1992. The meeting, known popularly as the Earth Summit of 1992, was the culmination of more than two decades of debate concerning the relationship between economic development and the environment. Besides outlining important global objectives, the Earth Summit and subsequent international environmental negotiations served to crystallize one unequivocal notion–any policies that severely reduce the prospects for economic growth will be met with substantial opposition.[1] Clearly, an understanding of the interconnections of capital flows, technology transfer, and environmental regulations is necessary to pursue the nascent concept of sustainable development.

Although popular streams of thought suggest that economic development and a clean environment are incompatible social objectives, certain policies may induce "clean" growth. One such policy is for a country to attract multinational firms that can provide an influx of pollution abatement technology. In this case, foreign direct investment (FDI) not only contributes to economic development via the benefits from additional employment, larger tax base, etc., but also provides an avenue for future clean growth through technological spillovers. These latter benefits can originate from domestic firms forming backward or forward linkages with foreign firms or from imitating foreign technology.[2] Despite the important link between economic growth, the environment, and technology transfer, it is surprising that we know very little about their interrelationships.

Our paper attempts to lend insight into these relationships by developing a positive theory linking FDI, intellectual property rights (IPR), and environmental regulations.[3] The theory, which builds on Ethier and Markusen (1996), is based on partial equilibrium modeling of two countries in the familiar role of North/South. The model predicts that strengthening

IPR protection (or environmental standards) in the Southern country will attract FDI from the Northern country. The effects are predicted to be heterogeneous across industries, however. In particular, stronger IPR protection or higher environmental standards in the South encourages more FDI inflows from Northern industries that are more sensitive to intellectual property protection or have cleaner production technologies relative to those in the South.

We test these theoretical predictions using panel data on outbound U.S. FDI into several countries from 1982-1992. Our empirical analysis includes FDI flows in two manufacturing industries: food and kindred products and chemical and allied products. These industries were chosen because, among manufacturing industries, they represent relatively heavy (chemical and allied products) and light (food and kindred products) spenders on pollution abatement equipment; and, they have been found to be the most (chemical and allied products) and least (food and kindred products) influenced by IPR rules.

In support of the theory, we find statistical evidence of a direct relationship between IPR protection and FDI into developing countries. Also consistent with our theory, we find that the effect of more stringent environmental standards is quite heterogeneous across industries, as flows of capital in the chemical industry are much more affected by environmental standards compared to flows in the food and kindred products industry. One commonality across industries is that a U-shaped relationship exists between FDI and environmental policy leniency, suggesting that over certain ranges of our data *stricter* environmental standards are an important factor in *attracting* foreign investment from the U.S. While developed countries are currently on this decreasing portion of the U, developing countries are on the opposite part, suggesting that stricter environmental standards will reduce FDI.

The strategy of the remainder of our paper is as follows. Section II provides a brief survey of the literature. Section III develops a theoretical model that provides an explicit link between environmental policy, IPR protection, and FDI. We provide descriptions of our data and econometric model in Section IV. Empirical results are presented in Section V. Section VI concludes.

II. PREVIOUS WORK

Given that our economic system is rapidly evolving from many relatively small markets into an integrated global market, firms are more readily using foreign countries to source production, add product market lines, and diversify. And, since economic growth critically depends on attracting external investment, recognizing the correct basket of incentives to attract FDI is invaluable. In academia, most studies have found relatively intuitive results−demand (market size) and supply side (infrastructure and input costs) considerations are both important to the foreign investor. In regards to our main hypothesis, there is some evidence that outbound U.S. capital flows are insensitive to host countries' environmental regimes. For example, Leonard (1984, 1988) and Low and Yeats (1992) present evidence that suggest strict environmental regulations do not significantly alter patterns of U.S. FDI. There is also some evidence that implies IPR protection at the country level matters. For example, Lee and Mansfield (1996) find that U.S. direct investment abroad is negatively related to the perceived weakness of host countries' IPR regimes.

There is also a literature developing that examines the converse of these two issues. Previous studies addressing the patterns of FDI flows into the U.S. have typically found that the effects of environmental regulations and IPR protection vary across industries. For example, List (2001) finds that the effects of more stringent environmental regulations are quite heterogeneous across industries–prospective new plants in pollution intensive sectors (non-pollution intensive sectors) are weakly deterred (not deterred) by more stringent pollution regulation.[4] With respect to IPR policies, using a 1991 survey of 100 major U.S. firms, Mansfield (1994) reports that approximately 50-60% of the respondents (94 firms) considered IPR protection important in their decision to set up production facilities abroad. Mansfield (1994) also presents evidence that suggests IPR protection is most valued by firms in the chemicals industry, and least valued by firms in the food and transport industries. Mansfield (1994) reconciles these findings by appealing to the level of difficulty of imitation of products, which is relatively minimal in chemicals compared to foods and transports.

III. THE CONCEPTUAL FRAMEWORK

III.1. Model

The structure of the model is similar in spirit to Ethier and Markusen (1996) and so we let the reader refer to their paper for most of the justifications of the modeling assumptions. Eithier and Markusen (1996) construct a two-period model to analyze how the firm in the source country with a new product decides its international expansion strategy: export, license, or FDI. They assume the complete absence of IPR protection in the host country. In contrast to their model, we introduce pollution to production, we include IPR protection and environmental policies, and we exclude licensing from the firm's strategy space. With regard to methodology, similar to the first part of Ethier and Markusen (1996), we focus on analyzing a firm's optimal international expansion strategy under a given policy and economic environment, but unlike the second part of their paper, we do not analyze the general equilibrium (e.g., the determination of wage rate) since our interest is on the effects of policies on the firm's optimal decision.

Assume there are two countries, A and B (North and South), which are different along several dimensions. Most importantly, innovation of new products only occurs in A. This result could hold due to inferior institutional structure in B, or any myriad of reasons. In the current period there is a firm in country A (firm A) that has a new product to produce and sell to the market in country B. The product remains modern or "new" for two periods and becomes "aged" thereafter. We refer to the current period as period one.

In period one, the representative consumer in country B derives utility from the consumption of this new product and other products as given by

$$u = Y - \frac{Y^2}{2} + \sum_{n=1}^{\infty} \nu^{-n} Y_n - \frac{\beta D^\gamma}{\gamma}$$

where $\nu>1$ is the value placed on *newness*,[5] Y is consumption of that product which is new, Y_n is consumption of the other good that was new n periods ago, D represents total pollution generated by production located in country B, and β and γ are (positive) constants. This type of disutility of pollution is similar to the construct in Copeland and Taylor (1995). The disutility justifies B's environmental regulation, but is not crucial in the present study because optimal environmental policy is of little concern here. Utility in period two takes the same form as above.

There is full IPR protection in A so that there is no imitation in A. The IPR protection in B is imperfect, however. If firm A chooses FDI into country B in period 1 (i.e., produce the new product in country B), the probability that this product will be imitated in period 2 by firms in B equals $(1-\alpha) \in [0, 1]$. In the case of full IPR protection, $\alpha=1$, whereas no IPR protection implies $\alpha=0$. For partial IPR protection, $0 < \alpha < 1$. Thus, α captures the degree of B's IPR protection. In contrast, if firm A chooses to serve country B's market through exportation, there is no possibility for B's firms to imitate. This assumption closely follows Ethier and Markusen (1996), but is not crucial to the results of this section provided the probability of being imitated via exporting is dominated by the probability of being imitated with FDI.[6] After the second period, any IPR protection regarding the product expires, the product becomes old, and knowledge about its production is symmetric across space.[7]

We now turn to describing the technology. One unit of labor is necessary for production of one unit of the product. Due to a lack of technical knowledge, however, if imitation occurs, imitators in country B use a technology that generates more pollution per unit of output than firm A. Consequently, if the pollution standard in country B, denoted by *s*, is binding, imitators in country B pay additional abatement cost equal to $c\tau(s)$ units of B's labor for each unit of output, where $c \in [0, 1]$. To meet the same standard, firm A's subsidiary pays additional abatement cost equal to $ec\tau(s)$, where $e \in [0, 1]$, in terms of B's labor. Let s_0 be the standard that the imitator's technology has already achieved without abatement. Then, $\tau(s)=0$ for all $s \leq s_0$, and $\tau(s)>0$ for all $s > s_0$, and $\tau'(s)>0$ for all $s > s_0$. Note that with the above specification, a smaller *c* indicates cleaner technology because abatement is necessary to achieve the same environmental standard; and a smaller *e* indicates that firm A has superior abatement technology relative to firms in country B. If firm A exports its product to B's market, its production is subject to the environmental standard in country A, denoted by s_A. Hence, its additional cost, in terms of A's labor, is $ec\tau(s_A)$.[8]

The imitators' technology also differs from firm A's in another important respect. The imitators incur an extra cost, measured by *g* units of B's labor, in each unit of production. The extra cost is a non-decreasing monotonic function in the level of technology embedded in the imitated product and serves to capture part of the technology gap between the two countries.

In addition to production cost, the additional constant transfer cost associated with exportation is *t* per unit, in terms of A's labor. This cost can be considered transportation cost or the specific import tariff. Firm A incurs a fixed setup cost, *k*, if it chooses FDI. To focus our analysis, we confine firm A's international strategies to include only exporting and FDI. The wage rate of country A is normalized to one and that of country B is given as $w < 1$.

A glossary of policies: α is the IPR protection in country B, *s* is the environmental standard in country B, s_A is the environmental standard in country A, and *t* can be considered country B's tariff. A glossary of cost parameters: *w* is the wage rate in country B, $c\tau(s)$ is the abatement cost to the imitators with *c* capturing the cleanness of the technology, *e* captures firm A's advantage over the imitators, *g* is the extra marginal cost of production by the imitators, and *k* is an FDI setup cost.

III.2. Analysis: Optimal International Strategy

In this subsection, we analyze firm A's optimal international strategy. In the following subsection we explore the effects of changes in IPR and environmental standards on FDI flows.

By imposing a budget constraint on each period's consumption: $I \geq pY + \sum_{n=1}^{\infty} wY_n$, where *I* is the period's income spent on products, we obtain the following demand structure:

$$Y = 1 - \frac{p}{vw}, \qquad Y_1 = \frac{I}{w} - \frac{p}{w} + \frac{1}{v}\left(\frac{p}{w}\right)^2, \qquad Y_s = 0 \quad \text{for } n > 1.$$

If L_B is the total population of country B, then the total demand for firm A's product in each of the first two periods is

$$y = L_B Y \quad \text{or} \quad p = wv - wby \quad \text{where} \quad b \equiv \frac{v}{L_B}.$$

When the product becomes "old" after the second period, assume B's firms have exactly the same technology as firm A; hence there is a perfectly competitive market for this product. We can simply assume that firm A withdraws from the market, or it exists with zero economic profit. This allows us to focus on analyzing periods one and two.

Note that in deriving demand functions, we assume that individual consumers dislike pollution, but are unable to affect total demand hence they ignore the disutility of pollution when deriving their demand. The main conclusions of our theoretic model are not disturbed if this assumption does not hold, but the analysis becomes quite tedious.

To emphasize the value of the newness of a product, we assume that v is sufficiently large in the following sense.

Assumption 1: $v > 1 + 2c\tau(s) + 2g$.

If firm A chooses FDI, its marginal cost (in terms of B's labor) equals $w+ec\tau(s)w$. If firm A's product has not been imitated, it is a monopolist and thus its single-period's output, price, and profit (not accounting for k) are (superscript f denotes FDI),

$$y^f = \frac{v-1-ec\tau(s)}{2b}, \quad p^f = \frac{(v+1+ec\tau(s))w}{2}, \quad \text{and} \quad M^f = \frac{(v-1-ec\tau(s))^2 w}{4b}.$$

Alternatively, if the product is imitated, firm A faces competition from the imitators. In this case, we assume that firm A uses limit pricing to deter entry,[9] and if the firm still chooses FDI, its single-period price and profit (not accounting for k) are (superscript i denotes imitation),

$$p^i = (1+c\tau(s)+g)w \quad \text{and} \quad M^i = \frac{w[g+(1-e)c\tau(s)]\big(v-1-g-c\tau(s)\big)}{b}.$$

Assumption 1 ensures that $p^f > p^i$ and $M^f > M^i$.

If firm A exports its product to country B, its marginal cost (including tariff or transportation cost and pollution tax) equals $1+t+ec\tau(s_A)$. If firm A faces no competition (i.e., when the product has not been imitated), its single-period's output, price, and profit are (superscript x denotes export),

$$y^x = \frac{v-m}{2b}, \quad p^x = \frac{(v+m)w}{2}, \quad \text{and} \quad M^x = \frac{(v-m)^2 w}{4b}, \quad \text{where} \quad m \equiv \frac{1+t+ec\tau(s_A)}{w}.$$

If, however, its product is imitated, firm A uses limit pricing and earns a profit denoted by M^{xi}.

We now describe various international strategies that may be taken by firm A when entering B's market. An international strategy specifies optimal actions for firm A in periods 1 and 2. We use Π^{j} to denote the (non-discounted) sum of profits when strategy *j* is adopted. Hence, we have

Strategy I: (Export, Export), with profit $\Pi^{I} = 2M^{x}$,

Strategy II: (Export, FDI), with profit $\Pi^{II} = M^{x} + M^{f} - k$,

Strategy III: (FDI, FDI), with profit $\Pi^{III} = (1+\alpha)M^{f} + (1-\alpha)M^{i} - k$,

Strategy IV: (FDI, Export), with profit $\Pi^{IV} = M^{f} + \alpha M^{x} + (1-\alpha)M^{xi} - k$,

where element *i* in brackets denotes firm A's strategy in the *i*th period. Our goal is to derive firm A's optimal strategy under several distinct scenarios.[10]

Before deriving the optimal international strategy, we first obtain the properties of various single-period profits. First,

$$M^{x} \text{ is independent of } \alpha \text{ and } s. \qquad [1]$$

This follows because pollution is a direct by-product of production, not consumption. Production technology (pollution generating) of goods cannot be used to exclude or limit exports.

Second, monopoly profit induces the following relationships

$$\frac{\partial M^{f}}{\partial \alpha} = 0, \quad \frac{\partial M^{f}}{\partial s} < 0, \quad \frac{\partial^{2} M^{f}}{\partial s^{2}} > 0. \qquad [2]$$

Third, imitation, and therefore limit pricing, leads to

$$\frac{\partial M^{i}}{\partial \alpha} = 0, \quad \frac{\partial^{2} M^{i}}{\partial s^{2}} < 0, \qquad [3]$$

and

$$\frac{\partial M^{i}}{\partial s} < 0 \quad \text{for} \quad e > \frac{v - 1 - 2c\tau(s) - 2g}{v - 1 - 2c\tau(s) - g}, \qquad [4]$$

$$\frac{\partial M^{i}}{\partial s} > 0 \quad \text{for} \quad e < \frac{v-1-2c\tau(s)-2g}{v-1-2c\tau(s)-g}. \qquad [5]$$

This last effect (given in equations [4] and [5]) is interesting and worthy of brief mention. While raising the environmental standard in country B unequivocally reduces firm A's FDI profit levels, *ceteris paribus*, as e approaches 1, the extra cost imposed on firm A is much smaller than that on its competitors, affording firm A a relative advantage over imitators in country B. Consequently, firm A "benefits" from an increase in s. In our North-South model, it is realistic to assume a small e value and therefore equation [5] prevails. Accordingly we impose

$$\textit{Assumption } 2: \qquad e < \frac{v-1-2c\tau(s)-2g}{v-1-2c\tau(s)-g}.$$

In analysing the optimal strategy, we first observe that strategy IV is universally weakly dominated and therefore never optimal. Note that in the extreme case with full IPR protection in country B, firm A will achieve the same profit level under strategy IV and strategy II. Yet less than full IPR protection yields strategy II strictly dominating strategy IV since there is a probability that the imitators will compete against the imported good in period 2, reducing firm A's period 2 profits. Our second observation is that the case of extremely large or extremely small k is uninteresting. Note that if k is extremely large (small), then strategy I always dominates (is dominated by) strategies II and III, independent of s and α.

We therefore focus the remaining discussion on the first three strategies. Based on [1]-[5], we obtain the impacts of policy changes on the total profits associated with each strategy:

$$\frac{\partial \Pi^{I}}{\partial s} = 0, \qquad \frac{\partial \Pi^{I}}{\partial \alpha} = 0, \qquad \frac{\partial \Pi^{II}}{\partial s} = \frac{\partial M^{f}}{\partial s} < 0, \qquad \frac{\partial \Pi^{II}}{\partial \alpha} = \frac{\partial M^{f}}{\partial \alpha} = 0, \qquad [6]$$

$$\frac{\partial \Pi^{III}}{\partial \alpha} = M^{f} - M^{i} > 0, \qquad [7]$$

$$\frac{\partial \Pi^{III}}{\partial s} = \frac{wc\tau'(s)}{2b}\{2(1-\alpha)[(1-e)(v-1-2c\tau(s))-(2-e)g]-(1+\alpha)e(v-1-ec\tau(s))\}. \qquad [8]$$

Note that the sign of equation [8] is positive for small α and negative for large α. To capture the feature of weak IPR protection in the South, we confine our analysis to the small α case. Hence, $\partial\Pi^{III}/\partial s > 0$.

We first compare strategies I and II. Under these two scenarios, since α does not affect M^f and M^x, it fails to influence the comparison of these two strategies. Focusing on environmental policy, we find that $m>1$ since $t+ec\tau(s_A)>0$ and $w<1$. Thus, when $s = s_0$, $M^f > M^x$. And, as s becomes sufficiently large (given $e \neq 1$), $M^f < M^x$. Using equation [6], we present Figure 1, which shows that a unique cut-off point exists, s^{II}, such that for s below this point, $\Pi^{II} > \Pi^{I}$ and for s above this point, $\Pi^{II} < \Pi^{I}$. Thus, we establish the following result.

Lemma 1. (i). $\partial(\Pi^{II}-\Pi^{I})/\partial\alpha=0$: *IPR policy does not affect the comparison between strategies I and II.*

(ii). $\partial(\Pi^{II}-\Pi^{I})/\partial s < 0$. *Moreover, for any given e, there exists* $s^{II} \in (0, 1)$ *such that strategy II (I) dominates strategy I (II) for s smaller (larger) than this cut-off point.*

Lemma 1(i) holds because imitation is not an issue under strategies I and II. The intuition for Lemma 1(ii) is straightforward. The extra cost associated with exporting is transportation cost, which is independent of s; but, the extra cost associated with FDI is pollution abatement expenditures, which decrease as s decreases. Thus, strategy II benefits from these changes while strategy I remains stable.

Figure 1 near here

Moving to a comparison of strategies II and III, we see that now IPR policy matters because imitation is an important issue. In what follows, we examine the effects of IPR policy (in Figure 2) and environmental policy (in Figure 3). Concerning the effects of IPR policy, we see that strategy II is preferred to strategy III because the product cannot be imitated in the second period under the former strategy. If exporting is costlier than FDI, and especially if $M^i > M^x$, there is a distinct disadvantage associated with strategy II, however. This trade-off suggests that the comparison depends on the IPR policy and other parameter values such as *g, c* and *e*.[11] Using equations [6] and [7], we have

$$\frac{\partial(M^{III} - M^{II})}{\partial \alpha} > 0,$$

and realizing that $M^i < M^f$, we provide Figure 2. However, note that if $M^i > M^f$, then $\Pi^{III} > \Pi^{II}$ at any α, hence $\alpha^{III}=0$ is possible.

Figure 2 near here

Turning to the effects of environmental policy, based on equations [6] and [8], we have

$$\frac{\partial(M^{III} - M^{II})}{\partial s} = \frac{\partial M^{III}}{\partial s} - \frac{\partial M^{II}}{\partial s} > 0,$$

which provides Figure 3. When $s = s_0$, $(\Pi^{III} - \Pi^{II})$ is positive iff α is not too small. Thus, either strategy III dominates strategy II, or there exists a cut-off point, $s^{III}(\alpha)$, such that strategy III dominates strategy II iff *s* exceeds the cut-off. The intuition is as follows: an increase in *s* lowers firm A's profit from FDI in the absence of imitation, but raises firm A's profit in the presence of imitation (equation [5]). The profit loss occurs in both strategies II and III, but the profit gain arises only in strategy III. That is, strengthening environmental policy helps firm A only when firm A is competing against imitators, i.e., in period 2 and when using strategy III. The above analysis leads to the following lemma.

Lemma 2. (i). $\partial(\Pi^{III}-\Pi^{II})/\partial\alpha > 0$. *Moreover, there exists* $\alpha^{III}(s) \in [0, 1)$ *such that strategy III (II) dominates strategy II (III) for* α *larger (smaller) than this cut-off point.*

(ii). $\partial(\Pi^{III}-\Pi^{II})/\partial s > 0$. *Given* α*, there exists* $s^{III}(\alpha) \in (0, 1)$ *such that strategy III (II) dominates strategy II (III) for s values larger (smaller) than the cut-off point.*

Figure 3 near here

Finally, we compare strategies I and III. The effect of increasing IPR protection on the profit difference ($\Pi^{III}-\Pi^{I}$) can be obtained directly from Lemmas 1 and 2. As for the effect of changing the environmental policy, we combine Figures 1 and 3 by dropping the profit curve associated with Strategy II (i.e., Π^{II}). Since Π^{I} is flat, but Π^{III} increases in *s*, the same qualitative result from comparing Strategy III and Strategy II directly applies to comparing Strategy III and Strategy I. We therefore establish the following lemma.

Lemma 3. $\partial(\Pi^{III}-\Pi^{I})/\partial\alpha > 0$ *and* $\partial(\Pi^{III}-\Pi^{I})/\partial s > 0$. *Moreover, given s ($\alpha$), there exists* α^* *(s^*), such that strategy III dominates strategy I for α (s) larger than the cut-off point, and strategy I dominates strategy III for α (s) smaller than the cut-off point.*

III.3. Analysis: Policy Changes and FDI Flows

Lemmas 1-3 compare firm A's international strategies and characterize policy conditions for a strategy to be dominant. To investigate how country B's policy changes affect FDI inflows, we extend the preceding single-industry model to a multi-industry variant, with one firm in each industry. Consider a continuum of industries (firms) that are different in *e, g, c* or any other aspects. Facing common policies *s* and α in country B, like firm A in the single-industry model, a firm in each industry chooses one of the four international strategies. For any given *s* and α, by Lemmas 1-3, each firm will have its optimal strategy. This serves as the base case. If a change in policy results in some firms (industries) switching their strategies from I to II, or from II to III, or from I to III, then FDI rises. An opposite change reduces FDI flows. This is the comparative static analysis to be taken below.

We now turn to an examination of the FDI effects of each policy change.

IPR protection. Let us derive a typical firm's optimal strategy. Suppose $\Pi^{I}<\Pi^{II}$, then we need only to focus on Figure 2. If $\Pi^{II}<\Pi^{III}$ for all $\alpha\in[0, 1]$, then this firm's optimal strategy is III and a change in IPR protection will not alter its optimal choice. If $\Pi^{II}>\Pi^{III}$ for small α, then whether a small increase in α by ε (>0) will alter this firm's optimal choice depends on the current policy level. For $\alpha \in (\alpha^{III}-\varepsilon, \alpha^{III})$, then an increase in α by ε will change the firm's optimal strategy from II to III. For $\alpha \notin (\alpha^{III}-\varepsilon, \alpha^{III})$, an increase in α by ε will not alter the firm's optimal strategy. Note that different firms will have different cut-off points α^{III}. Hence, given any α, for a continuum of industries, there will always exist a nonzero number of firms having the following features: (i) they have α^{III} such that $(\alpha^{III}-\varepsilon, \alpha^{III})$ contains α, which also implies that their base cases are Π^{II}; and (ii) an increase in α always results in their switching from II to III. Therefore, FDI rises.

Suppose $\Pi^{I}>\Pi^{II}$ for a typical firm, then we simply need to replace Π^{II} by Π^{I} in Figure 2. The same analysis conducted above applies, and the same α-FDI relationship result holds. In sum, we have established the following proposition.

Proposition 1. *As country B strengthens its IPR protection, direct investment flow into country B will rise.*

The above proposition is derived from a model with endogenous international strategies (i.e., export and FDI, and IPR and environmental regulations) and is consistent with Helpman (1993), who finds that stronger IPR protection in the South promotes inward FDI from the North.[12] It is, however, interesting to note that the negative effect of host country's IPR on inward FDI can exist because of resource competition between imitation and FDI production in the host country. Glass and Saggi (2002) find that stronger IPR protection in the South may in fact reduce FDI inflows.

We now examine how the effects of increasing IPR protection on FDI flows differ across industries. Our comparative static analysis will focus on two industry characteristics: the ease by which technology embedded in products produced by the industry can be copied and the industry's pollution intensity. We derive the following result.

Proposition 2. (i). *The positive effects of increasing the South's IPR protection on FDI inflows are weaker in industries whose technologies are harder to imitate.* (ii). *The positive effects of increasing the South's IPR protection on FDI inflows are stronger in industries with cleaner technologies.*

Proof. (i). Based on equation [6], we see that

$$\frac{\partial^2(\Pi^{II}-\Pi^{I})}{\partial\alpha\partial g}=0.$$

Based on equations [6] and [7], we have

$$\frac{\partial^2(\Pi^{III}-\Pi^{I})}{\partial\alpha\partial g}=\frac{\partial^2(\Pi^{III}-\Pi^{II})}{\partial\alpha\partial g}=\frac{\partial(M^f-M^i)}{\partial g}=-\frac{\partial M^i}{\partial g}=-\frac{w}{b}[v-1-(2-e)c\tau(s)-2g]<0,$$

by Assumption 1. When we apply the above inequality to the continuum-industry model, we find that with larger g, there are fewer industries with their intervals $(\alpha^{III}-\varepsilon, \alpha^{III})$ containing α, which, together with the analysis preceding Proposition 1, proves the result.

(ii). As indicated in Lemma 1(i), we only need to examine the effect of IPR changes on the choice between strategies I and III and between II and III. By equations [6] and [7], with some tedious calculation we have

$$\frac{\partial^2(\Pi^{III}-\Pi^{I})}{\partial\alpha\partial c}=\frac{\partial^2(\Pi^{III}-\Pi^{II})}{\partial\alpha\partial c}=\frac{\partial M^f}{\partial c}-\frac{\partial M^i}{\partial c}=-\frac{w(2-e)\tau}{2b}[v-1-(2-e)c\tau-2g]<0.$$

When we apply the above inequality to the continuum-industry model, we find that with smaller c there are more industries with their intervals $(\alpha^{III}-\varepsilon, \alpha^{III})$ containing α, which, together with the analysis preceding Proposition 1, proves the result. *Q.E.D.*

The intuition is that the key barrier to FDI is imitation. When g is larger, it is more difficult to imitate and so the role of increasing IPR protection to discourage imitation (encourage FDI) is smaller. For result (ii), in industries with cleaner production technology, the disadvantage of the Southern imitators relative to firm A becomes smaller. The imitators become more competitive and therefore threaten FDI. Hence, the role of increasing IPR protection to discourage imitation becomes larger.

Environmental standard. To derive a typical firm's optimal strategy, we present Figure 4, which is obtained directly from Figures 1 and 3. Given α, if $s \in (s^{II} - \varepsilon, s^{II})$, then an increase in *s* by ε will induce the firm to switch from strategy II to I; if $s \in (s^* - \varepsilon, s^*)$, then an increase in *s* by ε will induce the firm to switch from strategy I to III; if *s* is not in either of these two intervals, then an increase in *s* does not alter the firm's optimal strategy.

Figure 4 near here

Different firms have different cut-off points, s^{II} and s^*. Given a small *s*, for a continuum of industries, there are always some firms having the following features: (i) they have s^{III} such that $(s^{II} - \varepsilon, s^{II})$ contains s, which also implies that their base cases are Π^{II}; and (ii) an increase in *s* always results in some firms switching their optimal strategies from II to I. Hence, FDI inflows into country B decrease. If, alternatively, the given *s* is large, then for a continuum of industries there are always some firms having the following features: (i) they have s^* such that $(s^* - \varepsilon, s^*)$ contains s, which also implies that their base cases are Π^{I}; and (ii) an increase in *s* results in some firms switching their optimal strategies from I to II. Hence, FDI inflows into country B increase. This analysis establishes the following proposition.

Proposition 3. *The relationship between FDI inflow and the host country's environmental standard exhibits a U-shape. Specifically, when country B's current environmental standard is low (high), FDI inflows in country B will decrease (increase) as country B raises its standard.*

We now examine how the effects of increasing environmental stringency on FDI flows differ across industries. Focusing on the case in which country B does not currently have a strong IPR protection regime or environmental standard, we obtain the following result:

Proposition 4. (i). *The positive effects of increasing the South's environmental standard on FDI inflows are weaker in industries whose technologies are harder to imitate.* (ii). *The effects of increasing the South's environmental standard on FDI inflows are weaker in industries with cleaner technologies.*

Proof. (i). First, by equation [6], we have

$$\frac{\partial^2(\Pi^{II}-\Pi^{I})}{\partial s\partial g}=\frac{\partial^2 M^f}{\partial s\partial g}=0.$$

Second, by equations [6] and [8], we have

$$\frac{\partial^2(\Pi^{III}-\Pi^{I})}{\partial s\partial g}=\frac{\partial^2\Pi^{III}}{\partial s\partial g}=-\frac{wc\tau'(s)}{b}(2-e)(1-\alpha)<0.$$

When we apply the above inequality to the continuum-industry model, we find that with larger g, there are fewer industries with their intervals (s^*–ε, s^*) containing s, which, together with the analysis preceding Proposition 2, proves the result. Lastly, by equations [6] and [8], we have

$$\frac{\partial^2(\Pi^{III}-\Pi^{II})}{\partial s\partial g}=\frac{\partial^2\Pi^{III}}{\partial s\partial g}<0 \qquad \text{because} \quad \frac{\partial^2\Pi^{II}}{\partial s\partial g}=\frac{\partial}{\partial g}\left(\frac{\partial M^x}{\partial s}+\frac{\partial M^i}{\partial s}\right)=0.$$

When we apply the above inequality to the continuum-industry model, we see that with larger g, there are fewer industries with their intervals (s^{III}–ε, s^{III}) containing s, which, together with the analysis preceding Proposition 2, proves the result.

(ii). Note

$$\frac{\partial^2(\Pi^{II}-\Pi^{I})}{\partial s\partial c}=\frac{\partial^2 M^f}{\partial s\partial c}=-\frac{ew\tau'(s)}{2b}(v-1-2ec\tau)<0.$$

Moreover,

$$\frac{\partial^2(\Pi^{III}-\Pi^{II})}{\partial s\partial c}=-\frac{w\tau'(s)}{2b}\Phi \quad \text{and}$$

$$\frac{\partial^2(\Pi^{III}-\Pi^{I})}{\partial s\partial c}=\frac{\partial^2\Pi^{III}}{\partial s\partial c}=\frac{w\tau'(s)}{2b}[\Phi+(1+2\alpha)(v-1)+2e^2c\tau],$$

where $\Phi \equiv [2(1-\alpha)(1-e)-e\alpha](v-1)-2[4(1-\alpha)(1-e)-e^2\alpha]c\tau-2(1-\alpha)(2-e)g$. Given that *e* is not too large under Assumption 2 and (*v*−1) is large relative to $c\tau$ and *g* under Assumption 1, we have $\partial\Phi/\partial\alpha < 0$. Hence, there exists a critical level of α such that Φ>0 for α smaller than the critical level and Φ<0 for α larger than the critical level. Furthermore, there exists another (larger) critical level of α such that $\partial^2(\Pi^{III}-\Pi^{I})/\partial s \partial c > 0$ for α smaller than the critical level, and vice versa. Applying the above results to the continuum-industry model, we obtain that (a) for small α, the effect of increasing *s* on FDI inflows is weaker in industries with smaller *c*, and (b) for large α, the effect is weaker when *s* is small, but the effect is stronger when *s* is large. Hence, the effects of increasing the South's environmental standard on FDI inflows are weaker in industries with cleaner technologies, except in the case when the standard is already high and the IPR protection is already strong, which has been excluded because B is a developing country. *Q.E.D.*

The intuition is similar to that behind Proposition 2 so we do not repeat it here.

In summary, our propositions lead to the following testable hypotheses: i) keeping host country environmental standard constant, an increase in its IPR protection level is expected to induce greater FDI inflow; ii) keeping host country IPR protection regime constant, the effect of a change in its environmental standard depends on whether the existing standard is low or high. When the existing standard is low (high), an increase in the standard is expected to deter (increase) FDI inflow; and, iii) the magnitude of the effects in i) and ii) is expected to vary with the ease by which an industry's technology can be imitated and with the cleanliness of the industry's technology.

IV. EMPIRICAL METHODOLOGY AND DATA

To test the predictions of our theoretical model, we use annual panel data on U.S. direct investment into several countries from 1982-1992. These data are (net) capital transactions between U.S. parents and their foreign affiliates. They include equity investments made by U.S. parents in their affiliates or loans between U.S. parents and their affiliates.[13] We should note that since these figures capture investment decisions rather than decisions to transfer advanced technology, the question that we ask is limited to how the nature of capital investment flows in different industries is related to the strength of a country's overall environmental standards and IPR protection levels. More importantly, we focus our empirical analysis on regimes II and III—we take as given firms' decisions to engage in FDI and examine factors that induce greater flows of FDI. Assuming the relationship between FDI and exports is temporally invariant (they are and remain substitutes as our theory assumes), our goal is to estimate the sensitivity of FDI flows within industries of varying pollution and knowledge intensities. Our general empirical analysis proceeds by examining our FDI data and when flows into countries differ we analyze whether intellectual property rights and/or environmental standards might be responsible for the differences.

We investigate this relationship using U.S. FDI into developed and developing countries in two manufacturing industries: food and kindred products and chemical and allied products. These two industries were chosen because they have been found to differ in terms of their pollution intensities (chemical and allied products represent relatively heavy spenders on pollution abatement while food and kindred products represent light spenders) and sensitivity to intellectual property protection (chemical and allied products is most influenced by IPR rules while food and kindred products is influenced least by IPR rules).[14] One problem in estimating the model using the available panel data is the incompleteness of data–in both industries some data points are suppressed due to nondisclosure rules.[15] Since (regressand) data are missing mostly for countries where flows of FDI are small, incidental truncation or non-randomly missing data is an issue that must be addressed to avoid biased and inconsistent parameter estimates.

This situation is handled by applying Heckman's (1979) two-step selection model, which treats truncation as an omitted variable problem. In the first step, the probit model in the following equation is estimated for each industry type to explain whether FDI rates are observed:

$$Y_{i,t} = \beta_0 + \beta_1 X_{i,t}, \quad [9]$$

where $Y_{i,t}$ is equal to 1 if the FDI rate is observed for country i in time period t and 0 otherwise; $X_{i,t}$ is real per capita GDP in country i in time period t. We chose real per capita GDP as the sole regressor in our first-stage regression because relatively richer countries have been found to attract larger flows of FDI than poorer countries (see, e.g., Lipsey 1999). This first step is equivalent to estimation of an eleven period binomial probit panel data model (balanced) for fifty-three countries, yielding a total sample size of 583 in each industry regression. From estimation of equation [9], we compute the Inverse Mills Ratio (IMR) for each observation as

$$IMR_{i,t} = \frac{\pi_{i,t}}{(1 - \theta_{i,t})}, \quad [10]$$

where $\pi_{i,t}$ is the standard normal probability density of the $\beta'X$ vector from the first-stage estimation, and $\theta_{i,t} = \text{Prob}(Y_{i,t} = 1)$. Including the IMR as an independent variable in the second-stage panel data model mitigates the possibility of omitted variable bias.

The second-step of the Heckman approach estimates the impact of the regressor vector on the observed rate of FDI inflows using

$$\text{FDI}_{i,t} = \alpha_i + \beta_1 Z_{i,t} + \varphi_t + \beta_2 \text{IMR}_{i,t} + \varepsilon_{i,t}, \quad [11]$$

where $FDI_{i,t}$ is the rate of U.S. FDI flows into country i in period t, $Z_{i,t}$ is the independent variable vector, which includes a measure of intellectual property rights protection, an indicator of the stringency of environmental regulations, and various measures for economic activity that serve as control variables.[16] α_i is a fixed country effect, φ_t is a fixed time effect, and $\varepsilon_{i,t}$ is the contemporaneous error term. Equation [11] is estimated separately for both industries.

A few features of equation [11] warrant further discussion. First, the data used to estimate equation [11] do not form a balanced panel for either of the industries analysed. Therefore, unbalanced panel data techniques are used. Second, we include country- and time-specific effects as parametric shifts in the regression equation to control for unobserved heterogeneity. This approach has the distinct advantage of controlling for heterogeneity that would remain uncontrolled if least squares was applied to the pooled data. Examples of unmeasured, time-invariant country effects (α_i) include the level of development, geographic location, worker ethic, customs and traditions, and any other observable/unobservable factors that are static, or have minimally changed over the time period 1982-1992. Inclusion of country effects places great demands on the data as any between-country variation is captured by the country specific effects, leaving only within-country variation to be explained. A further constraint placed on the data is inclusion of country-invariant time effects (φ_t). Time effects might arise from changes in technology, overall currency trends, global macroeconomic factors, and other factors that are constant across countries but dynamic in nature. In essence, time effects capture the possibly non-monotonic effects of unidentified variables that are across country invariant but change over time.

Third, regressors included in $Z_{i,t}$ follow past studies and represent dynamic factors that attract FDI, including environmental standards, intellectual property rights and other control variables. Our measure to capture country-level environmental stringency is an index for the allowable lead content per gallon of gasoline. Data on total gasoline consumption are from OECD's energy statistics and data on lead content are from Octel's *Worldwide Survey of Motor Gasoline Quality*. This measure has been used previously (e.g, Deacon 1999; Damania, List, and Fredrikkson 2003), and to our knowledge represents the best available dynamic proxy that measures environmental stringency at the country level. As our model predicts a U-shape relationship between environmental stringency and FDI flow, we include the square of lead content per gallon of gasoline as a regressor as well.[17] For our purposes, the data are available annually from 1982-1992.

We capture the level of IPR protection using the index found in Ginarte and Park (1997).[18] The index ranges from zero to five with higher values indicating stronger protection. The index is compiled by summing scores of questions in five categories: types of inventions that can be patented, length of coverage, provisions for loses, memberships in major patent agreements, and existence of adequate mechanisms for enforcement. Multiple questions comprise each category. For example, in the category pertaining to the types of inventions that can be patented, items covered are pharmaceuticals, chemicals, food, plant and animal varieties, surgical products, microorganisms, and utility models. If a country covers five of the seven items in this category, then the score for this category is 5/7. These data are available quinquennially from 1960-1990.[19]

Besides these main variables, we also include three other regressors $Z_{i,t}$: growth in real GDP, real GDP per capita, and market size.[20] Growth in real GDP is used as a proxy for expected demand growth. Following Lipsey (1999, 7), real GDP per capita is included to "…reflect an orientation of U.S.-based firms towards goods and services typically purchased by higher income consumers…" Market size is calculated as the country's real GDP multiplied by a relative price index, and controls for the overall purchasing power of the host country. We provide a more complete description of all variables in the Data Appendix, while Table 1 contains the descriptive statistics for each variable.

Table 1 near here

V. EMPIRICAL RESULTS

Table 2 presents the empirical results from the second-stage estimation of equation [11].[21] A first consideration is whether data on U.S. FDI flows into developed and developing countries can be pooled.[22] A likelihood ratio test suggests that in each industry the homogeneity null should be rejected at the $p < 0.01$ level (foods: χ^2(6 d.f.) = 124; chemicals: χ^2(6 d.f.) = 170), and therefore we separately estimate the FDI model for developed and developing countries for both industries. A second consideration is whether country- and time-specific effects are necessary. F-tests indicate that jointly the homogeneity null is rejected at the $p < 0.05$ level for all model types except the developed countries model for the food and kindred products industry (see Table 2). Although F-tests do not indicate that the fixed effects are significantly different from zero at conventional levels in the food and kindred products developed countries model, we include the parametric shifters in this particular specification to control for the above mentioned influences. Exclusion of the fixed effects does not significantly change our major results.

Table 2 near here

Interestingly, coefficient estimates of the patent index for both industries for the developed country group are statistically insignificant at conventional levels (columns 1 and 3). This result has one intuitive explanation–the patent indices of the developed group are fairly close to that of the U.S., hence, this variable is not a major determinant of U.S. FDI abroad.

The level of patent protection, however, is important in the developing countries regression model (columns 2 and 4). Empirical estimates suggest that a one-point increase in the patent index (about 1½ standard deviations) is associated with increases in U.S. FDI of approximately \$170 million (chemicals) to \$207 million (foods). Given that the average FDI figure is \$31 million (chemicals) and \$20 million (foods), these effects are economically significant. This finding contrasts with results in Maskus and Eby-Konan (1994) and Mansfield (1993), who find statistically insignificant effects using alternative measures of patent protection.[23] One reason for the divergent conclusions could be that our estimates are derived from purely within-country variation and therefore control for unobserved heterogeneity, whereas their estimates are from cross-sectional regression models and thus use information across, rather than within, countries to derive parameter estimates. Our findings are consistent with Lee and Mansfield (1996), who perform the analysis using FDI data for all manufacturing industries from 1990-92 for fourteen developing countries. When they pool their data, they find that the volume of U.S. FDI increases with the strength of intellectual property protection. Our findings are also consistent with Maskus (1998), who estimates a SUR model using four measures of "international exploitation of intellectual assets," and finds that FDI is sensitive to intellectual property protection in developing countries.[24]

Recall that our theoretical model predicts that FDI and IPR stringency are directly related, and that the magnitude of the comparative static is an increasing function of the ease by which technologies can be imitated (i.e., how sensitive an industry is to intellectual property protection). This follows from the fact that stronger IPR protection discourages imitation; and, industries with technologies that are easier to imitate "benefit" more from stronger IPR protection. Although their confidence intervals overlap, coefficient estimates suggest the food and kindred products industry, which was used as a representative patent insensitive industry, is affected to a greater degree by IPR regimes than the representative patent sensitive industry (chemical and allied products). One possible explanation for this seemingly counter-intuitive result is that the food industry may be as sensitive (if not more sensitive) to intellectual property protection. For example, food and kindred products may be considered a patent insensitive industry (based on R&D intensity), but brands and trademarks play crucial roles in this industry.[25] Since countries with strong patent regimes also offer strong brand and trademark protection (see Maskus 1998), it is possible that our estimates for the patent index also capture this aspect of intellectual property protection.

Other parameter estimates suggest that environmental regulations influence U.S. manufacturers' investment decisions. In each model, our coefficient estimates imply that FDI and regulatory standards are related nonlinearly. Furthermore, our results support *ex ante* intuition–environmental regulations are found to have heterogeneous effects across industries. In the food and kindred product industry, we find that environmental standards do not affect FDI flows at conventional significance levels. Alternatively, coefficient estimates of lead content in the regression models for chemical and allied products suggest that a significant relationship exists between environmental standards and FDI flows. For developed countries, parameter estimates imply that the average country is to the left of the trough of the U-curve (developed minimum point: -(-190.7/2(52.2)) = 1.83), suggesting that further decreases in lead content are associated with increases in FDI flows for the average developed country.

In the developing country model, the average country is to the right of the trough of the U-curve (developing minimum point: -(-72.2/2(11.8)) = 3.06), indicating that environmental standards and FDI flows are inversely related for the average developing country. However, one should consider the noisiness of the data before concluding that the inverse relationship exists. From Table 2, we see that developing countries have quite heterogeneous standards on gasoline lead content (s.d. = 4.19). Coupling this sample statistic with the fact that the standard error of the developing country trough is computed to be 0.58, we view the findings from this particular regression model to suggest that although for some developing countries environmental standards and FDI flows are inversely related, it may not be the case for all developing countries.[26]

While these results are interesting, we should caveat that we have explicitly treated environmental regulation as exogenous in our model. Of course, our difference-in-differences estimation approach may attenuate potential problems, but if the error term is correlated with the level of environmental regulation our estimates will be inconsistent. We suspect that this potential nuance will induce further research in this area of study.

VI. CONCLUDING REMARKS

One of the issues facing member countries of the World Trade Organization (WTO) is to what extent environmental concerns should be included in the WTO framework.[27] Several items related to the environment are on the agenda of the Doha Round trade talks. For example, (i) the establishment of a procedure for the regular exchange of information between the WTO and the secretariats of the various multi-lateral environmental agreements; (ii) to clarify the relationship between WTO rules and how these apply to member countries who are also signatories to multilateral environmental agreements that contain specific trade obligations; and (iii) to lower (or eliminate) tariffs and non-tariff barriers on environmental goods.[28]

A common concern amongst many developing nations is that these initiatives, in conjunction with both the push for tougher environmental standards at the global level and the TRIPs Agreement, may curtail their competitiveness in the international marketplace. Although our findings deal with international capital movements, the positive linkages we uncover should serve to alleviate the uneasiness of developing countries. Our theoretical predictions and empirical results both suggest that international capital movements are sensitive to both types of regulations, however, the effects are not unequivocally in the direction that many developing countries fear. In fact, we provide initial evidence that in the long run, FDI may be an increasing function in the level of intellectual property rights *and* stringency of environmental standards.

Our findings may also be of interest to policymakers that are concerned with sustainable development policies. Given that FDI contributes to economic development via the benefits from additional employment, larger tax base, etc., and provides an avenue for technology transfer, the notion of "clean" growth may not be as elusive as first perceived. Certainly more research is necessary to establish firmly important empirical relationships, and we hope that richer panel data sets will be developed to make proper inference on these issues.

DATA APPENDIX

U.S. Direct Investment Abroad is (net) capital transactions between U.S. parent firms and their foreign affiliates. It includes equity investments, intercompany debt and reinvested earnings (in million dollars). A positive number indicates a net outflow from the U.S. The data are compiled from various editions of the *Survey of Current Business*. Capital transactions for "less than $500,000" are replaced with $250,000.

Patent rights index numbers are from Ginarte and Park (1997). They use a 0-1 scoring method for each of these five categories: types of inventions that can be patented, length of coverage, provisions for losses, memberships in major patent agreements and existence of adequate mechanisms for enforcement. For example, in the first category, the strength of protection is measured by the patentability of the following: pharmaceuticals, chemicals, food, plant and animal varieties, surgical products, microorganisms and utility models. A country that offers protection to the first three items would have a score of 3/7. Scores for all five categories are summed and fall between zero and five (with larger values implying more stringent regimes). Data for 110 countries are available every five years from 1960-1990.

Lead is allowable lead content per gallon of gasoline. A country with relatively strict environmental policy would allow lower lead content per gallon of gasoline. Data on total gasoline consumption are from OECD's energy statistics. Data on lead content are from Octel's *Worldwide Survey of Motor Gasoline Quality*.

Per capita real GDP (in international prices) and **growth in real GDP** are from the Penn World Table (PWT) version 5.6; see http://www.nber.org/pwt56.html. **Market size** is calculated as the country's real GDP multiplied by a relative price index.

Countries included in the developing group include Argentina, Bangladesh, Brazil, Chile, Colombia, Dominican Republic, Ecuador, Egypt, Ethiopia, Ghana, India, Jamaica, Jordan, Kenya, Korea, Malawi, Mexico, Morocco, Mozambique, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, Senegal, South Africa, Tanzania, Thailand, Trinidad and Tobago, Uruguay, Venezuela, Zambia and Zimbabwe. Developed countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, and Switzerland.

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Table 1. Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Food and Kindred FDI [a/]				
Developed	44.58	128.6	-645.0	708.0
Developing	20.11	57.1	-125.0	393.0
Chemical and Allied FDI [a/]				
Developed	103.0	170.0	-209.0	744.0
Developing	30.86	79.2	-154.0	475.0
%Growth in Real GDP				
Developed	5.93	2.9	-2.4	18.6
Developing	4.16	6.3	-16.2	21.0
Real GDP per capita [b/]				
Developed	12518.1	4487.6	3169.0	21631.0
Developing	3873.2	2203.7	843.0	10298.0
Market Size [c/]				
Developed	398260	610220	17800	3670000
Developing	88110	101590	2030	479000
Patent Index				
Developed	3.43	0.58	1.98	4.24
Developing	2.16	0.72	1.12	3.94
Lead Content				
Developed	1.18	0.84	0.00	3.18
Developing	5.60	4.19	0.00	15.84

Notes: [a/] In million U.S. dollars; [b/] In international prices; [c/] In million international prices.

Table 2: Panel Data Estimates

	Food and Kindreds		Chemical and Allieds	
	Developed Country	Developing Country	Developed Country	Developing Country
Growth in Real GDP	-4.04 (8.05)	3.96 [a/] (1.24)	-1.96 (6.87)	2.17 [a/] (1.02)
Real GDP per capita	-0.01 (0.03)	-0.02 (0.013)	0.04 [b/] (0.02)	-0.03 [a/] (0.01)
Market Size	-0.13E-6 (0.7E-5)	0.33E-3 [b/] (0.2E-3)	-0.12E-3 [b/] (0.7E-4)	0.7E-3 [a/] (0.2E-3)
Patent Index	-118.1 (133.1)	207.4 [b/] (113.0)	-52.7 (145.1)	169.9 [b/] (96.0)
Lead Content	-8.56 (102.3)	-36.0 (30.4)	-190.7 [a/] (96.2)	-72.2 [a/] (26.7)
$(\text{Lead Content})^2$	16.3 (29.1)	5.19 (0.76)	52.2 [a/] (27.2)	11.8 [b/] (6.0)
Country Effects	YES	YES	YES	YES
Time Effects	YES	YES	YES	YES
$F(\alpha_i = \varphi_t = 0)$ d.f.	0.77 (22,84)	1.71 [b/] (23,90)	1.74 [b/] (22,94)	3.82 [a/] (23,98)
n	112	119	122	127

Notes: a. α_i represents country-specific effects, φ_t represents time effects; b. Standard errors in parentheses beneath coefficient estimates; c. [a/] [(b/)] indicates significant at the $p < 0.05$ ($p < 0.10$) level; d. All models are significant at the $p < 0.0001$ level; e. Some figures are in scientific notation, denoted by an E.

LIST OF FIGURES

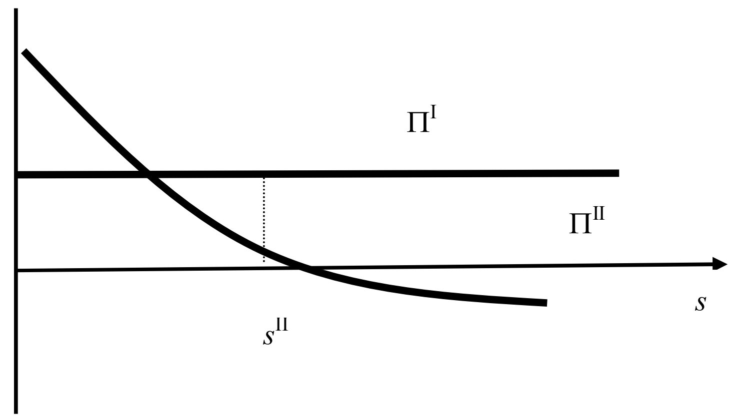

Figure 1. Comparing Strategies I and II based on s

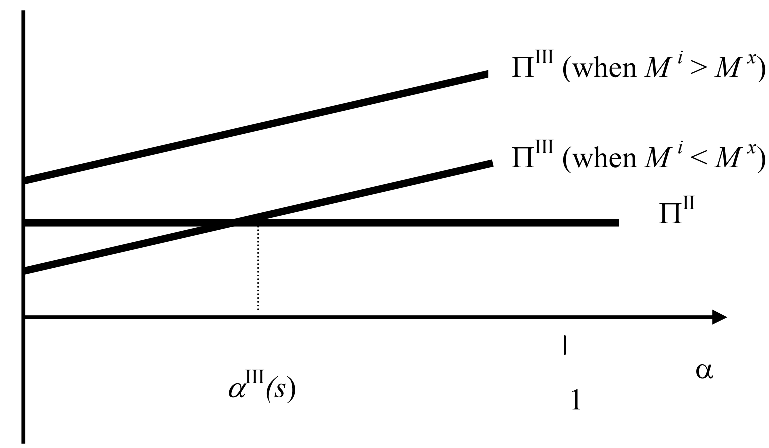

Figure 2. Comparing Strategies II and III based on α

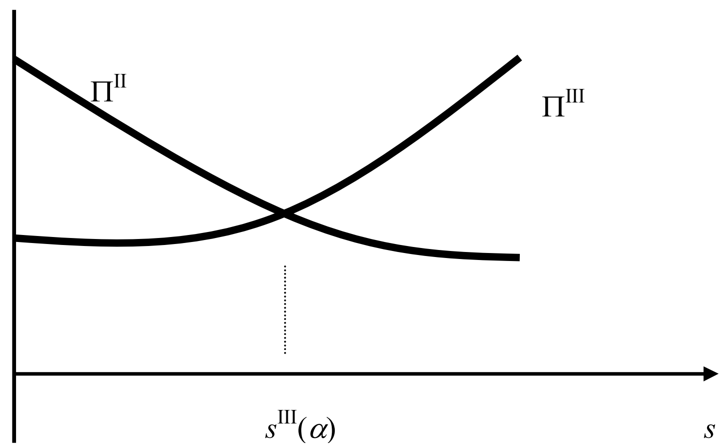

Figure 3. Comparing Strategies II and III based on s.

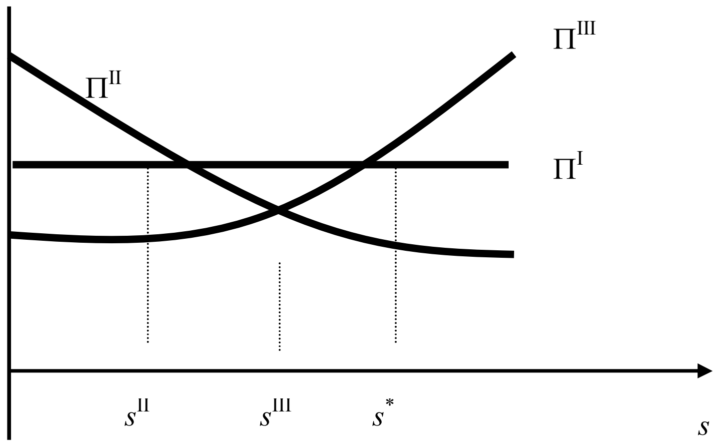

Figure 4. Comparing Strategies I, II and III based on s.

[1] This fact is highlighted in the U.S., where the Byrd-Hagel Resolution passed 95-0 on 7/25/97. The resolution included a stipulation that any climate change treaty that the Senate voted to ratify would not cause "serious harm to the economy of the United States."

[2] These are examples of what Blomstrom and Kokko (1998) call "productivity spillovers".

[3] Intellectual property rights include copyrights, trademarks, and industrial property rights (i.e., patent rights).

[4] See also List and Co (2000).

[5] One should not interpret "newness" literately. Here we just assume that a new product gives consumers more value (such as functions, features, look, and nutrition) compared to older products.

[6] In reality, there is also a probability that country B can imitate the imported product, but this probability is smaller than if the product is produced in country B. In this model, even without FDI, B can still imitate the product, but only after the second period.

[7] The model's major results can also be obtained in a two-country differential game.

[8] Such an environmental standard is defined assuming pollution is associated with production. If, however, pollution is associated with consumption, then firm A's product exported to B will be subject to B's environmental standard. In such a case, most results obtained in this section are reinforced.

[9] That is, firm A lowers its price to the level that makes it unprofitable for the imitators to enter the market.

[10] To permit a sharper focus, we omit the possibility that the demand in B's market is so weak that firm A's dominant strategy is not to enter.

[11] Recall that a larger g means that it is harder to imitate the technology embedded in products; a smaller c indicates a cleaner production technology; and a smaller e means that the northern firm has superior abatement technology.

[12] Lai (1998) also supports this finding.

[13] The Bureau of Economic Analysis defines U.S. direct investment abroad as "… the ownership or control, directly or indirectly, by one U.S. resident of 10 percent or more of the voting securities of an incorporated foreign business enterprise." See Mataloni (1995, 38).

[14] For example, Mansfield (1994) finds that firms in the food industry tend to be less sensitive to IPR than those in the chemical industry. Smith (1999) classifies the food and kindred

products industry as "patent insensitive" and the chemical and allied products industry as "patent sensitive."

[15] Data that disclose the identity of individual companies are suppressed by the Bureau of Economic Analysis.

[16] Some of our regressors are not explicit in our theoretic formulation. In specifying equation [11] we attempted to maintain consistency with previous work while providing a reduced-form representation that is in the spirit of our theoretical model. For a review of the capital location/environmental regulation relationship as well as a discussion of various empirical specifications see Jeppessen, List, and Folmer (2001).

[17] This U-shape relationship is also consistent with many studies that find a non-linear relationship between a measure of output (or incomes) and environmental standards (environmental Kuznets curve literature). To provide an external validity test of the lead measure, we constructed a dynamic measure of environmental regulatory stringency based on the cross-sectional index originally developed by Dasgupta et al. (1995). Their index is a 1990 measure of the stringency of environmental regulations as they pertain to the agricultural and industrial sectors. Using a forecasting method that included regressors such as income levels, percentage of urban citizens, labor force composition, and level of country development, we created a 1982-1992 panel-data index. This new measure exhibits a high degree of correlation with the lead index. In addition, empirical results are consistent across the two regulatory measures.

[18] This index pertains to industrial property rights (or patent rights).

[19] We are aware of the potential endogeneity problem identified by Maskus and Penubarti (1997) in their study of patents and international trade. They warn that trade flows may influence patent legislation hence the measured patent index. We use quinquennially data to attenuate the endogeneity problem. As such, we match the patent rights index measured in

1980 with FDI from 1982-1984, the 1985 index with 1985-89 FDI, and the 1990 index with the 1990-1992 FDI data.

[20] The basic specification we use is similar to that of Lipsey (1999). We initially included measures for wages and openness, but these variables were typically incomplete for a large number of countries and showed little temporal variation. Also, we should note that inclusion of both real per capita GDP and an environmental regulatory measure as regressors may be cause for concern given their perceived correlation. Their simple correlation coefficient is 0.26; hence we included both regressors in the final specification. Results are robust to exclusion of real per capita GDP.

[21] The first stage models were all significant at the $p < 0.0001$ level. Parameter estimates from these models suggest that GDP and data availability are positively correlated.

[22] The U.S. is taken to be the Northern country—not an unlikely supposition. On average, the U.S. has the second lowest level of allowable lead content at 0.42 per gallon of gasoline (Japan has 0.01 per gallon of gasoline). The U.S. also provides the highest level of intellectual property protection, on average, with an IPR index of 4.41.

[23] They use Rapp and Rozek's (1990) single year index. The correlation between this index and Ginarte and Park's index in 1985 and 1990 is 0.75 (Smith 1999).

[24] The four measures used by Maskus (1998) are the number of U.S. patent applications filed in host country, foreign affiliates' total sales, U.S. exports shipped to affiliates, and total assets of foreign affiliates of U.S. companies.

[25] Unlike Mansfield (1994) and Smith (1999), Maskus and Penubarti (1995), following Mansfield (1986), classify food and kindred products as patent sensitive.

[26] Other coefficient estimates primarily conform to economic intuition and previous findings. Growth in real GDP is statistically significant and positive in both developed country regressions. Real GDP per capita and market size are consistently relevant in the chemical

regression models. We should also note that the sign for real GDP per capita is significantly negative in the developed regression model whereas market size is significantly negative. The opposite holds for the developing country regression model. These results imply that in developed markets, U.S. firms increase their FDI with income, and in developing markets they increase their FDI with market size. We also estimate equation [11] with an interaction term between our environmental stringency measure and the IPR index. Overall, parameter estimates are generally robust to this inclusion, but they become less precise. The main repercussion is that the environmental stringency measures in the chemicals regression for developed countries are no longer individually significant at conventional levels. But, it is only in this specification where the interaction variable achieves significance.

[27] Intellectual property protection is currently included in the WTO framework via the Trade-Related Aspects of Intellectual Property (TRIPs) Agreement signed in 1995. TRIPs set forth strong minimum standards for the protection of patents and other forms of intellectual property. Whether an environmental agreement should be made within the purview of the WTO is more controversial. This is because environmental regulations are only moderately trade-related—Maskus (2000) provides an excellent summary of issues surrounding this debate.

[28] Information pertaining to the Doha Round is taken from the WTO's website.