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ABSTRACT

Innovation, antidumping, and retaliation*

We develop a North-South model of reciprocal antidumping (AD). We find that AD wars are winnable for the Northern firm if the Southern market is sufficiently small relative to the North's. The South can avert AD war with the North by expanding the home market size. It may however trigger AD war by improving its R&D capability. The model yields results that are largely consistent with recent empirical findings that (1) AD is concentrated in R&D intensive industries, (2) AD actions are mostly between industrial and developing countries, and (3) developing countries use AD to retaliate against industrial countries.

JEL Classification: F12, F13 and L13
Keywords: antidumping, intellectual property rights, R&D and reciprocal dumping

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1. Introduction

Today, international trade is freer than ever, thanks to the successful trade agreements to eliminate tariffs and quotas. Still, the rapid spread of antidumping (AD) poses a serious threat to free trade. Originally intended to protect domestic industries from unfair dumping, AD today has become simply a modern form of protection that restrains imports (Blonigen and Prusa 2001). In the U.S., in particular, the frequent use of "facts available" methods to estimate the costs and prices of exports has made dumping margin determination completely arbitrary. As a result, the U.S. Department of Commerce, which is responsible for dumping margin determination, almost always rules that dumping has occurred, even against firms making healthy profits from every sale of exports to the U.S. For example, from 1980 to 1992 Commerce ruled that dumping had occurred in 93% of all cases (Irwin 2002, pp. 114-115).

Furthermore, since the mid-1990s the use of AD has spread from a handful of users such as the U.S. and the E.U. to now over 100 countries, mostly developing and semi-industrialized countries.[1] Since this period saw the conclusions of international trade agreements to prohibit the use of tariffs and quotas, it is tempting to infer that the rapid spread of AD was due to countries simply substituting AD for the tariffs and quotas that they have

[1] For example, Mexico, China, India, Turkey, Egypt, and Brazil (Prusa 2001, Zanardi 2004).

eliminated as part of trade agreements. Recent empirical work however contradicts this hypothesis, indicating retaliation instead of substitution as the primary motive for the spread of AD use.[2]

Empirical research has also found that AD actions are concentrated in R&D-intensive industries (Niels 2000). Curiously, however, industrial countries do not seem to use AD against each other despite the high volumes of trade in R&D-intensive goods among them. They instead target developing countries with their AD actions (Bown et al., 2004).

With these stylized facts in mind, this paper has two primary objectives. The first is to account for the observed patterns of AD use in recent years; namely, AD actions and retaliations are more often than not between the North (developed countries) and the South (developing countries). To address this issue, we develop, in section 2, a multi-country version of the Brander-Krugman (1983) model of reciprocal dumping, in which national markets vary in size. The analysis shows that each firm has a unilateral incentive to file for an AD action against all foreign firms, no matter what size its home market is. However, when the rival

[2] Studies arguing that retaliation is the main determinant of AD filings include Martin and Vergote (2008), Feinberg and Reynolds (2006), Moore and Zanardi (2008), Prusa and Skeath (2002) and Vandenbussche and Zanardi (2008). Thus far, the substitution hypothesis has only been confirmed for India. Bown and Tovar (2008) show that Indian liberalization efforts have resulted in higher probability of antidumping filings.

retaliates with own AD protection, and when firms' home markets are similar in size, both firms are harmed by reciprocal AD. In the long run then, when firms interact over time repeatedly, the desire to avoid such prisoners' dilemma outcomes restrains the use of AD measures among countries with similar-sized home markets. In contrast, firms having larger home markets face winnable AD against firms having smaller home markets, even if there is retaliation. Thus, our model predicts that AD activity is mostly between the North and the South, where market size differences can be substantial.

The finding that AD is more concentrated in R&D-intensive industries motivates our second objective: examination of the effect of reciprocal AD on R&D activities. To address this issue, we expand the model so that firms now invest in cost-reducing R&D before competing in the national markets, and then examine how the firms' incentives to engage in reciprocal AD is affected by the opportunity to invest in R&D. On the other hand, to focus sharply on this issue, and to reflect the fact that reciprocal AD is mostly between the North and the South, we reduce the number of countries in the model to just two, representing the North and the South. Additionally, the model incorporates the two well-known features of North-South competition in R&D; the North's relative efficiency in R&D and the South's lax enforcement of intellectual property rights (IPRs).

Despite these additional structural differences between the two countries, it is again the home market size difference between the trading partners that plays a prominent role here. Assuming that the Southern market is smaller than the Northern counterpart, we find that reciprocal AD reduces the Southern firm's investment in R&D and its profit. Reciprocal AD reduces the Northern firm's R&D investment and profit, provided that the Southern market is comparable in size to the Northern market. If the Southern market is sufficiently small, however, reciprocal AD increases the Northern firm's R&D investment and its profit.

We also find that, when firms engage in R&D, the North faces a winnable AD war for a wider range of the country size parameter than when firms do not have the opportunity to invest in R&D. This result implies that AD war is more likely to occur in industries where firms are engaged in R&D activities, and is consistent with the empirical finding that AD actions are concentrated in R&D-intensive industries.

What is perhaps surprising is the finding that the above conclusion does not depend on the South's laxity in enforcement of IPR protection. What ultimately drives the North to initiate an AD action is the size difference with the South, not because the latter infringes the former's IPRs. Thus, our model shows that there is little ground in the rhetoric for the need of AD actions by advanced countries to counter the lack of IPR enforcement in developing countries.

Our analysis instead implies that the South must increase its home market size sufficiently in order to avoid being targeted by the North's AD actions. Put differently, a growing market size of the South will eventually avert AD wars. Lastly, we find that, if the South catches up to the North in R&D capability without a home market expansion, the likelihood of triggering AD actions from the North increases.

A brief review of the related literature is now in order. The Brander-Krugman model of reciprocal dumping has stimulated several studies of antidumping policy; e.g., Anderson, Schmitt and Thisse (1995), Bian and Gaudet (1997), Veugelers and Vandenbussche (1999) and Gao and Miyagiwa (2004). In particular, Gao and Miyagiwa (2004) examine the effect of antidumping measures on R&D activity, finding that reciprocal AD increases R&D investment. Their results contrast from ours. The difference is explained by their assumption that AD duty determination is endogenously determined by actual dumping margins (net profit differentials between markets). As mentioned in the opening paragraph of this section, however, today margin determination is completely divorced from actual dumping margins, as convincingly argued in an extensive survey by Blonigen and Prusa (2001). For this reason we treat AD duties as exogenous. The arbitrariness of margin determination also motivates the signaling model of dumping of Miyagiwa and Ohno (2007), where the rate of AD duty is treated as a random variable drawn from some distribution function.

The remainder of the paper is organized in 4 sections. The next section examines the possibility of reciprocal AD in a multi-country setting without R&D, finding that firms win trade wars in AD only with firms domiciled in countries having much smaller home markets. Hence, in a reciprocal context, AD wars only arise between countries whose market size difference is sufficiently large. Section 3 considers a North-South model with R&D competition. The Northern firm is more efficient in R&D than its Southern counterpart but the latter can appropriate part of the former's innovation. Despite these features only the country size matters in determining the benefit from or harm done by reciprocal AD. The final section concludes.

2. Model

2.1 Environment

Consider an industry spanning M (≥ 2) national markets. Market demands are assumed linear. Country m's inverse demand is given by $p_m = 1 - Q_m/b_m$, where the common demand intercepts are normalized to unity, Q_m denotes total sales in country m, and $b_m \in (0, 1]$

measures the size of market m. Markets are enumerated in the descending order, with the size of market one normalized to unity:

$$b_1 = 1 > b_2 > \ldots > b_M.$$

Turning to the production side of the model, assume that each country has a single firm producing a homogeneous good at constant marginal cost and playing a quantity-setting (Cournot) game with all others in each market.[3] Marginal costs are identical across firms and constant at c. Let $t_{i,j}$ denote a specific AD duty country i imposes on imports from country j, and let

$$T_i = t_{i,1} + t_{i,2} + \ldots + t_{i,i-1} + t_{i,\,i+1} + \ldots + t_{i,M}$$

be the sum of duties country i imposes on imports from all other countries.

Firms consider all national markets as segmented and maximize the profit in each market independently (Brander and Krugman 1985). Given Cournot competition, it is straightforward to show that firm m's profit from domestic sales equals:

(1) $$\pi_{m,m} = b_m[1 - c + (M - 1)t_o + T_m]^2/(1 + M)^2,$$

where t_o is the unit transport cost. Its profit from exporting to country e ($\neq$ m) equals

(2) $$\pi_{m,e} = b_e[1 - c - 2t_o - (M + 1)t_{e,m} + T_e]^2/(1 + M)^2.$$

[3] A price-setting game (played by differentiated-goods oligopolists) yields similar results without additional insight.

The total profit to firm m is the sum of these profits from all the M markets:

$$\pi_{m,1} + \pi_{m,2} + \ldots + \pi_{m,M}.$$

In the analysis to follow, assume that the transport cost t_o is arbitrarily small and there are no tariffs initially. In such an environment the profits from domestic sales in (1) and the profit from exports in (2) differ only in terms of market size:

$$\pi_{m,m} = b_m(1 - c)^2/(1 + M)^2$$

$$\pi_{m,e} = b_e(1 - c)^2/(1 + M)^2.$$

2.2. Bilateral AD and retaliation

We turn next to the effect of AD actions and retaliation. Assume that, when deviating from free trade, each country imposes an exogenously given small AD duty; i.e.,

$$dt_{m,j} = dt > 0$$

for all m and all j ($\neq$ m). Each firm m clearly benefits from its *own* AD action against any foreign firm, as shown by differentiating (1) with respect to $t_{m,j}$:

$$\partial\pi_{m,m}/\partial t_{m,j} = 2b_m[1 - c + (M - 1)t_o + T_m]/(1 + M)^2 > 0.$$

Since firm m's profits from its export markets remain unaffected, a unilateral AD action is a dominant strategy for any firm, independently of its home market size. Thus, in a one-shot game, the unique equilibrium has all firms taking AD actions against each other.

However, when country e retaliates with own AD, firm m's profit from that country falls by

$$\partial\pi_{m,e}/\partial t_{e,m} = -2Mb_e[1 - c - 2t_o - Mt_{e,m} + T_e]/(1 + M)^2 < 0.$$

When transport costs are arbitrarily small and there is free trade initially, the above two effects can be approximated by

$$\partial\pi_{m,m}/\partial t_{m,e} \approx 2b_m(1 - c)/(1 + M)^2$$

$$\partial\pi_{m,e}/\partial t_{e,m} \approx -2Mb_e(1 - c)/(1 + M)^2$$

so reciprocal AD between firm m and firm e changes firm m's profit from the two markets by

$$\partial\pi_{m,m}/\partial t_{m,e} + \partial\pi_{m,e}/\partial t_{e,m} = 2(b_m - Mb_e)(1 - c)/(1 + M)^2.$$

Thus, the change in firm m's profit from reciprocal AD depends on the sign of

$$b_m - Mb_e.$$

Proposition 1: If only countries m and e engage in reciprocal AD, firm m is harmed by it if and only if $Mb_e > b_m$.

If m is the smaller market i.e., $b_m < b_e$,

$$b_m - Mb_e < b_e - Mb_e = b_e(1 - M) < 0,$$

recalling that $M \geq 2$. Therefore, *a firm from a smaller home market never benefits from engaging in reciprocal AD with a firm based in a larger home market*. However, if m is a bigger market then it is possible that $b_m - Mb_e > 0$, if b_e is substantially smaller than b_m. That is, *a firm from a larger home market can benefit from reciprocal AD with a firm located in a much smaller home market*. This condition becomes more difficult to be satisfied as the number of countries grows. With only two countries, we have the next result, which is useful in Section 3.

Proposition 2: Consider firm 1 and another firm with home market size $b < 1$. With $M = 2$, firm 1 wins AD war if and only if $b < 1/2$.

2.3. Bilateral AD actions and retaliation in repeated-game settings

In a one-shot game, all countries impose AD duties against all others and end up in prisoners' dilemma situations. If firms interact repeatedly over time as they do in the real world, then they can avoid prisoners' dilemma outcomes. In this section we consider such a setting.

Consider firm m and firm e, with $b_m > b_e$. Thus, firm e never wants to engage in reciprocal AD. If both firms agree to refrain from reciprocal AD, firm m earns the total profit approximated by

$$\pi_m = b_m(1 - c)^2/(1 + M)^2 + b_e(1 - c)^2/(1 + M)^2.$$

When firm m deviates with AD at the rate dt one period, its profit from its home market increases to

$$b_m(1 - c + dt)^2/(1 + M)^2$$

during that period. However, a deviation initiates the punishing phase of the equilibrium the following period, in which both firms revert to reciprocal AD forever. During the punishing phase, the profit per period to firm m from market e is decreased to

$$b_e(1 - c - Mdt)^2/(1 + M)^2.$$

Therefore, firm m has no incentive to deviate if

$$b_m(1 - c)^2 + b_e(1 - c)^2$$

$$\geq (1 - \delta)\{b_m(1 - c + dt)^2 + b_e(1 - c)^2\} + \delta\{b_m(1 - c + dt)^2 + b_e(1 - c - Mdt)^2\}$$

where δ is the discount factor. This condition simplifies to

$$\delta b_e[(1 - c)^2 - (1 - c - Mdt)^2] \geq b_m[(1 - c + dt)^2 - (1 - c)^2].$$

Dividing both sides by dt, letting dt → 0, and canceling 2(1 + c) on both sides, we obtain the compact expression for an unprofitable deviation for firm m:

(3) $\delta b_e M \geq b_m$.[4]

In the one-shot game firm m gets hurt by reciprocal AD if $b_e M \geq b_m$. Since $\delta < 1$, condition (3) is more difficult to fulfill than its one-shot game version. That is, if $b_e M \geq b_m \geq \delta b_e M$, firm m wants to avoid an AD war against firm e but it is impossible to make such an agreement credible. So in equilibrium the firms use AD against each other and end up in the prisoners' dilemma situation.

2.4. Multilateral AD actions

So far we have only considered incentives to engage in AD actions between two firms. Consider now the following scenario. Firm 1 begins taking actions against all firms with whom it can win AD wars. All targeted firms then retaliate with own AD actions with firm 1. What is

[4] Interchanging the subscripts, we get the similar condition for firm e. Given however that $b_m > b_e$, this condition is automatically satisfied if (3) holds.

new in multilateral AD is that firm 1 may be more aggressive in its use of AD than when it targets just one country. To see this, suppose there is market $n < M$ such that

$$1 - Mb_n < 0 \text{ and } 1 - Mb_{n+1} > 0.$$

Then market 1 is harmed by reciprocal AD with any firm {2, …,n} but benefits from reciprocal AD against all firms {n + 1,…,M}, when each case is considered individually[5]. However, having AD against markets {n+ 1,…,M} can make AD against firm n profitable. That is because the cumulative AD duties on imports from firms n + 1 through M increase firm 1's profit from domestic sales, making an AD action on imports from firm n more profitable. To see this, with AD duties against firms {n + 1,…,M}, firm 1's profit from home market sales is

$$[1 - c + t_{m,n+1} + \ldots + t_{m,M}]^2/(1 + M)^2,$$

so that the effect of a small AD duty on firm n is given by

$$2[1 - c + t_{m,n} + t_{m,n+1} + \ldots + t_{m,M}]/(1 + M)^2.$$

as opposed to

$$2[1 - c + t_{m,n}]/(1 + M)^2,$$

[5] Antidumping duties in contrast to safeguards (Crowley, 2007) are trade defense instruments that can be use in a discriminatory way.

when it has no AD duties on other firms' exports. Thus, the firm with the largest home market files for AD protection with more firms collectively than when each firm is targeted singly.

When firm 1 is done, let firm 2 take winnable AD actions against all firms. Firm 2 targets a smaller set of countries than firm 1 for two reasons. A first is obvious: firm 2 has a smaller home market than firm 1 ($b_2 < 1$). A second reason is subtler. When there is already reciprocal AD going on between firm 1 and, say, firm e, firm 2 has less of an incentive to target firm e in AD action, even if firm 2 faces a winnable AD war with firm e in isolation; that is, $Mb_e < b_2$. This is because firm e's AD action against firm 1 causes trade diversion, expanding market share of firm 2 (and all other firms) in country e. With exports to country e more profitable now, AD war against firm e may becomes unprofitable for firm 2 (and all other firms). For example, when country e imposes no AD duty on any other firm, AD by firm e against firm 2 reduces the latter's export profit by

$$\partial\pi_{2,e}/\partial t_{e,2} = -2Mb_e(1 - c)/(1 + M)^2 < 0.$$

In contrast, when firm e already has AD against firm 1, firm e's AD action against firm 2 reduces firm 2's profit by a greater amount:

$$\partial\pi_{2,e}/\partial t_{e,2} = -2Mb_e(1 - c \;\; + t_{e,1})/(1 + M)^2 < 0,$$

Thus, retaliatory AD by country e is more damaging to firm 2 when firm e has AD against firm 1. As this example shows, by retaliating against one country, the target may be able to prevent future AD wars against others. For this reason, the target may have a greater incentive to retaliate any firm to be targeted in AD by other countries.

Our scenario completes when all firms take winnable AD actions. Then, it is obvious that firms having similar-sized home markets do not wish to take AD actions against each other and can remain AD-free with each other when they interact over time. Thus, reciprocal AD occur only between countries with substantial size differences in home markets.

To summarize this section, firms face winnable AD war only against firms having substantially smaller home markets. This result is consistent with the findings that AD actions are mostly between the industrial North and the developing South, where market size differences can be substantial. Our model is also consistent with the empirical findings that developing countries use AD to retaliate against industrial countries.

3. Innovation and antidumping

The preceding section has shown why there are more AD activities between the North and the South than within each region. Given that AD actions are concentrated in R&D-

intensive industries, in this section focus shifts to the effect of R&D on the likelihood of reciprocal AD between the North and the South. To address this issue we extend the model so that firms now face the opportunities to invest in cost-reducing R&D before competing in national markets. To focus sharply on this issue, we however consider a world with only two countries, the industrial North and the developing South. The Southern firm now differs from the Northern rival in three respects. First, its home market is smaller. Second, its R&D capability is inferior. Thirdly, it can appropriate the Northern firm's innovation thanks to the weak IPR protection in the South.

3.1. Environment

We consider a model with two firms and two national markets. As before, inverse demands are given by $p_i = 1 - Q_i/b_i$, where p_i is price and Q_i is total sale in market i. We normalize the size of the Northern market to one and let $b \in (0, 1)$ be the size of the Southern market.

The firms now play a two-stage game, first investing in cost-reducing R&D and then competing in both markets. Marginal production costs are assumed constant with respect to output but can be reduced by R&D. The Southern firm is less efficient in R&D in the following sense: the cost of investment k in R&D is $\gamma_s k^2/2$ in the South and $\gamma_n k^2/2$ in the North with $\gamma_s > \gamma_n$.

Further, we assume that IPRs are well protected in the North. However IPR protection is lax in the South so the Sothern firm can appropriate the Northern firm's innovation. We express this asymmetry in IPR law enforcement as follows. In the North, firm N's ex-post marginal cost depends only on its own investment level in R&D, k_n, and is written as

$$c_n = c_o - k_n,$$

where c_o denotes the ex ante marginal cost. In contrast, firm S's ex post marginal cost is given by

$$c_s = c_o - k_s - \alpha k_n$$

As the last term on the right indicates, firm S benefits from firm N's innovation in proportion to the parameter $\alpha \in (0, 1]$, which reflects the degree of laxity in IPR protection in the South.[6]

3.2. Equilibrium Profits

[6] Thus we draw on d'Aspremont and Jacquemin (1988), who first discussed R&D competition with technology spillovers.

We solve the model backward. With the ex post marginal costs given, the second-stage game equilibrium (Cournot) profits are straightforward to calculate. In market N, firm N faces the unit cost c_n while firm S incurs the unit cost $c_s + t_o + t_n$, where t_o is international transport cost and t_n is an AD duty by country N. Thus, firm N's equilibrium profit from domestic sales equals

$$[(1 - 2(c_o - k_n) + (c_o - k_s - \alpha k_n) + (t_o + t_n)]^2/9$$

$$= [W + (2 - \alpha)k_n - k_s + t_n]^2/9,$$

where

$$W \equiv 1 - c_o + t_o.$$

In market S, the firms' positions are reversed as firm N now incurs transport cost t_o and possibly country S's AD duty, t_s. Thus, firm N's equilibrium profit from exporting to the South is

$$b[1 - 2(c_o - k_n) + (c_o - k_s - \alpha k_n) - 2(t_o + t_s)]^2/9$$

$$= b[w + (2 - \alpha)k_n - k_s - 2t_s]^2/9,$$

where

$$w \equiv 1 - c_o - 2t_o.$$

We assume that all the parameter values are such that there is an interior solution to the Cournot game; i.e., each firm always produces strictly positive output for all relevant parameter values.

Collecting terms and subtracting the cost of R&D, we obtain firm N's first-stage profit:

(4) $$\pi_n = [W + (2 - \alpha)k_n - k_s + t_n]^2/9 + b[w + (2 - \alpha)k_n - k_s - 2t_s]^2/9 - (\gamma_n/2)k_n^2,$$

Likewise, the first-stage profit to firm S is expressed as

$$\pi_s = [w + 2k_s - (1 - 2\alpha)k_n - 2t_n]^2/9$$

$$+ b[W + 2k_s - (1 - 2\alpha)k_n + t_s]^2/9 - (\gamma_s/2)k_s^2.$$

In the analysis to follow we assume that transport costs are arbitrarily low so that W = w and there is free trade initially. That is, we evaluate all derivatives at $t_0 = t_n = t_s = 0$.

3.3. Optimal R&D investments

Firms choose R&D investment levels simultaneously to maximize the respective profits, given the rival's investment in R&D. For firm N, maximizing π_n in (4) yields the first-order condition

(5) $$2(2 - \alpha)[W + (2 - \alpha)k_n - k_s + t_n]$$

$$+ 2b(2 - \alpha)[w + (2 - \alpha)k_n - k_s - 2t_s] - 9\gamma_n k_n = 0.$$

The second-order condition is satisfied if

(6) $$Z_n = 9\gamma_n - 2(2-\alpha)^2(1+b) > 0.$$

Collecting terms, (5) can be written as

(7) $$A_n + 2(2-\alpha)^2(1+b)k_n - 2(2-\alpha)(1+b)k_s - 9\gamma_n k_n = 0.$$

where

(8) $$A_n \equiv 2(2-\alpha)(W+bw) + 2(2-\alpha)(t_n - 2bt_s) > 0;$$

where the inequality follows from the assumption of positive equilibrium output in both markets.

Similarly, the first-order condition for firm S is

$$4[w + 2k_s - (1-2\alpha)k_n - 2t_n] + 4b[1 - c_o + t_o + 2k_s - (1-2\alpha)k_n + t_s]$$

$$- 9\gamma_s k_s = 0,$$

which simplifies to:

(9) $$A_s + 8(1+\beta)k_s - 4(1-2\alpha)(1+b)k_n - 9\gamma_s k_s = 0,$$

where the positive equilibrium output in both markets implies

$$A_s \equiv 4(w + bW) + 4(bt_s - 2t_n) > 0.$$

The second-order condition requires that

(10) $$Z_s = 9\gamma_s - 8(1+b) > 0.$$

Assume that γ_n and γ_s are sufficiently large so the second-order conditions (6) and (10) always hold.[7]

The first-order conditions (7) and (9) are arranged to yield the best-response functions:

(7’) $$k_n = [A_n - 2(2 - \alpha)(1 + b)k_s]/Z_n$$

(9’) $$k_s = [A_s - 4(1 - 2\alpha)(1 + b)k_n]/Z_s$$

(see Appendix A for the derivations of these expressions). Differentiating (7’) yields

$$dk_n/dk_s = - 2(2 - \alpha)(1 + b)/Z_n < 0,$$

so k_n is a strategic substitute to k_s. Differentiating (9’) we obtain

(11) $$dk_s/dk_n = - 4(1 - 2\alpha)(1 + b)/Z_s.$$

dk_s/dk_n is negative if and only if $\alpha < 1/2$. In other words, k_s is a strategic substitute to k_n only if the IPR protection in the South is strict enough to have $\alpha < 1/2$; otherwise k_s is a strategic complement to k_n. Intuitively, if $\alpha < ½$ and firm S increases investment in R&D, firm N’s Cournot profits fall in both markets, prompting firm N to reduce investment in R&D. On the other hand, if $\alpha > 1/2$, an increase in R&D investment by firm N increases firm S’s Cournot profit due to spillovers, inducing firm S to invest more in R&D. Thus, for $\alpha > 1/2$, k_s is a strategic complement to k_n.

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[7] If the second-order fails, R&D is so cheap that firm S invests until marginal production cost drops to zero.

The Nash equilibrium (k_n*, k_s*) is given by:

(12) $$k_n^* = \{A_n Z_s - 2(2-\alpha)(1+b)A_s\}/\Delta$$

(13) $$k_s^* = \{A_s Z_n - 4(1-2\alpha)(1+b)A_n\}/\Delta$$

where

$$\Delta \equiv Z_n Z_s - 8(2-\alpha)(1-2\alpha)(1+b)^2$$

is positive by the Hahn stability condition, which we assume holds throughout.

We want to make sure that k_n* and k_s* are positive. Since $\Delta > 0$, that means the numerator in (12) and (13) must be positive. In the absence of AD duties

$$A_n = 2(2-\alpha)(W + bw) > 0,$$

$$A_s = 4(w + bW) > 0.$$

Substituting these values into (12) and (13) yields the necessary and sufficient conditions for $k_n^* > 0$:

(14) $$(W + bw)Z_s - 4(1+b)(w + bW) > 0$$

and for $k_s^* > 0$:

$$(w + bW)Z_n - 2(1-2\alpha)(1+b)(2-\alpha)(W + bw) > 0$$

If the transport costs are arbitrarily small, $W \approx w$. Under this condition (14) is written as

$$Z_s - 4(1+b) = 9\gamma_s - 12(1+b) > 0.$$

We thus assume that

(15) $\gamma_s > 4(1 + b)/3$

for the remainder of the analysis.

3.4. AD actions and retaliation

In this subsection we examine the effect of AD actions and retaliation on investment. We first study how reciprocal AD affects firms' investment in R&D. Differentiating (12) and (13) with respect to $dt_n = dt_s = dt$ yields the desired results:

(16) $dk_n^*/dt = \{Z_s dA_n/dt - 2(2 - \alpha)(1 + b)dA_s/dt\}/\Delta$

(17) $dk_s^*/dt = \{Z_n dA_s/dt - 4(1 - 2\alpha)(1 + b)dA_n/dt\}/\Delta$

To evaluate these derivatives, differentiate A_n and A_s in (8) and (9):

$$dA_n/dt = 2(2 - \alpha)(1 - 2b),$$

$$dA_s/dt \equiv 4(b - 2) < 0.$$

Substituting these expressions into (16) and (17) yields

(18) $dk_n^*/dt = 2(2 - \alpha)\{(1 - 2b)Z_s + 4(1 + b)(2 - b)\}/\Delta,$

(19) $dk_s^*/dt = 4\{(b - 2)Z_n - 2(2 - \alpha)(1 - 2\alpha)(1 + b)(1 - 2b)\}/\Delta.$

We now examine each expression closely. On the right-hand side of (18) the expression in braces in the denominator simplifies to the quadratic in b:

(20) $$12b^2 - 2(9\gamma_s - 6)b + 9\gamma_s.$$

This is positive at b = 0. At b = 1, it is negative, given the condition (15): $\gamma_s > 4(1 + b)/3$. Thus, there is the unique $\tilde{b} \in (0, 1)$, at which the expression in (20) vanishes:

$$\tilde{b} = \frac{3\gamma_s - 2 - \sqrt{(3\gamma_s - 2)^2 - 12\gamma_s}}{4} .$$

Since $\Delta > 0$, we conclude that AD raises R&D investment for firm N, $dk^*_n/dt > 0$, if and only if the South's market size is less than $\tilde{b}$, or $b \in (0, \tilde{b})$. Calculation shows that this cutoff value $\tilde{b} > 1/2$.

The right-hand side of (19) is more complicated, but it is shown in Appendix B that it is negative for all relevant values of α and b so that $dk_s^*/dt < 0$. The next proposition summarizes the effect of reciprocal AD on investment in R&D.

Proposition 3:

(A) If $b < \tilde{b}$, $dk_n^*/dt > 0$ and if $b > \tilde{b}$, $dk_n^*/dt < 0$.

(B) $dk_s^*/dt < 0$.

Thus, with reciprocal AD, firm S always invests less in R&D while firm N invests less if and only if market S is larger than $\tilde{b}$.

Note that the signs of derivatives in (18) and (19) are independent of the appropriation parameter α. Regardless of how lax IPR protection is in the South, reciprocal AD always discourages firm S's R&D effort. On the other hand, whether firm N's investment in R&D increases or decreases with reciprocal AD depends only on the South's market size but not on the value of α.

Although it has no qualitative effect on R&D, α affects the magnitudes of changes in R&D investment from AD. It is easy to show that $\partial^2 k_n^*/\partial t \partial \alpha < 0$, implying that laxer IPR enforcement in the South reduces firm N's investment in R&D. In contrast, $\partial^2 k_s^*/\partial t \partial \alpha > 0$ implies that laxer IPR protection lessens the fall in investment in R&D by firm S. We collect these findings in

Proposition 4. (A) The South's IPR policy has no qualitative effect on R&D investment from reciprocal AD.

(B) Suppose that the South's IPR protection becomes laxer. Then, if $b < \tilde{b}$, reciprocal AD raises firm N's investment in R&D but to a lesser extent than when IPR protection is stricter. If

$b > \tilde{b}$, reciprocal AD decreases firm N's investment in R&D more than when IPR protection is stricter.

(C) When the South's IPR protection becomes laxer, reciprocal AD still lowers firm S's investment in R&D but to a lesser extent.

Now we turn to the effect on the profits from reciprocal AD actions. The total effect for firm N is, by the envelope theorem, given by

$$d\pi_n/dt = \partial\pi_n/\partial t + (\partial\pi_n/\partial k_s^*)(\partial k_s^*/\partial t).$$

There are two effects from reciprocal AD. The direct effect, the first term on the right, is the pure effect from reciprocal AD duties, while the indirect effect, the second term on the right, affects the profits through changes in R&D investment of firm S. For the direct effect straightforward calculation yields:

$$\partial\pi_n/\partial t = 2[W + (2-\alpha)k_n - k_s + t_n] - 4b[w + (2-\alpha)k_n - k_s - 2t_s].$$

For the indirect effect we have:

$$\partial\pi_n/\partial k_s = -2[W + (2-\alpha)k_n - k_s + t_n] - 2b[w + (2-\alpha)k_n - k_s - 2t_s].$$

To evaluate these effects, assume that transport costs t_o are arbitrarily low and initially there are no AD duties, that is, $W = w$ and $t_n = t_s = 0$. Then, these effects can be written as

$$\partial\pi_n/\partial t = 2(1-2b)[w + (2-\alpha)k_n - k_s],$$

$$\partial\pi_n/\partial k_s = -\ 2(1+b)[w + (2-\alpha)k_n - k_s],$$

so the total effect on the profit to firm N is

$$d\pi_n/dt = 2[w + (2-\alpha)k_n - k_s]\{(1-2b) - (1+b)\partial k_s{*}/\partial t\}$$

Since the term in brackets is positive due to positive output, conclude that

$$\text{sgn}\ \{d\pi_n/dt\} = \text{sgn}\ \{(1-2b) - (1+b)\partial k_s{*}/\partial t\}.$$

Substituting from (19) allows us to rewrite the expression on the right-hand side as:

$$(1-2b)\Delta/\Delta - (1+b)\partial k_s{*}/\partial t$$

$$= (1-2b)\{Z_n Z_s - 8(2-\alpha)(1-2\alpha)(1+b)^2\}/\Delta$$

$$-4(1+b)\{Z_n(b-2) - 2(1-2\alpha)(1+b)(2-\alpha)(1-2b)\}/\Delta,$$

which simplifies, after some manipulation, to

(21) $$Z_n\{(1-2b)Z_s + 4(1+b)(2-b)\}/\Delta.$$

A comparison with (18) shows that (21) is positive only if $dk_n{*}/dt > 0$. We prove a similar result for firm S, in the appendix. The next proposition summarizes the findings.

Proposition 5:

(A) $\text{sgn}\ \{d\pi_n/dt\} = \text{sgn}\ \{dk_n{*}/dt\}$

(B) $\text{sgn}\{d\pi_s/dt\} = \text{sgn}\{dk_s^*/dt\}$

The positive linkage between the changes in profits and investment in R&D yields the following observations. First, by Propositions 2 and 4, firm S never wins AD war against firm N, no matter how much it infringes firm N's IPRs. In contrast, firm N wins AD war against firm S if and only if the Southern market is small enough ($b < \tilde{b}$). As mentioned before, South's IPR enforcement policy plays no role.

Second, recall Proposition 1; without R&D, firm N wins AD war against firm S if and only if b < 1/2. When firms can invest in cost-reducing R&D, this cutoff condition is replaced by $b < \tilde{b}$. Since $\tilde{b} > 1/2$, if the South has the market size b satisfying $1/2 < b < \tilde{b}$, then an AD war that was unwinnable to firm N without R&D becomes winnable when firms can invest in R&D. This result is consistent with the fact that AD actions are concentrated in R&D-intensive industries, and is noted in

Proposition 6: Without R&D, the Northern firm faces a winnable AD war if the Southern market is less than half as large as the Northern market (b < ½). When firms can invest in R&D, this cutoff point for winnable AD wars increases to $\tilde{b} \in (1/2, 1)$.

Finally, calculation shows that $\partial \tilde{b} / \partial \gamma_s < 0$ and $\partial \tilde{b} / \partial \gamma_n = 0$. Thus, if firm S becomes more efficient in conducting R&D, the cutoff point $\tilde{b}$ rises, making firm S a more likely target of AD actions by firm N. We note this result in the next proposition.

Proposition 7: If the South catches up to the North in terms of R&D capability, it is more likely to trigger an AD war.

In contrast, an increase in firm N's R&D capability has no effect on the likelihood of AD war.

4. Summary and discussion

During the last two decades the use of AD has spread from a handful of traditional users to a huge number of developing and semi-developed nations. There is recent empirical evidence that new users are retaliating against the traditional users that have used AD against them before. There is also evidence that most AD actions today occur between the industrial North and the developing South. Our multi-country analysis shows that firms want to avoid AD actions against foreign firms having larger home markets, but that firms with large home markets (North) prey on firms having sufficiently small home markets, who then retaliate. The model's prediction thus corresponds to the stylized facts that most AD actions are between the industrial North and the developing South.

There is also empirical evidence that AD activities are found mostly in R&D-intensive industries. Our analysis shows that, if firms can invest in R&D, then the range of parameter values that makes AD war winnable for the North expands. Thus, our model is also consistent with the fact that AD activities are concentrated in R&D-intensive industries.

Developing countries are less capable of doing R&D but often appropriate inventions discovered in advanced countries. Our analysis shows that stricter enforcement of IPRs in the South has no qualitative effect on the North's incentive to engage in reciprocal AD. This runs counter to the conventional view that AD is necessary to penalize foreign firms appropriating technologies invented in industrial nations.

To conclude, firms in the North face winnable AD wars against those in the South if the latter have much smaller home markets than the North. Thus, reciprocal AD is likely to continue until the South expands its home market size substantially. In contrast, catching up to the North in R&D capability without home market expansion makes the South a more likely target of the North's AD action.

Appendix A

To compute the Nash equilibrium, substitute (9') for k_s into (7') to obtain

$$k_n Z_n = A_n - 2(2-\alpha)(1+b)[A_s - 4(1-2\alpha)(1+b)k_n]/Z_s.$$

Multiplying through by Z_s yields

$$k_n Z_n Z_s = A_n Z_s - 2(2-\alpha)(1+b)[A_s - 4(1-2\alpha)(1+b)k_n].$$

Collecting terms, we obtain

$$k_n^* = \{A_n Z_s - 2(2-\alpha)(1+b)A_s\}/\Delta$$

Similar operations yields

$$k_s^* = \{A_s Z_n - 4(1-2\alpha)(1+b)A_n\}/\Delta.$$

Appendix B

Proof that

(B1) $$dk_s^*/dt = 4\{(b-2)Z_n - 2(2-\alpha)(1-2\alpha)(1+b)(1-2b)\}/\Delta < 0.$$

Given

$$Z_n - 2(2-\alpha)(1-2\alpha)(1+b) > 0$$

by the second-order condition, we have, for $1 - 2b \leq 0$, that

$$-(1-2b)Z_n + 2(2-\alpha)(1-2\alpha)(1+b)(1-2b) > 0.$$

Adding this to the expression in braces in (B.1) yields $3(b - 1)Z_n < 0$. Therefore, for any $b \geq 1/2$, that expression in braces in (B.1) must be negative and hence $dk_s^*/dt < 0$. For $b < 1/2$, differentiate the numerator of dk_s^*/dt with respect to α to get

$$4\{4(b - 2)(2 - \alpha)(1 + b) - 2(-5 + 4\alpha)(1 + b)(1 - 2b)\}$$

$$= 8(1 + b)\{2(b - 2)(2 - \alpha) - (-5 + 4\alpha)(1 - 2b)\} = -24(1 + b)[1 + 2b(1 - \alpha)] < 0$$

and the denominator to get

$$d\Delta/d\alpha \equiv 4(2 - \alpha)(1 + b)Z_s - 8(-5 + 4\alpha)(1 + b)^2 > 0.$$

Thus, dk_s^*/dt is decreasing in α and hence takes the maximum value at $\alpha = 0$, which is

$$dk_s^*/dt = 4\{(b - 2)Z_n - 4(1 + b)(1 - 2b)\}/\Delta < 0.$$

Thus, for any $b < 1/2$, $dk_s^*/dt < 0$ for any α. We have shown that for any value of b and α $dk_s^*/dt < 0$. QED

Appendix C:

The total profit to firm S is

$$\pi_s = [w + 2k_s - (1 - 2\alpha)k_n - 2t_n]^2$$

$$+ b[W + 2k_s - (1 - 2\alpha)k_n + t_s]^2 - (\gamma_s/2)k_s,$$

where k_n and k_s are evaluated at the Nash equilibrium values. The direct effect is

$$\partial\pi_s/\partial t = -4[w + 2k_s - (1-2\alpha)k_n - 2t_n] + 2b[W + 2k_s - (1-2\alpha)k_n + t_s].$$

We also have

$$\partial\pi_s/\partial k_n = -2(1-2\alpha)[w + 2k_s - (1-2\alpha)k_n - 2t_n]$$

$$- 2b(1-2\alpha)[W + 2k_s - (1-2\alpha)k_n + t_s].$$

As in the text if transport costs are arbitrarily small and free trade initially, these are written as

$$\partial\pi_s/\partial t = (b-2)H.$$

$$\partial\pi_s/\partial k_n = -(1-2\alpha)(1-b)H$$

where

$$H \equiv 2[w + 2k_s - (1-2\alpha)k_n - 2t_n] > 0.$$

Therefore,

$$d\pi_s/dt = \{(b-2) - (1-2\alpha)(1+b)(dk_n/dt)\}H.$$

The term in braces is written as

$$(b-2) - (1-2\alpha)(1+b)dk_n/dt$$

$$= (b-2) - (1-2\alpha)(1+b)2(2-\alpha)\{(1-2b)Z_s + 4(1+b)(2-b)\}/\Delta$$

$$= (b-2)\{Z_nZ_s + 8(2-\alpha)(1-2\alpha)(1+b)^2\}/\Delta$$

$$- 2(1-2\alpha)(1+b)(2-\alpha)\{(1-2b)Z_s + 4(1+b)(2-b)\}/\Delta$$

$$= Z_s\{(b-2)Z_n - 2(1-2\alpha)(2-\alpha)(1+b)(1-2b)\}/\Delta,$$

which has the sign of $\{dk_s*/dt\}$ found in the text. Therefore,

$$\text{sgn}\{d\pi_s/dt\} = \text{sgn}\ \{dk_s*/dt\}.$$

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