Trade Contests

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Abstract

In this paper a new benchmark case for describing international trade is analysed: trade transactions as the outcome of contests between rival exporting firms. Contests between firms trigger non-cooperative strategic trade policies by countries. In the noncooperative subgame perfect equilibrium, one country subsidizes its domestic firm, the other country chooses an export tax. Both exporting countries are better off than in the equilibrium without strategic trade policy.

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1 Introduction

Orders for big projects or large scale sales contracts are often strongly contested even if there are few suppliers, particularly in the international trade of technologically advanced goods. The outcome of negotiations with potential buyers is not just a matter of prices - it also depends crucially on the seller's efforts to persuade the buyer that his offer is preferable to that of other competitors.

Consider, for instance, the decision to adopt a system of new high-speed trains. The international competition for such an order is poorly described by an ordinary market or by a standard price auction. Prices certainly matter, but the agreed price in the final contract is only one of many decision criteria. Acquisition of this contract has many of the features of a contest.

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Potential international contractors, like the French producer of the TGV and the German producer of the ICE, made considerable efforts to make their offers attractive. More generally, the effort involved may consist of (1) R&D effort, aimed at improving and tailoring the firm's product. (2) Firms may expend effort on making a credible commitment to future behavior that is desirable for the buyer. For the buyer of a system of high-speed trains or a new type of aircraft, it is important to know whether the seller intends to invest further in improving the product. If the buyer's decision implies that he is locked-in to a particular technology, it is important to know whether the seller will sell for a low price in the future. Where network externalities are involved, it is important to know whether this seller's product is likely to acquire a large market share.[1] Some commitment on these issues is feasible, but not costless.[2] Firms also expend effort on building up a reputation for providing reliable maintenance of their products. Almost all of these costs are not recoverable if the firm's effort is not successful. (3) Firms also usually expend considerable effort on activities like treating decision makers generously, or on other bribes. Recent scandals in the U.S. and in Italy[3] and the discussion in some countries about a reform of current tax law that allows tax deductibility of bribes suggest that bribes are important in modern trade.

What distinguishes effort in these examples from the standard instruments of competition, e.g., price reductions, is that these efforts are, in effect, sunk costs; the costs are incurred whether or not they lead to successful acquisition of the sales contract. Hence, sales contracts are allocated like the prizes in contests.[4]

Strategic trade theory has highlighted the idea that a government's trade policy can be seen as a commitment device for a domestic exporting firm that competes with a few firms from other countries as in the strategic trade model by Brander and Spencer (1985) with Cournot competition, or in its variant with Bertrand competition (Eaton and Grossman 1986). This paper considers strategic trade policy when international trade is the outcome of contests between exporting firms. The results are surprisingly different from standard results in strategic trade theory: Non-cooperatively chosen governmental export subsidies/taxes in the subgame perfect equilibrium in a set-up with two exporting countries are asymmetric even if countries are perfectly symmetric. One country chooses a tax, the other country chooses a subsidy. As a result compared to a free-trade situation strategic trade policy is beneficial for both exporting countries, for reasons different from the Bertrand price competition results in Eaton and Grossman (1986). If firms differ, world welfare may be higher in the strategic trade equilibrium, because strategic trade policy can increase the probability that the more efficient firm wins the contest.

International trade and government policy has always been closely linked with contests. The rent-seeking literature originated in trade theory (Krueger 1974, Tullock 1967) and rent seeking is an established issue in the modern theory of international trade (see, e.g., Hillman 1989). There is, however, a fundamental difference between the rent seeking literature in trade theory and the role of contests in trade discussed in this paper. Generically, the rent-seeking literature on trade considers firms' or other private agents' lobbying for governmental trade policy favors, such as import restrictions or export subsidies. Government action is the target of lobbyists. In these lobbying models the government can be bribed, but the actual international trade occurs in markets where prices are the determinants of trade flows. In this paper, by contrast, government is fully benevolent and simply maximizes national welfare. Firms do not contest for government favors. The trading process itself is the contest.

The paper is more closely related to the recent literature that emphasizes contests, or, equivalently, all-pay auctions, as a general allocation mechanism which often complements and sometimes even substitutes more conventional market transactions. [5] For general discussion and motivation see Dixit (1987), Garfinkel and Skaperdas (1996), and Skaperdas and Syropoulos (1997).

2 The model

Consider two firms, 1 and 2. Firm 1 resides in country 1, firm 2 resides in country 2. These firms compete in the international market. A customer in a third country wants to buy one unit of some good (for instance, a system of high-speed trains) which firms 1 and 2 could both supply. The firms compete for the contract. Let B_i be firm i's benefit from being awarded the contract if there are no export taxes or subsidies. We assume that these benefits are strictly positive and given[6] for the two firms. Without export taxes or subsidies both firms would like to acquire the contract. Without loss of generality we assume $0 < B_1 \leq B_2$ throughout the paper, where $B_2 - B_1$ is called firm 2's cost advantage.

We justify $B_i > 0$ in two ways. First, for hi-tech goods that involve a technological lock-in for the buyer, or for goods which have strong network externalities, the benefit B_i can be considered as a reduced form of a more complicated model with information asymmetries and incomplete contracts in which the buyer cannot fully appropriate the firm's rents.[7] Second, models of international trade usually ignore the contest aspects of sales contracts completely, although promotional effort is a fact of life. They concentrate

on a special benchmark case. This paper considers the opposite benchmark case in which the allocation function of prices is removed from the picture, but the contest aspect is fully taken into consideration.

The contract is awarded to one of the two firms in a contest according to a contest success function. Contest success is a function of the up-front effort e_1 and e_2 firms spend to persuade the buyer that a firm's product is preferable to others: firm 1 wins the contract with probability

$$\pi_1(e_1, e_2) = \begin{cases} 1 & if \quad e_1 > e_2 \\ 1/2 & if \quad e_1 = e_2 \\ 0 & if \quad e_1 < e_2. \end{cases} \tag{1}$$

Firm 2 wins the contract with the remaining probability $\pi_2 = 1 - \pi_1$. In the contest literature, the contest success function in (1) is called fully discriminatory, because a small difference in effort is decisive. The contest success function (1) is particularly relevant because a buyer who wants to maximize expected contest effort and can choose the contest success function chooses a fully discriminatory contest success function. But the results obtained are qualitatively robust for other contest types which allow for some "noise".[8] This will be discussed later.

Consider the following 2-stage game. In STAGE 1, before the firms choose their contest efforts, the governments in countries 1 and 2 simultaneously choose subsidies, s_1 and s_2, respectively. The subsidy can be negative, in which case it is a tax. The subsidy s_i changes firm i's benefit from being awarded the contract from B_i to

$$V_i \equiv B_i + s_i. \tag{2}$$

Subsidies cannot be infinitely high: $s_i \leq s_{\max}$ with $s_{\max} \in [0, \infty)$. The maximum subsidy $s_{\max}$ is the same for both firms (for simplicity), taken as exogenously given and publicly known.[9] The main results do not qualitatively depend on the size of $s_{\max}$.[10] Empirically, possible values of subsidies are implicitly determined by international agreements like the GATT rules, and by the opportunities the countries' governments have for not strictly obeying the rules.

Subsidies are paid only if the firm wins the contract. Subsidies that are paid independently of success would not alter the firms' valuation of winning the contest as in (2). Empirically, many subsidies are tied to firms' actual exports. This is also the ongoing assumption in much of the strategic trade literature (e.g., Brander and Spencer 1985).

Trade theory with strategic R&D subsidies typically assumes that R&D subsidies are tied to the R&D effort, but are independent of how successful a firm eventually is as an exporter (e.g., Spencer and Brander 1983, and Bagwell and Staiger 1992, 1994). The outcome in these models is also very different from the outcome here, although the structure of R&D contests is related, particularly if firms use R&D in a contest for monopoly, as in Bagwell and Staiger (1994). The fact that R&D subsidies are independent of success in these models may explain why the equilibrium strategic trade policy in this paper is different from trade policy with strategic R&D subsidies.

In STAGE 2 the firms simultaneously choose their efforts in the contest. When making this choice they take the governments' choices of export subsidies into account.

3 The trade contest

In STAGE 2 government export subsidies s_1 and s_2 are given. The firms contest for the contract. They choose their contest efforts e_1 and e_2 simultaneously and the winner of the contest is determined according to the contest success function as in (1). Firm i's payoff ψ_i for given effort choices equals the firm's expected benefit from winning the contest minus the firm's effort:

$$\psi_i = \pi_i(e_1, e_2)V_i - e_i \tag{3}$$

for $i = 1, 2$, where V_i is defined in (2). There is no equilibrium in pure strategies[11] but a unique equilibrium in mixed strategies exists. Strategies are characterized by cumulative density functions (c.d.f.'s) $F_1(e_1)$ and $F_2(e_2)$ with regard to firm 1's and firm 2's efforts. The equilibrium c.d.f.'s for $0 < V_1 \leq V_2$ are[12]

$$F_1(e_1) = 1 - (V_1/V_2) + e_1/V_2 \text{ for } e_1 \in [0, V_1], \tag{4}$$

$$F_2(e_2) = e_2/V_1 \text{ for } e_2 \in [0, V_1], \tag{5}$$

with $F_i(e_i) = 0$ for $e_i < 0$, and $F_i(e_i) = 1$ for $e_i > V_1$ for $i = 1, 2$ (see Hirshleifer and Riley 1992 and, for an elegant proof of this result, Baye, Kovenock and deVries 1996). Firm 1 puts probability mass equal to $1 - \frac{V_1}{V_2}$ on $e_1 = 0$. If $0 < V_2 \leq V_1$, subscripts «1» and «2» have to be interchanged in (4) and (5) to obtain the stage-2 equilibrium.

In a mixed strategy equilibrium, for the whole support of firm 1's equilibrium effort distribution, firm 1 must be indifferent to whether to change

its effort marginally. If firm 1 increases its effort by one marginal unit, the marginal cost is one unit. The marginal benefit of this is the gain in firm 1's winning probability by $\frac{dF_2(e)}{de}$ at $e = e_1$ times firm 1's valuation of the contract. Hence, the marginal condition that must hold in the equilibrium is $1 = \frac{dF_2}{de} V_1$. This explains the uniform distribution $F_2(e_2)$ in (5). The same argument applies for firm 2 and the distribution $F_1(e_1)$.

Firm 1 will never spend more than $e_1 = V_1$. Firm 2 could always choose effort (slightly higher than) V_1 and obtain a payoff of $V_2 - V_1$. In the equilibrium firm 2 also chooses effort levels from the support $[0, V_1]$. This is possible only if these choices yield at least this payoff. This is the case for (4) and (5) because the distribution of firm 1's effort has a mass point at zero. Thus, even if e_2 is infinitesimally close to zero, there is a probability $(1 - V_1/V_2)$ that firm 2 will win. This probability mass that firm 1 chooses zero effort is higher if firm 1's valuation of the contract is lower, and if firm 2's valuation is higher.

The firms' winning probabilities, expected effort, and payoffs in the equilibrium can be derived from (4) and (5). For $V_1 \leq V_2$, firms win with probabilities

$$\pi_1^*(V_1, V_2) = \frac{V_1}{2V_2} \text{ and } \pi_2^*(V_1, V_2) = 1 - \frac{V_1}{2V_2}. \tag{6}$$

Expected efforts in the equilibrium are

$$Ee_1{}^*(V_1, V_2) = \frac{(V_1)^2}{2V_2} \text{ and } Ee_2{}^*(V_1, V_2) = \frac{V_1}{2}. \tag{7}$$

An increase in firm 2's valuation only reduces the equilibrium effort of firm 1, whereas an increase in firm 1's valuation increases both firms' efforts.

A firm's payoff is the same for all effort levels which are in the firm's equilibrium support $[0, V_1]$. If, for instance, firm i chooses $e_i = V_1$, it wins with probability 1 and has a payoff equal to $V_i - V_1$. Hence, the firms' equilibrium payoffs are

$$\psi_1^*(V_1, V_2) = 0 \text{ for all } e_1 \in (0, V_1) \text{ and} \tag{8}$$

$$\psi_2^*(V_1, V_2) = V_2 - V_1 \text{ for all } e_2 \in (0, V_1). \tag{9}$$

Subsidies change the firms' valuations according to (2). As long as $V_1 < V_2$, firm 1 will spend expected effort equal to the expected gains (its valuation times winning probability). Firm 1's equilibrium payoff is equal to zero and is independent of firms' valuations. Firm 2's payoff is the difference between

the firms' contract valuations. It increases in its own valuation and decreases in the other firm's valuation:

$$\frac{d\psi_1^*}{dV_1} = \frac{d\psi_1^*}{dV_2} = 0 \text{ and } \frac{d\psi_2^*}{dV_2} = 1 = -\frac{d\psi_2^*}{dV_1}. \tag{10}$$

(For $V_2 \leq V_1$ all subscripts 1 and 2 in this paragraph and in (6), (7), (8), (9) and (10) have to be interchanged.)

4 Strategic trade policy

Consider now the countries' simultaneous choices of strategic trade policies in stage 1. The government in each country is assumed to place equal weight on the home-firm's profit and the government's tax revenue in evaluating social welfare. Its objective is therefore one of maximizing expected national rents Λ_i, with

$$\Lambda_i = \pi_i^* B_i - Ee_i{}^* \tag{11}$$

for $i = 1, 2$. Here, π_i^* and $Ee_i{}^*$ are functions of V_1 and V_2 as defined in (6) and (7). The subsidy payment to the firm nets out in (11). When maximizing Λ_i, the government in country i takes the other country's strategic trade policy as given and takes into account the fact that the firms' equilibrium choices of effort in stage 2 are functions of the trade policies. The export subsidies/taxes in the subgame perfect equilibria in pure strategies are characterized as follows.[13]

Proposition 1
(i) *There are at most two subgame perfect equilibrium choices of subsidies* (s_1, s_2) *in pure strategies*
(E1) $(s_1, s_2) = ((-B_1/2), s_{\max})$ *and*
(E2) $(s_1, s_2) = (s_{\max}, (-B_2/2))$.
(ii) *Given* $B_1 \leq B_2$, *the equilibrium* (E1) *always exists.*
(iii) *For any given* $(B_2 - B_1)$, *a sufficiently large* $s_{\max}$ *exists such that* (E2) *is also an equilibrium pair of strategic trade policies.*
(iv) *For any given* $s_{\max} \geq 0$, *the pair of policies* (E2) *is also an equilibrium if* $(B_2 - B_1)$ *is sufficiently small. In particular, both* (E1) *and* (E2) *are equilibria if* $B_2 = B_1$.

A proof is in the appendix. Here we only confirm that $s_1 = -B/2$ and $s_2 = s_{\max}$ are optimal replies to each other for firms with $B_1 = B_2 \equiv B$.

Suppose $s_1 = -B/2$ (or, equivalently, $V_1 = B/2$), and consider country 2's optimal reply. Country 2's payoff is $\Lambda_2 = \pi_2^* B - Ee_2{}^*$. For all

$s_2 \in [-B/2, s_{\max}]$, $Ee_2{}^* \underset{(7)}{=} \frac{V_1}{2}$ and B are independent of s_2. The equilibrium probability π_2^* is strictly increasing in s_2 by (6). If firm 2's valuation of the contract increases, the probability that firm 1 chooses to quit (choose $e_1 = 0$) increases. Hence, country 2 maximizes its expected rent by maximizing V_2, that is, by a choice $s_2 = s_{\max}$.

Suppose $s_2 = s_{\max}$ and consider country 1's optimal reply. Country 1 knows that firm 1 will make zero profit in the contest, as $V_1 \leq V_2$ for all feasible choices $s_1 \in [-B, s_{max}]$. Country 1's payoff, however, depends on s_1. The firm spends expected effort equal to $Ee_1{}^* = V_1\pi_1^*(V_1, B + s_{\max})$ which is also a cost to the country, and the country's expected benefit from this is $B\pi_1^*(V_1, B + s_{\max})$. Hence, country 1's payoff is

$$\Lambda_1 = (B - V_1)\pi_1^*(V_1, B + s_{\max}) \underset{(2),\ (6)}{=} (-s_1)\frac{B + s_1}{2(B + s_{\max})}. \tag{12}$$

The country's payoff in the equilibrium is equal to the tax payment times the probability with which this payment occurs. If country 1 chooses $s_1 = 0$, the country's payoff is exactly zero. V_1 exceeds B for positive subsidies, yielding a negative payoff, and for negative subsidies the country's payoff is positive. Payoff (12) is maximized for $s_1 = -B/2$.

In the strategic trade policy game with trade contests, countries use two different types of policies that have effects similar to the 'strategic effects' discussed in strategic trade theory. This can be seen as follows.

The positive export subsidy in one country increases the firm's benefit from winning the contract in this country. This firm becomes a stronger contestant. This has a 'strategic effect'. It induces the firm in the other country to reduce contest effort (i.e., choose zero effort with higher probability). In the trade contest equilibrium one of the countries pursues this policy as far as possible and chooses the highest possible subsidy.

In most strategic trade models, the incentive to increase the home firm's competitiveness is mutual: both countries use the same mechanism in the equilibrium, because the first units of a subsidy increase the home firm's expected profit by more than the cost of the subsidy. In the trade contest, however, the incentive is not mutual. If one country chooses the maximum subsidy, it is harmful for the government in the other country to follow a similar strategy: given that country 2 chooses $s_{\max}$, country 1 cannot generate any positive expected profit for its firm. Any positive subsidy s_1 even generates a welfare loss in country 1 equal to the subsidy times firm 1's win probability.[14]

The nature of the trade contest opens up a different way for the government in country 1 to obtain a rent. Even if firm 1's benefit from winning the

contract is lower than firm 2's benefit, in a contest firm 1 has a strictly positive probability ($\pi_1^* = \frac{V_1}{2V_2}$) for winning the contract. Firm 1's expected profit net of the tax is exactly zero in the trade contest. In expectation the firm spends the same amount of contest effort as this profit net of the tax, equal to $\pi_1^* V_1$. But this implies that the country's expected benefits $\pi_1^* B_1$ exceed expected effort $\pi_1^* V_1$ if $s_1 < 0$. The difference is $(-s_1)\pi_1^*$. This difference is maximized for a given V_2 by a choice $s_1 = -B_1/2$.[15]

This result can also be interpreted in terms of a strategic effect. If country 1 increases its tax, this reduces V_1 and, in turn, this reduces firm 2's equilibrium effort: the equilibrium c.d.f. of firm 2's effort shifts to lower effort levels in the sense of first-order stochastic dominance. Thus, the tax in country 1 induces the firm in country 2 to behave less agressively in the contest.

Because there is a one-to-one correspondence between subsidies and firms' valuations by (2), countries can be considered as choosing their firms' valuations. Countries' reaction curves $\sigma_i(V_j)$ are derived more formally in the Appendix. For symmetric firms ($B = B_1 = B_2$),

$$\sigma_1(V_2) = \begin{cases} B + s_{\max} \text{ if } B + s_2 \leq \bar{V}_2 \\ B/2 \text{ if } B + s_2 > \bar{V}_2 \end{cases} \tag{13}$$

where $\bar{V}_2$ is the critical value of firm 2's valuation that makes country 1 just indifferent between pursuing a maximum subsidy or a tax equal to $s_1 = -B/2$. For $\sigma_2(V_1)$ all subscripts have to be interchanged. Regardless of the other country's choice, only two strategies can be optimal for a country. A country can go for the tax revenue (in which case $s_i = -B/2$ is a dominant strategy) or for the large firm profit (in which case $s_i = s_{\max}$ is a dominant strategy). Which strategy yields higher rents for the country depends on the other country's strategic trade policy. If country 2 chooses a subsidy $s_2 < \bar{V}_2 - B$, firm 2 will not contest very fiercely. Country 1 can generate rent in this case by making its home firm very eager to win the contest. If country 2 chooses subsidies higher than $\bar{V}_2 - B$, it is not desirable for country 1 to try to increase its home firm's profits by making its own firm very eager to win the contest. Since the other firm is also very eager to win, this would lead to a fierce contest and yield a rent lower than the one that can be obtained from taxing the home firm. It does not make sense for a country to pursue the same strategy as the other country here. Instead, taxing the home firm, the country can generate a strictly positive payoff.[16]

5 Welfare

The welfare properties of strategic trade policy games with trade contests as in Proposition 1 differ from those in the standard strategic trade model.

We concentrate on the symmetric case with $B_1 = B_2 = B$. In a free-trade situation with $s_1 = s_2 = 0$ firms have the same benefits $V_1 = V_2 = B$ from being awarded the contract. In the contest equilibrium both the firms make zero expected profit and the payoffs for the two countries are also zero.

In the strategic trade policy equilibrium as in (E1) (or, analogously in (E2)) the taxed firm in country 1 makes zero expected profits and the subsidized firm 2 in country 2 makes strictly positive expected profits equal to $V_2 - V_1 = (B/2) + s_{\max}$. Both countries have strictly positive expected rents. The equilibrium payoffs are $B - \frac{1}{2}\frac{(2B+s_{\max})}{(B+s_{\max})}\frac{B}{2} > 0$ in the country that chooses $s_j = s_{\max}$, and $\frac{1}{B+s_{\max}}\frac{B^2}{8} > 0$ in the country that chooses $s_j = -B/2$. Strategic trade policy is beneficial for both exporting countries. The sum of the countries' rents is equal to the reduction in total contest effort in the strategic trade policy equilibrium, compared to free trade. Total effort is reduced from $\frac{B}{2} + \frac{B}{2}$ (with free trade) to $\frac{B}{4}\frac{B}{2(B+s_{\max})} + \frac{B}{4}$.

In a strategic trade policy game with Cournot competition as in Brander and Spencer (1985), each country's activity reduces the competition activity (output) in the other country's firm, but also increases the competition acitivity (output) in their own firm. Since the latter effect is stronger, both countries lose, compared to free trade. In the strategic trade policy game with trade contests, each country does something to reduce the firm's equilibrium effort in the other country. In contrast to the Brander and Spencer framework, these activities also do not induce their home firms to increase wasteful contest effort. Hence, total effort is reduced and the benefits of this decreased effort are shared between the two countries. The welfare result is stated more generally as

Proposition 2: *In a trade contest with symmetric firms and non-cooperative governmental strategic trade policies, total contest effort is lower and both exporting countries enjoy a higher payoff in the equilibrium than in the equilibrium without strategic trade policies.*

The result in Proposition 2 holds for the equilibrium (E1) *a fortiori* if $B_2 > B_1$: both countries enjoy a higher payoff in (E1) than in a situation $(s_1, s_2) = (0, 0)$. Proposition 2 states that the strategic trade policy game leads to increased rents in the exporting countries. If both countries have the same valuation of the prize, this increase in rents is equal to the reduction in contest efforts. In particular, if contest effort is fully wasteful, the reduction in contest effort can also be seen as efficiency enhancing. However, effort

may or may not generate beneficial effects in the importing country, making a welfare analysis with respect to changed effort less straightforward.

A second welfare relevant dimension is the firms' costs of carrying out the contract. Consider the equilibrium (E1) characterized above by $s_1 = -B_1/2$ and $s_2 = s_{\max}$. This equilibrium always exists by (ii) in Proposition 1. Strategic trade policy can be efficiency enhancing in the following sense:

Proposition 3: *In the strategic trade policy equilibrium as in (E1), the probability is higher that the contract is awarded to the firm that has a cost advantage than in the situation without strategic trade policy.*

Proof. Consider firm 2 that has a cost advantage: $B_2 - B_1 \geq 0$. In the situation $(s_1, s_2) = (0, 0)$ without strategic trade policy, firm 2 wins the contest with probability $\pi_2 = 1 - \frac{B_1}{2B_2}$. In the strategic trade policy equilibrium as in (E1), this firm wins the contest with probability $\pi_2^* = 1 - \frac{V_1}{2V_2} = 1 - \frac{B_1/2}{2(B_2 + s_{\max})}$. As $s_{\max} \geq 0$ this implies $\pi_2^* > \pi_2$. □

Consider country 1 that has chosen $s_1 = -B_1/2$. Its payoff could be increased relative to the subgame perfect equilibrium outcome if country 2 could be induced to choose a subsidy that is smaller than country 2's equilibrium choice $s_2 = s_{\max}$, as $\frac{d\Lambda_1}{ds_2}\big|_{s_1 = -B/2} \underset{(11),(6),(7)}{=} -\frac{1}{(B_2+s_2)^2}\frac{(B_1)^2}{8} < 0$. Country 1 has an interest in a trade agreement that limits the amount of export subsidies. On the other hand, neither country would like to limit or ban export taxes. The fact that country 1 decreases its domestic firm's after-tax benefit V_1 in the equilibrium causes an increase in both countries' payoff.

Country 1's choice $s_1 = -B_1/2$ highlights the non-cooperative nature of the equilibrium. The sum of the payoffs of the two countries would be maximized if the government in country 1 chose $s_1 = -B_1$ (that is, $V_1 = 0$). However, a choice $s_1 = -B_1$ does not constitute a non-cooperative equilibrium strategy. Country 1 had an incentive to defect and to choose a lower tax. Note also that the choice $s_1 = -B_1$ would further enhance cost efficiency, as the firm 2 (the firm that has a cost advantage) would be awarded the contract with probability $\lim_{V_1 \to 0}(1 - \frac{V_1}{2V_2}) = 1$.

In addition to the equilibria in pure strategies in stage 1, mixed strategy equilibria also exist and become relevant if firms are unable to solve the coordination problem for choosing one of the two equilibria (E1) or (E2), if both exist. As will be shown in Section 5, the mixed strategy equilibria also have a strictly positive sum of payoffs, strictly higher than in the case of free trade.

6 Mixed strategy equilibria

In proposition 1, if two non-cooperative equilibria in pure strategies exist, coordination is required. In (E1), and also in (E2) if the difference between B_1 and B_2 is not very big, both countries gain compared to the laissez-faire equilibria without strategic trade policies. However, typically, each country would like to be the one that chooses the highest possible subsidy. Country 1 prefers to coordinate on (E2) and country 2 prefers to coordinate on (E1). Accordingly, coordination may fail. The mixed strategy equilibria without coordination share one property with the equilibria characterized in proposition 1:

Proposition 4: *In any strategic trade policy equilibrium with the fully discriminatory trade contest, the expected rent in both countries is strictly positive.*

A proof is by contradiction. Let $G_i(s_i)$ with $s_i \in [-B_i, s_{\max}]$ be the cumulative distribution function of country i's subsidy in stage 1 in the strategic trade policy equilibrium, for $i = 1, 2$. In stage 2 the actual pair of trade policies is observed by the firms and the resulting trade contest equilibrium is unique and is in mixed strategies as described in section 3. Consider the particular strategy of country 2: a tax equal to $s_2 = -B_2/2$. Let country 1 choose some arbitrary $s_1 \in [-B_1, s_{\max}]$. By (16) in the appendix, the expected rent of country 2 is

$$B_2 - (B_1 + s_1)\frac{3}{2} \tag{14}$$

if $(B_1 + s_1) < B_2/2$, and by (18), the expected rent of country 2 is

$$((B_2)^2/8)(1/(B_1 + s_1)) \tag{15}$$

if $(B_1 + s_1) \geq B_2/2$. In both cases the expected payoff is strictly positive, and hence, country 2's payoff is also positive for any mixed equilibrium strategy $G_1(s_1)$ of country 1. In an equilibrium, the strategies chosen by country 2 are optimal responses to $G_1(s_1)$. It must be true that country 2's payoff in a (mixed) equilibrium strategy cannot be lower than the payoff from simply choosing $s_2 = -B_2/2$. Hence, country 2's payoff in the equilibrium is strictly positive. The same argument applies for country 1, which could also obtain a positive payoff by choosing $s_1 = -B_1/2$. □

Proposition 4 shows that the countries' gains in the strategic trade equilibria are not only due to the coordination that is needed to reach the equilibria characterized in proposition 1. Non-cooperative strategic trade policies in trade contests can increase the payoffs of both countries, whether countries

coordinate on non-cooperative pure-strategy equilibria or not. This follows directly from considering the perfectly symmetric case. If the two firms have the same valuation, both countries earn a payoff equal to zero in the free-trade contest equilibrium. In the pure strategy equilibria characterized in Proposition 1, both countries earn strictly positive payoffs. Proposition 4 shows that both countries also earn a strictly positive payoff even in a mixed strategy equilibrium without coordination.

7 Conclusions

In this paper a new benchmark case for describing international trade has been analysed: trade transactions as the outcomes of contests between rival exporting firms. The incentives for strategic trade policy in the benchmark case have been contrasted with results in the strategic trade literature. Even if countries are perfectly symmetric, trade contests trigger asymmetric non-cooperative strategic trade policies. One country may increase its exporting firms' net benefits of winning the trade contest, whereas another country may tax its exporting firms. The subgame perfect equilibria are not a prisoners' dilemma outcome. Both exporting countries are better off in the non-cooperative equilibrium with strategic trade policies than without government intervention.

8 Appendix

Proof of Proposition 1. Recall that the stage-2 equilibrium is uniquely determined and depends only on (V_1, V_2) . Consider country 2's reaction function. By $V_i = B_i + s_i$ there is a one-to-one correspondence between s_i and V_i. Hence, the reaction function can be stated as $V_2 = \sigma_2(V_1)$. For any V_1, if country 2 chooses $V_2 > V_1$, the expected payoff of country 2 is

$$\Lambda_2 = B_2 \int_0^{V_1} F_1(e)F_2'(e)de - \int_0^{V_1} eF_2'(e)de = B_2(1 - \frac{V_1}{2V_2}) - \frac{V_1}{2} \qquad (16)$$

with $F_1(e_1) = 1-(V_1/V_2)+e_1/V_2$ and $F_2(e_2) = e_2/V_1$ the stage-2 equilibrium c.d.f.s. The payoff is equal to B_2 times the equilibrium probability that firm 2 is awarded the contract, minus the expected effort spent by firm 2. The subsidy or tax that is paid by the government in country 2 to its domestic firm nets out. The payoff in (16) is strictly increasing in V_2 and is maximal for the largest possible choice of $V_2 = B_2 + s_{\max}$. This maximum value is

$$\hat{\Lambda}_2 = B_2 - \frac{1}{2}\frac{(2B_2) + s_{\max}}{B_2 + s_{\max}} V_1. \tag{17}$$

Alternatively, country 2's government could choose some $V_2 \leq V_1$. In this case the stage-2 equilibrium c.d.f.s of effort are $F_1(e_1) = e_1/V_2$ and $F_2(e_2) = 1 - (V_2/V_1) + e_2/V_1$, and country 2's payoff is

$$\Lambda_2 = B_2 \int_0^{V_2} F_1(e) F_2'(e) de - \int_0^{V_2} e F_2'(e) de = (B_2 - V_2)\frac{V_2}{2V_1} \tag{18}$$

Subject to the constraint $V_2 \leq V_1$ this function assumes its maximum for a given choice V_1 at $V_2 = V_1$ in the range of $V_1 \leq B_2/2$, and at $V_2 = B_2/2$ in the range of $V_1 \geq B_2/2$. The maximum values are

$$\check{\Lambda}_2 = \begin{cases} (B_2 - V_1)/2 & for \quad V_1 \leq B_2/2 \\ [(B_2)^2/8](1/V_1) & for \quad V_1 \geq B_2/2 \end{cases} \tag{19}$$

Note that $\hat{\Lambda}_2 > \check{\Lambda}_2$ for $V_1 \in [0, (B_2/2)]$. Further, $\hat{\Lambda}_2$ and $\check{\Lambda}_2$ intersect exactly once for V_1 being in the interval $[(B_2/2), \infty)$, as $\hat{\Lambda}_2 > \check{\Lambda}_2$ at $V_1 = B_2/2$, $\check{\Lambda}_2 > 0$ for all $V_1 \in [(B_2/2), \infty)$, $\lim_{V_1 \to \infty} \check{\Lambda}_2 = 0$, $\partial \check{\Lambda}_2/\partial V_1 < 0$, $\partial^2 \check{\Lambda}_2/(\partial V_1)^2 > 0$ on the interval $V_1 \in ((B_2/2), \infty)$, and $\hat{\Lambda}_2$ downward sloping and linear in V_1. The point of intersection is implicitly defined by the larger of the two solutions for V_1 of

$$\frac{(B_2)^2}{8}\frac{1}{V_1} = B_2 - \frac{1}{2}\frac{(2B_2) + s_{\max}}{B_2 + s_{\max}} V_1. \tag{20}$$

Denote this solution $\bar{V}_1$. In particular, $\bar{V}_1 > B_2/2$. This yields country 2's reaction function

$$\sigma_2(V_1) = \begin{cases} B_2 + s_{\max} & for \quad V_1 < \bar{V}_1 \\ (B_2/2) & for \quad V_1 \geq \bar{V}_1 \end{cases} \tag{21}$$

Similarly, we obtain country 1's reaction function as

$$\sigma_1(V_2) = \begin{cases} B_1 + s_{\max} & for \quad V_2 < \bar{V}_2 \\ (B_1/2) & for \quad V_2 \geq \bar{V}_2 \end{cases} \tag{22}$$

with $\bar{V}_2$ being the larger value of the two solutions for V_2 of

$$\frac{(B_1)^2}{8}\frac{1}{V_2} = B_1 - \frac{1}{2}\frac{(2B_1)+s_{\max}}{B_1+s_{\max}}V_2. \tag{23}$$

This yields the following pure strategy equilibria as the only possible intersections of the two reaction curves:

$$(V_1, V_2) = ((B_1 + s_{\max}), (B_2/2)) \text{ if } B_1 + s_{\max} \geq \bar{V}_1, \tag{24}$$

$$(V_1, V_2) = ((B_1/2), (B_2 + s_{\max})) \text{ if } B_2 + s_{\max} \geq \bar{V}_2. \tag{25}$$

The argument that yields the equilibria in (24) and (25) makes use of the result $(B_1/2) < \bar{V}_1$ and $(B_2/2) < \bar{V}_2$. This confirms (i).

Now consider claim (iii). Note that $\hat{\Lambda}_i = B_i$ for $V_j = 0$ and the slope of $\hat{\Lambda}_i$ is $\partial\hat{\Lambda}_i/\partial V_j \in [-1, -1/2]$. Hence, $\bar{V}_j \leq 2B_i$. This implies that the condition $B_i + s_{\max} \geq \bar{V}_i$ is always fulfilled for both countries if $s_{\max}$ is sufficiently large. This in turn implies that both asymmetric equilibria exist if $s_{\max}$ is sufficiently large and this shows (iii).

Next consider claim (ii). To see that $B_2 + s_{\max} \geq \bar{V}_2$ is always fulfilled for country 2 for any $s_{\max} \geq 0$, we substitute $B_2 + s_{\max}$ for V_2 in $\check{\Lambda}_1$ and $\hat{\Lambda}_1$ and show that $\check{\Lambda}_{1|V_2=B_2+s_{\max}} > \hat{\Lambda}_{1|V_2=B_2+s_{\max}}$ for all $s_{\max} \geq 0$. Substituting according to (17) and (19), but for $i = 1$ yields the equivalent inequality

$$\check{\Lambda}_{1|V_2=B_2+s_{\max}} = \frac{(B_1)^2/8}{B_2+s_{\max}} > B_1 - \frac{(2B_1)+s_{\max}}{2(B_1+s_{\max})}(B_2+s_{\max}) = \hat{\Lambda}_{1|V_2=B_2+s_{\max}} \tag{26}$$

which is fulfilled by $B_2 \geq B_1$ for any $s_{\max} \geq 0$. Hence, $(V_1, V_2) = ((B_1/2), (B_2 + s_{\max}))$ is an equilibrium choice of strategic trade policies. This shows (ii).

Notice finally that for $B_2 = B_1$ (or actually, for sufficiently small differences between B_1 and B_2) condition (26) and the corresponding condition for country 1,

$$\frac{(B_2)^2/8}{B_1+s} \geq B_2 - \frac{(2B_2)+s}{2(B_2+s)}(B_1+s) \tag{27}$$

are fulfilled, implying that both asymmetric equilibria as in (E1) and (E2) exist if $B_1 = B_2$. This shows (iv).

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10 Footnotes

[1] Many examples of the contest nature of business when network effects are important are described in the literature on network externalities. Katz and Shapiro (1994, p. 107) explain in their survey paper that, in the competition between incompatible systems, firms are effectively bidding for future monopoly profits if the medium or long run outcomes are expected to be tipping towards a single system.

[2] For a discussion see, for instance, Farrell and Gallini (1988) who consider second-sourcing and Thum (1995) who considers capacity commitment.

[3] Pervasiveness of bribes in Italy's business world was the reason for several government crises in Italy in this decade. Bribes may be even more pervasive in the new market economies in former socialist countries. There, the issue of bribes is intermingled with issues such as protection and extortion carried out by organized crime.

[4] The contest aspect is more important in some types of international trade than in others. When firms trade quantities of standardized and highly divisible goods and compete with many other firms, neglecting contest aspects altogether may be justified. However, particularly when a few firms contest for large indivisible projects, contest aspects may well become dominant, when aspects like the accountability of the firm or prospects about the firm's future technological achievements and updates of its product matter, or if compatibility issues combined with technological uncertainty create problems related to network externalities (Besen and Farrell 1994).

[5] Lobbying more generally, and campaign contributions (see, e.g., Skaperdas and Grofman 1995) is a major field in which this insight has been applied. But the role of contests is more pervasive than this. See, for instance, Hirshleifer (1995) on military conflict, Skaperdas (1992) on production and appropriation in the absence of property rights, or Rosen (1986) and Glazer and Hassin (1988) on tournaments in the labor market.

[6] Exogeneity of B_i is assumed for simplicity. If the benefits B_i are not exogenously given, the pricing decisions and the firms' efforts as part of the contest activities are not necessarily independent. However, here it is left to future research to investigate these dependencies in a richer setting.

[7] Even in a standard agency model with a continuum of types, all types except the 'lowest' type receive an information rent. This generates strictly positive benefits B_i with probability one.

[8] Contests in which the contestant who spends less effort can still win with positive probability are sometimes called non-discriminatory. For an axiomatization of such contests see Skaperdas (1996).

[9] For the results about the equilibrium in Proposition 1 below, it is not

necessary that both countries know the other country's precise value of the maximum subsidy. It can be shown that it is sufficient for the intervals of possible values of the other country's $s_{\max}$ to be sufficiently narrow.

[10] The upper limit $s_{\max}$ could also be endogenized in several ways. Suppose, for instance, that countries have a political cost if they violate GATT rules by choosing a subsidy that exceeds zero, and let this cost function be strictly convex in the size of the violation. This yields similar equilibrium results to those obtained in section 4. The case with exogenous $s_{\max}$ becomes a special case with a cost function which has zero cost for $s_i \leq s_{\max}$ and infinite cost for $s_i > s_{\max}$.

[11] A proof is by contradiction. Clearly, $(e_1^*, e_2^*) = (0, 0)$ is not an equilibrium. Let the equilibrium be (e_1^*, e_2^*) with some positive effort, e.g., $e_1^* > 0$. Firm 2's optimal reply is $e_2^* = 0$ or $e_2^* = e_1^* + \varepsilon$, slightly higher than e_1^*. But this $e_1^* > 0$ is not an optimal reply to $e_2^* = 0$ or to $e_2^* = e_1^* + \varepsilon$. Hence, (e_1^*, e_2^*) is not an equilibrium.

[12] If $V_i \leq 0 < V_j$, the stage-2 equilibrium is characterized by $e_i = 0$ and firm j choosing the smallest positive effort that is possible. Finally, if $V_i \leq V_j \leq 0$, the equilibrium choices of effort are $e_i = e_j = 0$. These further results are reported only for completeness. As we assumed $B_1 > 0$ and $B_2 > 0$, it can be shown by contradiction that only $0 < V_i \leq V_j$ are possible outcomes in any subgame perfect equilibrium.

[13] If the trade contest is not fully discriminatory, equilibria that are qualitatively similar to the ones characterized in Proposition 1 occur. For instance, if the trade contest is a standard Tullock (1980) contest, the strategic trade equilibrium has a tax in one country and the maximum subsidy in the other for a wide parameter range. As a full analysis is very space consuming, a numerical example may illustrate this point. Let the contest success probabilities be $\pi_i = e_i/(e_i + e_j)$. Further, let $B_1 = 3B_2/4$ and $s_{max} = 0$. Straightforward calculations show that the equilibrium has $V_1 = 3B_2/5$ and $V_2 = B_2$, implying that $s_1 = -3B_2/20 < 0$ and $s_2 = s_{max} = 0$. Like in Proposition 1, one country taxes its firm whereas the other country chooses the highest possible subsidy.

[14] More generally, it does not pay for country 1 to match or top the subsidies of country 2 if these subsidies are very high, even if country 2 does not choose the maximum subsidy. In topping country 2's subsidy, country 1 could generate some profit for the home firm, but the contest between firms is extremely wasteful. This argument can be used to generalize the results in Proposition 1 if countries have different maximum subsidies, or if countries know their own maximum subsidy, but not that of the other country.

[15] Bagwell and Staiger (1997) consider strategic trade policy with two firms competing for a natural monopoly. Firms have fixed cost of entry. If

only one firm enters it has a monopoly. Firms play a Bertrand game with homogenous products if both firms enter. In the free-trade situation firms fail to co-ordinate on entry. Firms' expected profits are zero and the exporting countries have zero payoffs in the equilibrium. In the strategic trade policy game the countries commit to subsidize their firms' exports before firms make an entry decision. The subsidy game is a Bertrand game. A symmetric mixed strategy equilibrium in government export subsidies exists that solves the coordination failure. The firm in the country that had chosen the lower subsidy does not enter. This country earns zero payoff. This is a crucial property. The firm in the country with the higher subsidy enters and earns the monopoly rent, but, because the payoff in the country with the lower subsidy is zero, the expected equilibrium subsidies are so high that even the country with the higher subsidy earns zero payoff. In contrast, in the contest model, the firm in the country that chooses a lower subsidy wins the contest with strictly positive probability. The country can use this property to earn a strictly positive payoff by taxing the home firm. This, in turn, limits the countries' competition for the higher subsidy.

[16] A similar asymmetric equilibrium has been found by Salant and Shaffer (1998) in a different context. They have shown that asymmetric research effort can be the outcome in R&D research joint ventures. Aysmmetric R&D effort leads to asymmetric production cost and this can increase the sum of firms' rents; in their case this is true because production is reallocated to the lower-cost producer.

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