Strategic Trade and Delegated Competition*

Nolan H. Miller† and Amit Pazgal‡

June 17, 2003

Abstract

Strategic trade theory has been criticized on the grounds that its predictions are overly sensitive to modeling assumptions. Applying recent results in duopoly theory, this paper considers three-stage games in which governments choose subsidies, firms' owners choose incentive schemes for their managers, and then the managers compete in the product market. We show that if firms' owners have sufficient control over their managers' behavior, then the optimal strategic trade policy does not depend on the mode of product-market competition, i.e., whether firms compete by setting prices or quantities.

Keywords: Strategic international trade, delegation games.

JEL classification codes: F1, L1.

*We thank Chris Avery, Robert Jensen, Asim Khwaja, Jennifer Reinganum, Dani Rodrik, Richard Zeckhauser, Jonathan Eaton and an anonymous referee for helpful comments.

†John F. Kennedy School of Government, Harvard University, 79 JFK St, Cambridge, MA 02138. Phone: 617-496-8959. Fax: 617-496-5747. Email: Nolan_Miller@harvard.edu.

‡Olin School of Business, Washington University, St. Louis. pazgal@olin.wustl.edu.

1 Introduction

One of the chief shortcomings of strategic trade theory has been that its predictions are highly sensitive to assumptions about the nature of product-market competition. For example, Eaton and Grossman (1986) show that Brander and Spencer's (1985) seminal result – i.e., when firms compete by setting quantities the optimal policy involves governments subsidizing their domestic industries – is reversed if the firms compete by setting prices.[1] This disparity lead Paul Krugman to remark that the "flurry of excitement" over Brander and Spencer's original theories had died down:

> After several years of theoretical and empirical investigation, it has become clear that the strategic trade argument, while ingenious, is probably of minor real importance. Theoretical work has shown that the appropriate strategic trade policy is highly sensitive to details of market structure that governments are unlikely to get right. (Krugman 1993, p.363)

James Brander echoes this statement in his 1995 survey of the strategic trade literature, noting that:

> The Bertrand [price-setting] model is not necessarily any less plausible than the Cournot model as an approximation to actual conduct. Because it is hard to know in practice which of the two models (if either) is appropriate in a given case, the Eaton-Grossman analysis implies that even finding the sign or direction of the optimal policy might be difficult. (Brander 1995, p. 1417)

The dependence of optimal trade policy on the nature of product market competition follows from the fact that, despite appearing similar, the strategic interaction between two firms that compete by setting quantities is fundamentally different than the interaction between two firms who compete by setting prices. A number of papers have studied this distinction (Singh and Vives (1984); Cheng (1985); Klemperer and Meyer (1986)). They show that when firms produce differentiated products, the disparity between the price-competition (i.e., Bertrand) and quantity-setting (i.e., Cournot) outcomes arises from the fact that the elasticity of residual demand facing

[1] Balboa, Daughety, and Reinganum (2001) provide a recent study of the interaction between assumptions about market structure and optimal strategic trade policy.

a firm whose opponent holds price constant is greater than the elasticity of demand facing a firm whose opponent holds quantity constant, and that price competition is generally "more aggressive" than quantity competition in the sense that it leads to smaller prices and larger quantities.

The industrial organization literature on strategic delegation explores the idea that altering a firm's behavior can alter equilibrium outcomes. Typical models, such as Fershtman and Judd (1987), Sklivas (1987), Vickers (1985), Fumas (1992), and Miller and Pazgal (2002), consider two-stage duopoly games in which, during the first stage, profit-maximizing owners choose the incentive schemes they will give to their managers. During the second stage each manager chooses the strategy that maximizes his utility, given his incentive scheme and his opponent's behavior. In each case, owners use the incentive schemes they set to influence managers' behavior, which in turn alters the equilibrium outcome (prices, quantities, and profits) of the two-stage game.

In recent work, Miller and Pazgal (2001), henceforth MP, provide a bridge between the price vs. quantity competition literature and the strategic delegation literature in which it is shown that if owners have sufficient control over their managers incentives, then the set of equilibrium outcomes of a two-stage delegation game does not depend on whether the managers ultimately compete in prices or in quantities.[2] Although players in undelegated price competition behave more aggressively than players in undelegated quantity competition, when owners can manipulate their managers' incentives they make price-setting managers less aggressive and quantity-setting managers more aggressive, mitigating the difference in behavior, and, if owners have sufficient control over their managers' incentives, eliminating it.

In this paper we apply the delegated-competition methodology to the strategic-trade problem. In a three-stage game in which governments set subsidies, owners set incentive schemes, and then managers compete in a third country, we show that once the role of delegation in the owner-manager relationship is taken into account, the optimal trade policy depends only on factors such as the firms' cost and demand functions, and not on the particular mode of product market competition assumed by the modeler. In a model with linear demand and constant marginal cost in which owners compensate their managers based on a linear function of own- and other-firm profit (which we term linear-performance incentive schemes), we show that if products are substitutes, the equilibrium involves subsidies, while if products are complements, it involves taxes.

[2] Throughout the paper, we refer to this as the MP equivalence result.

In more general environments, it is more difficult to characterize the optimal strategic trade policy. Nevertheless, it remains the case that the optimal policy does not depend on the mode of product market competition, provided that owners can exercise sufficient control over their managers incentives. In light of this, we argue that the sensitivity of the optimal policy instrument that Eaton and Grossman (1986) identify derives not from the mode of competition (i.e., whether firms compete in prices or quantities), but rather that different modes of competition imply different managerial behavior. This suggests that conjectural variations models and other approaches to studying the strategic trade problem that take behavior as primitive may be more appropriate and ultimately more successful than those that attempt to determine the correct model of product market competition. Indeed, since there are generally multiple models of competition that agree with any particular behavior, there may be no such thing as a single correct model.

Maggi (1996) considers a strategic-trade model in which owners choose capacities and then managers' compete in the product market. He shows that as the cost of capacity increases, the outcome varies between the Bertrand and Cournot outcomes, and that a small capacity subsidy always increases domestic welfare. Maggi's approach is fundamentally different than ours in that he shows that, by varying the capacity-cost parameter, the same model leads to either the Bertrand or Cournot outcome. Our approach, on the other hand, argues that any equilibrium outcome that arises when managers compete by setting price is also an equilibrium when managers compete by setting quantity, if owners have sufficient power to delegate.

The rest of this paper proceeds as follows. In section 2 the optimal trade policy is derived in the context of a linear model with relative-performance delegation. Sections 3 derives the general result. Section 4 discusses implementation of the results and concludes. Supporting proofs are contained in the Appendix.

2 Strategic Trade and Delegation Games: The Linear Case

2.1 An Example

We begin with an example of the strategic trade game in which the owners of firms may influence their managers' behavior. Consider two nations. In each nation, a firm produces a product, and the two nations' products are imperfect substitutes. Within each firm, there is an owner and a manager. The owner is residual claimant on the firm's profit, while the manager makes the actual product-market decisions. We assume that the products are sold in a third country. The benefit of this strategy is that we can ignore domestic consumer surplus in our measure of national welfare.

We consider three-stage games. In the first stage, the government chooses a per-unit subsidy (or tax) to be imposed on its domestic firm. In the second stage, each owner, knowing the subsidies chosen by both nations, chooses a relative-performance incentive scheme for its manager. In the third stage, each manager, knowing the subsidies and incentive schemes chosen by both sides, chooses a value of its strategic variable, i.e., a quantity if the product-market competition is à la Cournot, or a price if it is à la Bertrand.

Since this is a dynamic game of complete information, our equilibrium concept is subgame perfect Nash equilibrium. We will often refer to the second and third stages of the game as the "delegation game," and the equilibrium of the second and third stages, taking subsidies as fixed, as the "delegation game equilibrium."

Denote the two nations by 1 and 2. We refer to the government, owner, and manager in nation i as G_i, Oi, and M_i, respectively. Throughout the paper, we use $j = 3 - i$ to refer to firm i's rival. Inverse demand for nation i's product is given by:

$$p_i(q_i, q_j) = \alpha - q_i - \gamma q_j \ , \tag{1}$$

where q_i and q_j denote the quantities supplied by the two firms.[3] Parameter γ captures the degree of substitutability between the two nation's products, with $\gamma > 0$ for substitutes and $\gamma < 0$ for complements. We assume that $|\gamma| < 1$, i.e., that prices are more responsive to an increase in the firm's own quantity than to an increase in its opponent's quantity.

Let c_i denote the constant marginal cost of production for firm i, and note that c_i will eventually consist of the firm's marginal production cost net of the subsidy set by its government. Hence $c_i = c - s_i$, where c is the common marginal production cost of the two firms and s_i is the side-specific subsidy chosen by G_i.[4] There are no fixed costs of production.

Since we are interested in considering both price and quantity competition, we must impose a number of regularity conditions that ensure that the demand system is invertible and that both price and quantity competition have well-behaved solutions in the absence of delegation. Along these

[3] As usual, (inverse) demand is defined only for non-negative prices and quantities, i.e., $q_1 \geq 0$, $q_2 \geq 0$, $p_1(q_1, q_2) \geq 0$, and $p_2(q_2, q_1) \geq 0$. The assumptions below ensure that equilibrium prices and quantities are non-negative.

[4] The restriction to symmetric demand and marginal cost is merely for convenience. See MP for the general linear case with $p_i = \alpha_i - \beta_i q_i + \gamma_i q_j$ and firm-specific marginal cost c_i.

lines, we assume that $\alpha > c_i > 0$, and $(\alpha - c_i) - \gamma(\alpha - c_j) > 0$ for $i = 1, 2$. The first assumption ensures that if $q_j = 0$, firm i is willing to produce a positive quantity. The second assumption ensures that if firms charge prices $p_1 = c_1$ and $p_2 = c_2$, both firms sell positive quantities.[5]

We assume that the incentive scheme set for M_i takes the form:

$$m_i = \pi_i + v_i \pi_j,$$

where v_i is the incentive parameter chosen by O_i, and $\pi_i = (p_i - c_i) q_i$ is the profit (inclusive of the subsidy paid or tax charged by the government) earned by firm i. We refer to schemes such as m_i as relative-performance incentive schemes.

We begin by considering the game under the assumption that product market competition takes place in quantities. Manager M_i chooses q_i in order to maximize:

$$m_i = (p_i(q_i, q_j) - c_i) q_i + v_i (p_j(q_j, q_i) - c_j) q_j. \tag{2}$$

The optimality condition for the manager's problem (i.e., M_i's reaction function) is given by:[6]

$$q_i = \frac{1}{2}(\alpha - c_i - (1 + v_1)\gamma q_j), \tag{3}$$

and the equilibrium quantities are found by solving conditions (3) for q_1 and q_2, yielding third-stage equilibrium quantities (as functions of the incentive parameters):

$$q_i = \frac{2(\alpha - c_i) - \gamma(1 + v_i)(\alpha - c_j)}{4 - \gamma^2(1 + v_i)(1 + v_j)}. \tag{4}$$

Evaluating firm i's profit at quantities (4), profit as a function of v_i and v_j is given by:

$$\pi_i = \frac{\left((\alpha - c_i)\left(2 - \gamma^2 v_i (1 + v_j)\right) - (\alpha - c_j)\gamma(1 - v_i)\right)(2(\alpha - c_i) - \gamma(1 + v_i)(\alpha - c_j))}{(4 - \gamma^2(1 + v_i)(1 + v_j))^2}. \tag{5}$$

Next, we move to Owner i's optimal choice of incentive parameter v_i in the second stage. The equilibrium values of v_1 and v_2 (as functions of c_1 and c_2) are found by solving first-order conditions $\frac{d}{dv_1}\pi_1 = 0$, and $\frac{d}{dv_2}\pi_2 = 0$ for v_1 and v_2, where π_i is as in (5).[7] This yields equilibrium incentive parameter values (denoted with an asterisk):

$$v_i^* = -\frac{\gamma((\alpha - c_i) - \gamma(\alpha - c_j))}{\alpha(2 - \gamma - \gamma^2) + c_i\gamma - c_j(2 - \gamma^2)}, \tag{6}$$

[5] These conditions depend on c_i and c_j which, in turn, depend on s_i and s_j. Below we show that the equilibrium subsidy is the same for both firms and ranges between $-\frac{1}{5}(\alpha - c)$ and $\frac{1}{3}(\alpha - c)$, which implies that these assumptions are satisfied at (and near) the equilibrium.

[6] To verify the second order conditions, note that $\frac{\partial^2 m_i}{\partial q_i^2} = -2$.

[7] The assumption that $(\alpha - c_i) - \gamma(\alpha - c_j) > 0$ ensures that the second-order conditions are staisfied.

and, substituting (6) into (4), equilibrium quantities:[8]

$$q_i^* = \frac{(\alpha - c_i)\left(2 - \gamma^2\right) - (\alpha - c_j)\gamma}{4\left(1 - \gamma^2\right)}. \tag{7}$$

Next, we derive the equilibrium of the delegation game under the assumption that managers compete by setting prices in the product market. Inverting (1) yields direct demand functions:

$$q_i(p_i, p_j) = \frac{\alpha}{1+\gamma} - \frac{1}{1-\gamma^2}p_i + \frac{\gamma}{1-\gamma^2}p_j. \tag{8}$$

Let M_i be compensated according to the relative-performance incentive scheme, $\tilde{m}_i = \pi_i + z_i\pi_i$, where z_i is the incentive parameter in the price-setting version of the delegation game. Manager i chooses p_i in order to maximize:

$$\tilde{m}_i = (p_i - c_i)\left(q_i(p_i, p_j)\right) + z_i(p_j - c_j)\, q_j(p_j, p_i).$$

Continuing through the same process as above to find the equilibrium of the two-stage delegation game under price competition, the equilibrium incentive parameters and prices (denoted with two asterisks) are given by:

$$z_i^{**} = \frac{\gamma(\alpha - c_i)}{2(\alpha - c_j) - (\alpha - c_i)\gamma}$$

$$p_i^{**} = \frac{2(\alpha - c_i) - (\alpha - c_j)\gamma}{4} + c_i.$$

Finally, evaluating $q_i\left(p_i^{**}, p_j^{**}\right)$ yields equilibrium quantities:

$$q_i\left(p_i^{**}, p_j^{**}\right) = \frac{(\alpha - c_i)\left(2 - \gamma^2\right) - (\alpha - c_j)\gamma}{4\left(1 - \gamma^2\right)}, \tag{9}$$

which are identical to the equilibrium quantities from the quantity-setting version of the game (7). Therefore, since prices determine quantities and vice versa, the equilibrium outcome is the same in the two versions of the delegation game. Further, since the outcomes are identical as functions of the firms' costs, and, by extension, as functions of the governments' choices of subsidies, the optimal subsidy policy must also be the same regardless of the mode of product-market competition.

Expression (9) is an instance of the MP equivalence result. Before going on to consider the government's optimal policy choice in this environment, we briefly discuss the intuition for why delegated price and quantity competition lead to the same equilibrium outcomes. From Singh and

[8] The assumptions that $(\alpha - c_i) - (\alpha - c_j)\gamma > 0$ and $(\alpha - c_i) > 0$ ensure that $q_i^* > 0$.

Vives (1984), we know that when products are substitutes, price competition is more aggressive than quantity competition in the sense that the former leads to lower prices and higher quantities in equilibrium. Delegation diminishes this difference. When goods are substitutes and managers compete by setting quantities, owners choose $v_i^* < 0$. In this case, the manager is rewarded for increasing his own profit and also for decreasing the other firm's profit, which makes him more aggressive. On the other hand, when managers compete by setting prices, owners choose $z_i^{**} > 0$, and managers are rewarded for increasing either firm's profit. This tends to make them less aggressive. Hence it stands to reason that delegation should narrow the gap between the price-setting and quantity-setting outcomes. The fact that the equilibria actually coincide is somewhat surprising. However, as we shall see, this property holds quite generally whenever owners have sufficient power to delegate.

We now turn to the first stage of the game, in which the government chooses subsidy rates in order to maximize home-country welfare given that owners and managers will play equilibrium strategies in the delegation game. Recall that $c_i = c - s_i$, where s_i is the subsidy chosen by nation i. Making this substitution, the equilibrium quantities and profits in the delegation game depend only on the subsidies:

$$\begin{aligned} q_i(s_i, s_j) &= \frac{(2-\gamma^2)(\alpha - (c - s_i)) - (\alpha - (c - s_j))\gamma}{4(1-\gamma^2)}, \text{ and} \\ \pi_i(s_i, s_j) &= \frac{(2(\alpha - (c - s_i)) - (\alpha - (c - s_j))\gamma)\left((2-\gamma^2)(\alpha - (c - s_i)) - (\alpha - (c - s_j))\gamma\right)}{16(1-\gamma^2)}. \end{aligned}$$

Domestic welfare is given by home-country net industry profit less subsidies paid: $w_i(s_i, s_j) = \pi_i(s_i, s_j) - s_i q_i(s_i, s_j)$. The optimal subsidies s_1^* and s_2^* are found by solving first-order conditions $\frac{\partial w_1(s_1,s_2)}{\partial s_1} = 0$ and $\frac{\partial w_2(s_2,s_1)}{\partial s_2}$ for s_1 and s_2.[9] Solving this system yields:

$$s_i^* = -\gamma^3 \frac{(\alpha - c)}{8 - 4\gamma^2 + \gamma^3}, \tag{10}$$

from which Proposition 1 is immediate.

Proposition 1 *If the goods are substitutes* ($-1 < \gamma < 0$) *then the equilibrium trade policy involves subsidization of the domestic industry. If the goods are unrelated, free trade is optimal. If the goods are complements* ($0 < \gamma < 1$) *then the equilibrium subsidy policy involves taxing the domestic industry.*

[9] The second-order conditions are satisfied, since $\frac{\partial^2 w_i}{\partial s_i^2} = \frac{2-\gamma^2}{-4+4\gamma^2} < 0$.

Proof. For $|\gamma| < 1$, the denominator of (10) is positive, from which it follows that the sign of the optimal subsidy is opposite that of γ. ■

The magnitude of the optimal subsidy increases as the goods become closer substitutes, reaching $\frac{1}{3}(\alpha - c)$ when the goods are perfect substitutes. When the goods are unrelated, $\gamma = 0$, free trade is optimal. As γ becomes positive, it is optimal to tax the domestic industry, with the optimal tax reaching $\frac{1}{5}(\alpha - c)$ as γ approaches 1.[10] The main difference between Proposition 1 and previous results in strategic trade theory such as Brander and Spencer (1985) and Eaton and Grossman (1986) is that the optimal policy depends only on whether the goods are substitutes or complements and not on the form of product-market competition.[11]

The use of relative-performance incentive schemes may seem somewhat *ad hoc*. While we are unaware of any firms that employ this incentive scheme, there is substantial theoretical and empirical evidence that relative performance concerns are important determinants of managerial behavior (see the discussion in Miller and Pazgal (2002)). In addition to capturing this real-world motive (albeit in a simple manner), in the context of this illustrative example, relative-performance schemes are useful for two additional reasons. First, they are sufficiently flexible that the MP equivalence result obtains, allowing us to illustrate that the optimal trade policy is invariant to the form of product-market competition. Second, relative performance schemes are not so flexible that there are multiple equilibria in the game. As discussed in MP, as owners' degree of control over their managers' incentives increases, so do the number of equilibria. For example, when owners can choose *any* linear reaction curve for their managers, then *regardless of the type of product-market competition, any outcome can be supported as an equilibrium of the delegation game.* While the MP equivalence result continues to hold, i.e., any outcome that can be supported as an equilibrium outcome of delegated price competition can also be supported as an equilibrium outcome of delegated quantity competition, the multiplicity of equilibria make these cases less useful in conveying the essence of the result. We present the application of the MP equivalence result to the general (i.e., nonlinear) strategic trade context in Section 3.

[10] As remarked in footnote 5, since s_i^* varies between $\frac{1}{3}(\alpha - c)$ and $-\frac{1}{5}(\alpha - c)$, the assumptions that $\alpha > c_i > 0$ and $(\alpha - c_i) - (\alpha - c_j)\gamma > 0$ are satisfied for the relevant subsidy range.

[11] Indeed, in the linear example we have been studying, the MP equivalence result also extends to the case in which managers' compete by setting linear supply functions (as in Klemperer and Meyer (1989)) and to mixed competition cases, where one manager sets price and the other quantity, etc.

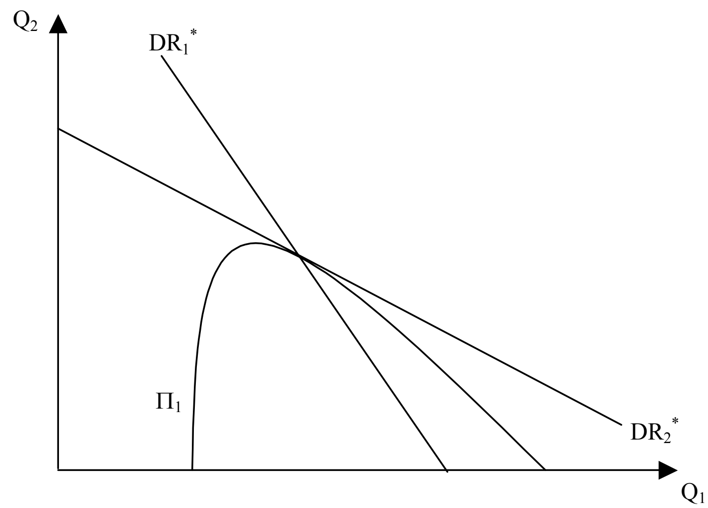

Figure 1: The delegation-game equilibrium (free trade).

2.2 Intuition for the Result

The difference in the direction of beneficial strategic trade policy in non-delegated Cournot vs. Bertrand competition has to do with the difference in the relative slopes of the profit isoquants through the equilibrium point and the slope of the other firm's reaction function. In quantity competition, the profit isoquant is flatter, and subsidies improve welfare. In price competition, on the other hand, the isoprofit curve is steeper, and taxation in beneficial. This comparison is at the heart of the Eaton and Grossman (1986) analysis, and will continue to be central to our analysis.

In our three stage game, the analysis is slightly more complicated. For brevity, we consider only the case of substitute goods, and begin with a free-trade situation, so that, initially, national welfare is identical to the profit earned by the domestic firm. Holding fixed the other owner's incentive parameters, each owner chooses the incentive parameter that results in the third-stage equilibrium that maximizes its profit. The geometric implication of this is that, at the equilibrium choice of incentive parameters, firm 1's isoprofit line through the equilibrium is tangent to firm 2's reaction curve, and vice versa. This situation is (partially) depicted in Figure 1, where DR_i indicates firm i's equilibrium reaction curve in the delegation game and Π_i denotes the profit (national-welfare) indifference curve.

When the firms choose incentive parameters optimally, the equilibrium outcome is the point along firm 2's reaction curve that maximizes firm 1's profit (and vice versa). Hence, shifting

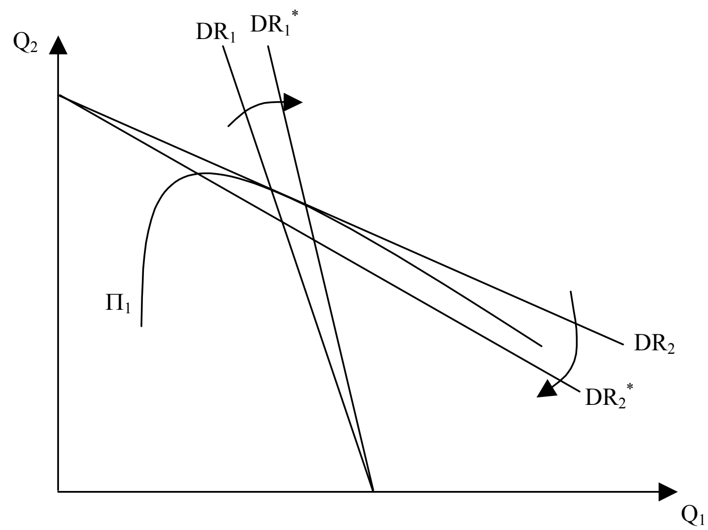

Figure 2: Impact of an increase in s_1.

firm 1's reaction curve through strategic trade policy cannot increase domestic welfare unless it also influences firm 2's equilibrium incentive parameters (i.e., moves DR_2). However, since each owner's optimal choice of incentive parameters depend on the subsidies chosen by *both* governments, varying the subsidy influences both firms' second-stage reaction functions.

From the optimal incentive parameters given by (6), it is easily shown that, over the relevant range of subsidies, $\frac{dv_i}{ds_i} < 0$ and $\frac{dv_i}{ds_j} > 0$. Therefore an increase in s_1 pivots firm 1's optimal reaction curve outward and firm 2's optimal reaction curve downward, as in Figure 2. Hence, following an increase in s_1, the equilibrium point moves to the right of DR_1 and below DR_2 to the intersection of DR_1^* and DR_2^*. Since firm 1's isoprofit line was originally tangent to DR_2, this necessarily increases profit. Subsidizing the domestic industry improves domestic welfare, and the optimal policy involves subsidization.

The simultaneous determination of equilibrium trade policy in the three-stage game is slightly more complicated, but the same basic intuition drives the results.

3 Strategic Trade and Delegation Games: The General Case

The discussion in the previous section has focused on the case of linear demand, constant marginal cost, and relative-performance incentive schemes. Under these conditions, there is a unique equilibrium of the delegation game, and the optimal trade policy is unambiguous, which makes that case particularly useful for the purposes of illustration. In more general environments (e.g., ones involving nonlinear cost, demand, or incentive schemes), the delegation game may have multiple equilibria, each of which is supported by complicated incentives. Nevertheless, the MP equivalence result continues to hold in the delegation game: if owners have sufficient control over their managers' incentives, then for any equilibrium of the delegation game when managers set prices there is a corresponding equilibrium of the delegation game when managers set quantities that results in the same final prices and quantities (and vice versa). Consequently, it remains true that if owners have sufficient power to control their managers' incentives, then the optimal trade policy does not depend on the mode of product market competition.

We relegate the formal statement and proof of this result to the Appendix. Here, we focus on a less formal discussion of what it means for owners to have sufficient control over their managers' incentives. In order to compare price and quantity competition, we define an **outcome set** as the projection of a manager's best response correspondence (i.e., reaction curve) into the four-dimensional (q_1, q_2, p_1, p_2)-space. The key condition, which we denote Outcome Set Equivalence (OSE), is that the set of behaviors (i.e., outcome sets) the owner can induce on the part of its manager must be the same regardless of whether the managers choose prices or quantities.[12]

If OSE holds, then the difference between price- and quantity-competition in the final stage of the delegation game amounts to nothing more than a difference in the naming of outcome sets. The fundamental game is unchanged, and consequently the set of equilibrium outcomes of the delegation game does not depend on the form of the product market competition.

Proposition 2 *If OSE holds, then, for any choice of subsidies by the governments, the set of equilibrium outcomes of the delegation game is the same regardless of whether the firms compete in prices, quantities, or one firm chooses price and the other chooses quantity.*

Proof. *See the Appendix.* ■

[12] Outcome sets (or some similar construction) are necessary to compare price and quantity competition reaction curves because price reaction curves lie in (p_1, p_2)-space, while quantity reaction curves lie in (q_1, q_2)-space. However, since fixing any two elements of $\{p_1, p_2, q_1, q_2\}$ determines the other two, price and quantity reaction curves are comparable once they are cast in the right frame of reference. Looking at the four-dimensional outcome set is one way to do so. Another would be to project price reaction curves into the quantity space, as we do in the geometric analysis. Thus price reaction curve r_i generates the same outcome set as quantity reaction curve R_i if and only if the projection of r_i into (q_1, q_2)-space coincides with R_i.

Proposition 2 implies that the set of possible equilibria and outcomes of the delegation game that can arise given particular subsidy choices does not depend on the mode of product market competition. Thus, even when there are multiple equilibria in the delegation game, if OSE holds then there is no equilibrium outcome that can arise under one type of product market competition and not the other. And since the governments care about their subsidy choices only inasmuch as they affect the equilibrium outcome of the delegation game, this implies that the equilibrium trade policies are independent of the form of product market competition as well.

Proposition 3 *If OSE holds, then the equilibrium trade policies do not depend on whether firms compete by setting prices or quantities.*

Proof. *See the Appendix.* ■

While Proposition 3 is stated in terms of an equivalence between price- and quantity-competition outcomes, it also holds more generally. For example, in MP (Proposition 4) it is explicitly shown that, in the linear case, the equivalence result also holds when the firms compete by choosing linear supply functions.[13] Intuitively, this is because linear supply functions lead managers to have linear reaction curves, and if owners have sufficient control over their managers' incentives, then any linear reaction curve that can be induced through delegated price or quantity competition can also be induced through delegated supply-function competition. The same idea holds in the general delegation environment of Propositions 2 and 3. If managers compete by setting supply functions that are optimal given the incentive schemes chosen by their owners, and if owners have sufficient (in the sense of OSE) power to manipulate managers' incentives, then the equivalence result extends to the include the possibility of supply-function competition.

Proposition 3 does not provide a method of determining the equilibrium trade policy or even whether subsidizing its domestic industry helps or harms a country. However, if we take seriously the possibility of delegation, it suggests that a "correct" model of the product market should not be necessary in order to answer this question. Any conclusion that can be drawn about trade policy knowing the true mode of product-market competition is also consistent with any other model of (delegated) competition that leads to the same managerial behavior.

How, then, might the direction of beneficial trade policies be determined? At its most basic level, answering this question involves determining whether increasing the subsidy increases or

[13] In the general, linear case, it is shown that any outcome is a possible equilibrium if owners have sufficient power to delegate, further complicating the search for the "correct" model of product-market competition.

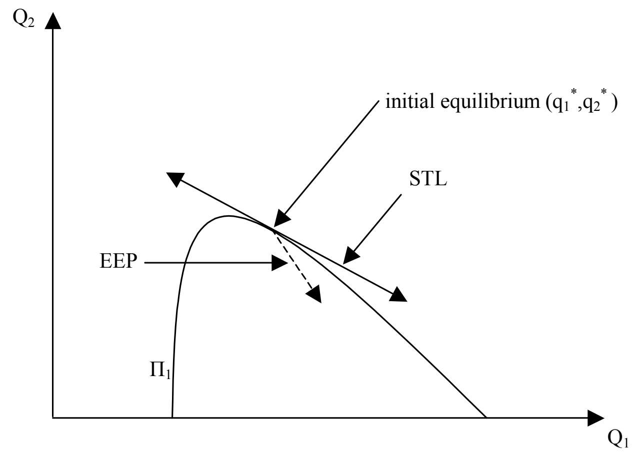

Figure 3: If EEP is steeper than STL, increasing the subsidy increases domestic welfare.

decreases domestic profit. This is a question that can, in principle, be answered empirically, and without requiring a correct model of product-market competition or data beyond that which we might reasonably expect to be obtainable by outside analysts.

Suppose that products are substitutes and the players are currently playing an equilibrium of the delegation game, and let the equilibrium quantities be (q_1^*, q_2^*). Determining whether increasing the subsidy increases domestic welfare then comes down to whether, as the subsidy increases, the equilibrium expansion path (EEP) is steeper or flatter than the line tangent to firm i's profit isoquant through (q_1^*, q_2^*). We denote this supporting tangent line STL. If EEP is steeper than STL, then increasing the subsidy benefits the domestic country, as is depicted in Figure 3. If, on the other hand, EEP is flatter than STL, then increasing the subsidy decreases domestic welfare.[14]

Determining the direction of beneficial policy change does require information about the firms. However, data about the mode of product-market competition or nature of managers' incentive schemes are not needed. Determining the direction of STL requires estimating the demand and cost functions facing the firm. As highlighted in our analysis of the linear case, the effect of a change in the government's subsidy has the same effect on the final equilibrium outcome as a change in the firm's marginal cost. Thus, in principle, the direction of EEP could be inferred from observing how the equilibrium quantities vary with changes in input costs. These inferences require information on output prices and quantities and input costs and usages, but do not require information about

[14] For complementary goods, the relationships reverse, i.e., subsidies are beneficial if EEP is flatter than STL.

the mode of product-market competition or nature of managerial incentive schemes that is, even in principle, unobservable.

The approach we advocate is similar to the one conjectural variations-based approach to strategic trade adopted by Eaton and Grossman (1986). The main result of Eaton and Grossman is that the desirability of increasing (or decreasing) the subsidy to the domestic industry depends on how the conjectured change in the foreign firm's output following an increase in the domestic firm's output compares with actual variation following that change (Eaton and Grossman, 1986, Theorem 1). Note, however, that since each firm optimizes given its conjecture about the other firm's behavior, in equilibrium, moving in the direction of the conjectured change must not increase profit. Hence the direction of the conjectured change in the other firm's behavior is the same as the direction of STL. On the other hand, as the firm increases its output, the equilibrium moves down the other firm's reaction curve. Hence, in the Eaton-Grossman model, the actual change in the equilibrium is in the direction of the other firm's reaction function. The actual change in our model is slightly different, since both firms change their incentive parameters (and therefore their reaction curves) in a response to one nation changing its subsidy. Nevertheless, the idea is similar.

Our OSE condition is strong and would be hard to verify in any practical situation. However, while this is true, it would also be difficult to falsify without the type of detailed knowledge of the inner workings of firms and product markets that is widely believed to beyond the grasp of government and academic analysts. That is, suppose it were proposed that managers in a particular strategic-trade problem competed by setting quantities. Propositions 2 and 3 establish that the possibility that the observed market behavior arose from delegated price competition could not be ruled out using only data on market prices and quantities. Thus, in addition to establishing that determining equilibrium strategic trade policies cannot depend on the model of product market competition, they also establish that any analysis that claims to establish the "correct" model of product market competition must do so using data other than market outcomes.

4 Discussion

In this paper, we have argued that the theoretical case for strategic trade policy is not as flawed as the statements from Brander and Krugman quoted in the introduction would suggest. If owners have sufficient control over their managers' incentives, then the optimal/equilibrium trade interventions do not depend on the mode of product market competition. In the linear model, we showed that owners' ability to set simple, relative-performance incentive schemes is sufficient for the invariance result to hold. In more complicated environments, more complicated incentive schemes may be required, but the basic result is robust.

Our conclusions offer support to Eaton and Grossman's conjectural variations-base approach to strategic trade and to the empirical strategic-trade literature that relies on conjectural variations.[15] The conjectural variations approach is often criticized on the grounds that players' conjectures may be inconsistent in that they posit behavior on the part of their opponents that is not confirmed in the equilibrium. Our delegation approach avoids this criticism. In our model, managers' behavior is optimal given the incentive schemes set by owners, and owners' incentive schemes are optimal given the trade policies adopted by the governments. Hence, the managers' conjectures are justified by the owners' and governments' strategies, which are, themselves, optimal. Thus, there is no inconsistency problem in the model.

The most general insight to be taken from the results derived here is that, at its base, equilibrium depends on the behavior of managers and not on whether that behavior derives from delegated price- or quantity-setting. Therefore, even though it may be difficult to determine the right model of product market competition, this is not really necessary to solve the strategic trade problem. In fact, our model suggests that, from a descriptive perspective, there may be no such thing as the "correct model." For this reason we argue that, in approaching the strategic trade problem, the primitive notion should be the behavior of the product market, not the model of the product market. In other words, it is not that determining the "correct model" is hard and it is necessary for determining the right policy. Rather, it is that determining the right model is impossible, but this is not necessary for determining the potential effects of a policy change. Determining the direction of beneficial policy change is, in principle, an empirical task that does not require information about the mode of product market competition or the nature of managerial incentive schemes.

[15] See Krugman (1989;1212-1213) and Krugman (1994; 1-9) for discussions of empirical strategic trade papers employing the conjectural variations approach, and various essays in Krugman (1994) for studies employing the methodology.

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A Development of Propositions 2 and 3

In this section, we extend the MP equivalence result to the strategic trade context, proving that if owners have sufficient control over their managers' incentives, then the equilibrium subsidies do not depend on the form of product market competition. The derivation consists of two parts. First, following Proposition 3 in MP, we establish that when owners have sufficient control over their managers' incentives, the set of equilibrium outcomes of the delegation game, parameterized by the governments' choices of trade policies (s_1, s_2), does not depend on the form of product market competition. Second, we show that the equilibrium choices of trade policies do not depend on the form of product market competition.

We begin by making precise what is required for owners to have "sufficient control" over their managers' incentives. Throughout this section, r, t, x, y will stand for elements of the set $\{p, q\}$ and will be used to denote either price or quantity competition in various contexts.[16] Let $q_i(p_1, p_2)$ be the demand function for product i, where $q_i(p_1, p_2) \geq 0$ for all p_1, p_2. Let $\Theta_i^r \subseteq \Re^k$ (where k is a

[16] We will use s_i to denote the particular strategy choice by manager i when he competes by setting s. For example, when $s = p$, $s_i = p_i$ stands for the particular price he chooses.

positive integer) be the set of incentive parameters available to owner i when her firm competes by setting r, and θ_i^r be a generic element of Θ_i^r. Let $U_i(p_1, p_2, q_1, q_2 | \theta_i^r, t_j, s_1, s_2)$ be manager $i\prime s$ utility function conditional on owner $i\prime s$ incentive parameter choice, θ_i^r, strategy choice t_j by manager j, and subsidy choices s_1 and s_2.

Holding fixed the governments' subsidies, s_1 and s_2, let the outcome set for manager i consist of all price-quantity quadruples that:

i) are consistent with the demand system

ii) represent a utility maximizing choice for manager i given the strategic choice of manager j, the incentive parameters chosen by owner i, and the two governments' subsidy choices.

The outcome set represents the set of price-quantity quadruples that could occur given that manager i responds optimally to the incentives he is given. If firm i competes by setting $r \in \{p, q\}$ and firm j competes by setting $t \in \{p, q\}$, denote the outcome set for player i by:

$$\Omega_i^{rt}(\theta_i^r | s_1, s_2) = \left\{ \begin{array}{c} (p_1, p_2, q_1, q_2) : q_1 = q_1(p_1, p_2), q_2 = q_2(p_1, p_2), \text{ and} \\ r_i \in \arg\max U_i(p_1, p_2, q_1, q_2 | \theta_i^r, t_j, s_1, s_2). \end{array} \right\}$$

The set of third-stage equilibrium outcomes when incentive parameters θ_i^r and θ_j^t are chosen is given by the intersection of the two managers' outcome sets $\Omega_i^{rt}(\theta_i^r | s_1, s_2) \cap \Omega_j^{tr}\left(\theta_j^t | s_1, s_2\right)$.

Now consider the second-stage equilibrium. Owners choose incentive parameters in order to maximize profit subject to the constraint that the resulting prices and quantities comprise a third-stage equilibrium outcome, given the choice of incentive parameters by the other owner and the governments' subsidy choices. Assuming owner i sets $r \in \{p, q\}$ and j sets $t \in \{p, q\}$ in the second stage, in the first stage the owner solves:

$$\max_{\theta_i^r \in \Theta_i^r} (p_i - c_i) q_i \tag{11}$$

$$\text{subject to} \qquad (p_1, p_2, q_1, q_2) \in \Omega_i^{rt}(\theta_i^r | s_1, s_2) \cap \Omega_j^{tr}\left(\bar{\theta}_j^t | s_1, s_2\right),$$

where $\bar{\theta}_j^t$ is firm $j\prime s$ equilibrium incentive parameter choice.

A sufficient condition for the equivalence result to hold is that, holding the rival manager's behavior fixed, the set of behaviors (i.e., outcome sets) the owner can induce on the part of its manager must be the same regardless of whether the managers choose prices or quantities.

Formally, this condition can be stated as:

Outcome Set Equivalence (OSE). For player $i \in \{1, 2\}$, for any $s, t, x, y \in \{p, q\}$, and any $\theta_i^s \in \Theta_i^s$, there exists a $\theta_i^x \in \Theta_i^x$ such that $\Omega_i^{xy}(\theta_i^x) = \Omega_i^{st}(\theta_i^s)$.

If condition OSE holds, the distinction between price, quantity, and mixed competition reduces to mere differences in the naming of outcome sets. The equivalence of outcomes in the delegation game follows immediately.

Proposition 2: *If OSE holds, then, for any choice of subsidies by the governments, the set of equilibrium outcomes of the delegation game are the same regardless of whether the firms compete in prices, quantities, or one firm chooses price and the other chooses quantity.*

Proof: *Suppose that firm i sets r and firm j sets t in the second stage competition. We will show that the same prices and quantities are an equilibrium outcome when firm i sets x and firm j sets y. firm i's profit maximization problem is:*

$$\begin{aligned} &\max_{\theta_i^r \in \Theta_i^r} \left(p_i - (c_i + s_i)\right) q_i \\ \text{subject to} \quad &(p_1, p_2, q_1, q_2) \in \Omega_i^{rt}(\theta_i^r) \cap \Omega_j^{tr}\left(\bar{\theta}_j^t\right). \end{aligned} \tag{12}$$

The firm does not directly care about the incentive parameters; only the prices and quantities are payoff relevant. The set of feasible prices and quantities is given by:

$$\left\{(p_1, p_2, q_1, q_2) : (p_1, p_2, q_1, q_2) \in \Omega_i^{rt}(\theta_i^r) \cap \Omega_j^{tr}\left(\bar{\theta}_j^t\right) \text{ for some } \theta_i^r \in \Theta_i^r\right\}. \tag{13}$$

By OSE : i) there exists a $\hat{\theta}_j^y \in \Theta_j^y$ such that $\Omega_j^{tr}\left(\bar{\theta}_j^t\right) = \Omega_j^{yx}\left(\hat{\theta}_j^y\right)$, and ii) the set of feasible outcome sets for manager i when i sets r and j sets t are identical to the set of feasible outcome sets for manager i when i sets x and j sets t. Hence (13) is identical to:

$$\left\{(p_1, p_2, q_1, q_2) : (p_1, p_2, q_1, q_2) \in \Omega_i^{xy}(\theta_i^x) \cap \Omega_j^{yx}\left(\hat{\theta}_j^y\right) \text{ for some } \theta_i^x \in \Theta_i^x\right\}.$$

Since the feasible set in

$$\begin{aligned} &\max_{\theta_i^x \in \Theta_i^x} \left(p_i - (c_i + s_i)\right) q_i \\ \text{subject to} \quad &(p_1, p_2, q_1, q_2) \in \Omega_i^{xy}(\theta_i^x) \cap \Omega_j^{yx}\left(\hat{\theta}_j^y\right) \end{aligned}$$

is the same as in (12) and only prices and quantities are payoff-relevant, firm i must choose an incentive parameter that results in the same prices and quantities as in (12), provided that one *exists. By OSE, there exists a* $\hat{\theta}_i^x \in \Theta_i^x$ *such that* $\Omega_i^{rt}\left(\bar{\theta}_i^r\right) = \Omega_i^{xy}\left(\hat{\theta}_i^x\right)$*, which implies the same prices and quantities, and so* $\hat{\theta}_i^x$ *is a best response to* $\hat{\theta}_j^y$*. Reversing the roles of* i *and* j *completes the proof.* ■

While OSE is sufficient for Proposition 2, it is by no means necessary. MP decompose OSE into two weaker conditions, termed Replication and Feasibility, that also imply Proposition 2. See MP pp. 292-293 for details.

Proposition 3: *If OSE holds, then the equilibrium trade policies do not depend on the form of product market competition.*

Proof: *Suppose that* M_1 *competes by setting* $x \in \{p, q\}$ *in the product market, while* M_2 *competes by setting* $y \in \{p, q\}$*. Let* $Q^{xy}(s_1, s_2)$ *denote the (non-empty) set of equilibrium quantity vectors of the delegation game. In the first stage, the* G_i *chooses* s_i *in order to maximize domestic welfare, subject to the constraint that the resulting prices and quantities comprise an equilibrium of the delegation game. Hence* G_i*'s problem is written:*

$$\begin{aligned} & \max_{s_i} (p_i - c_i) q_i \qquad (14) \\ \text{subject to } (q_1, q_2) & \in Q^{xy}(s_i, s_{3-i}), \text{ and} \\ q_i & = q_i(p_1, p_2). \end{aligned}$$

A pair of trade policies (s_1^*, s_2^*) *(along with the resulting equilibrium of the delegation game) comprise an equilibrium of the three-stage strategic trade game if* s_i^* *solves (14) when* $s_{3-1} = s_{3-i}^*$*, for* $i = 1, 2$.

By Proposition 2, $Q(s_1, s_2)$ *is invariant to the form of product market competition whenever Replication and Feasibility hold. Hence* $Q^{xy} = Q^{rt}$ *for* $r, t, x, y \in \{p, q\}$*, from which Proposition 3 is immediate.*