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**OLIGOPOLY AND TRADE**

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## Abstract

In this chapter we present a selective analytic survey of some of the main results of trade under oligopoly. We concentrate on three topics: oligopoly as an independent determinant of trade, as illustrated by the reciprocal-markets model of Brander (1981); oligopoly as an independent rationale for government intervention, as illustrated by strategic trade and industrial policy in the third-market model of Spencer and Brander (1983); and the challenges and potential of embedding trade under oligopoly in general equilibrium as illustrated by the GOLE model of Neary (2002).

*Keywords:* GOLE (General Oligopolistic Equilibrium); reciprocal dumping; strategic trade policy.

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# 1 Introduction

Oligopoly means competition among the few, and the study of markets with a relatively small number of large firms is an important branch of industrial organisation and microeconomics more generally. However, it plays a smaller role in the theory of international trade. From its inception in the work of Ricardo in 1817 until the 1980s, trade theory was dominated by perfectly competitive models. What is sometimes called the “new trade theory” revolution from 1979 onwards led to a surge of interest in the implications for trade of imperfectly competitive models.<sup>1</sup> Since then, two different routes to incorporating imperfect competition into trade theory have been explored, so different that the process could be described as two revolutions rather than one. On the one hand, monopolistically competitive models of large-group competition have been applied to the study of intra-industry trade and a host of other topics; on the other hand, oligopolistic models have been applied to both positive and normative questions. Of these two, monopolistic competition quickly became the preferred approach, so much so that, in the words of Paul Krugman, it could be said that there are now “Two and a Half Theories of Trade”, with the theory of oligopoly a poor relation of the two dominant paradigms, perfect and monopolistic competition.<sup>2</sup>

However, despite their dominance, there are many issues in trade which the theories of perfect and monopolistic competition are inherently ill-fitted to address. The assumptions which they share, of an infinitely elastic supply of atomistic firms, that are *ex ante* identical and do not engage in strategic interaction, are not obviously appropriate to many global markets. Casual empiricism suggests that many industries are dominated by a small number of firms, and an increasing body of applied work shows that large firms account for a dominant share of exports as well as foreign direct investment and spending on research and development.<sup>3</sup> By contrast, the theory of oligopoly is suited to study the distinctive features of concentrated industries, and in particular, the persistence of profits, as well as strategic behaviour by firms and governments to preserve and enhance these profits.

In this survey, we present an analytic overview of some of the main theoretical results of trade under oligopoly. Following Brander (1995), we concentrate on two canonical models. Section 2 considers the “reciprocal-markets” model, which has been used to analyse a variety of positive and normative questions in cases where both domestic and foreign firms compete both at home and away. Most notable among these was the demonstration by Brander (1981) that oligopolistic competition is an independent source of trade, and in particular of intra-industry trade, distinct from either comparative advantage or product differentiation. Section 3 turns to consider issues of “strategic” trade and industrial policy in models of multi-stage competition, which are most easily studied in the “third-market” model first developed by Spencer and Brander (1983). Finally, Section 4 turns to consider the objection that oligopoly models

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<sup>1</sup>See Krugman (1979) for an early contribution, and Neary (2009) for an overview and further references.

<sup>2</sup>See Neary (2010) for further discussion.

<sup>3</sup>See Bernard, Jensen, Redding, and Schott (2007) and Mayer and Ottaviano (2007).

have not been embedded in general equilibrium, and reviews some recent work which tries to overcome this.

## 2 Trade under Oligopoly

### 2.1 The “Reciprocal-Markets” Model

The reciprocal-markets model is a simple framework for studying trade under oligopoly, which has the convenient property that it is possible to study each country’s market in isolation. An essential assumption which makes this possible is that national markets are segmented. On the one hand, this implies that third-party arbitrage is not possible, so a firm’s output can command different equilibrium prices in different countries. On the other hand, it implies that firms make distinct output or price decisions for each market. The latter is not a primitive assumption, and Venables (1990) and Ben-Zvi and Helpman (1992) have explored the conditions under which it will emerge as an equilibrium outcome of a multi-stage game where firms first invest in their worldwide capacity and then decide on prices and/or sales volumes for each market. Such models have the attractive feature that firms decide endogenously how to supply different markets, but their greater complexity has limited their appeal. As a result, most of the literature has continued to adopt the segmented markets assumption and we follow that approach here.<sup>4</sup>

In addition to market segmentation, the ability to consider one market in isolation requires that firms produce under constant marginal costs. Otherwise, output or price decisions in one market have implications for the costs at which other markets can be served. A rare example of a model with such cost linkages between markets is provided by Krugman (1984). He assumes falling marginal costs and shows that an import protection policy that raises a firm’s home sales also increases that firm’s market share in its export market. Here, by contrast, we will follow most of the literature and assume that marginal costs are independent of scale. The combination of this and the assumption of segmented markets implies that changes in policy or other exogenous variables in one market have no effect on the other market.

Armed with these assumptions, we can now explore the properties of a canonical reciprocal-markets model, first presented by Brander (1981). Consider a single oligopolistic industry, the output of which is consumed in two countries, labelled home and foreign. The firms competing in this industry are also from the home and foreign country, with just one firm in each.<sup>5</sup> We confine attention to the symmetric case, where the home and foreign firms have the same marginal cost of production  $c$  and face the same trade cost  $t$ . For most of the discussion the trade costs are assumed to reflect natural barriers to trade, though we note on occasions where tariffs have different implications. Without loss of generality we will

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<sup>4</sup>Empirical studies by Goldberg and Verboven (2001) and others document an apparently high degree of market segmentation in oligopolistic industries.

<sup>5</sup>Bernhofen (1999) extends the basic duopoly model to allow for more home and foreign firms.

restrict attention to the home market, where the sales of the home and foreign firms are denoted  $x$  and  $y$  respectively. Because of symmetry, foreign market sales of the home and foreign firms are also equal to  $y$  and  $x$  respectively.

Brander (1981) and Brander and Krugman (1983) used the reciprocal-markets model to consider multilateral trade liberalisation between two identical countries under Cournot competition with identical goods. They demonstrated that under Cournot competition intra-industry trade can occur in equilibrium even when goods are identical, and they showed that welfare is U-shaped in transport costs. In the next subsection we will illustrate their results in a more general setup that allows for product differentiation.<sup>6</sup> Then, in Section 2.3, we will illustrate the corresponding results under Bertrand competition that were first derived by Clarke and Collie (2003). Finally, in Section 2.4, we extend the analysis to repeated interaction between firms, and explore how trade liberalisation affects the incentives for firms to collude.

Throughout this section, we use a simple common specification of preferences and technology to obtain explicit solutions and to allow us to compare the results under Cournot and Bertrand competition. On the demand side we assume that preferences are quadratic; the qualitative results continue to hold for more general specifications. Thus the domestic utility from consumption of the oligopolistic goods is represented by the following:<sup>7</sup>

$$u = a(x + y) - \frac{1}{2}b(x^2 + 2exy + y^2). \quad (1)$$

where  $e$  is an inverse measure of the degree of product differentiation, ranging from the case of perfect substitutes ( $e = 1$ ) to that of independent demands ( $e = 0$ ). This yields linear inverse demand functions:

$$p = a - b(x + ey), \quad (2)$$

$$p^* = a - b(ex + y), \quad (3)$$

where  $p$  and  $p^*$  are the prices of the home and foreign varieties respectively. On the cost side, we assume that marginal costs are constant and we ignore fixed costs. Hence the home and foreign firms' operating profits in the home market are:

$$\pi = (p - c)x \quad (4)$$

$$\pi^* = (p - c^* - t)y \quad (5)$$

where  $c$  and  $c^*$  are the marginal production costs of the home and foreign firms, assumed to be indepen-

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<sup>6</sup>Bernhofen (2001) introduced product differentiation into Cournot and Bertrand oligopoly models of intra-industry trade, focusing on the effect of trade on profits and consumer surplus.

<sup>7</sup>This ignores the utility derived from other goods. One justification for this specification is that  $u$  is a sub-utility function where the upper-tier utility function is quasi-linear. See Section 4 for further discussion.

dent of output, and  $t$  is the per-unit cost of international transportation.

## 2.2 Quantity Competition

We will first consider the output effects of symmetric multilateral trade liberalisation between two identical countries under quantity competition. As the countries are mirror images of each other we need only consider the effect of a transport cost reduction on equilibrium in the home market. Using the linear inverse demand functions (2) and (3), the firms' first-order conditions for output are  $bx = p - c$  and  $by = p^* - c - t$ . These can then be solved for the Cournot-Nash equilibrium outputs:

$$x = \frac{1}{b(2+e)} \left[ a - c + \frac{e}{2-e}t \right] \quad (6)$$

$$y = \frac{1}{b(2+e)} \left[ a - c - \frac{2}{2-e}t \right] \quad (7)$$

At free trade ( $t = 0$ ), imports  $y$  equal the home firm's sales  $x$ , giving the first result of the model: oligopolistic competition is an independent determinant of trade. Most remarkably, this is true even when products are identical ( $e = 1$ ), the case of "cross-hauling" or "two-way trade in identical products" in the words of Brander (1981). As goods become more differentiated,  $e$  falls below one and the volume of trade rises further: consumers' love of variety is a second source of intra-industry trade, though in this model it is a less important one than oligopolistic competition.<sup>8</sup>

As trade costs increase, cross-hauling persists, though at a diminishing level: home sales rise and imports fall. They finally reach zero at the prohibitive level of trade costs  $\hat{t}^C$ , which from (7) equals:

$$\hat{t}^C = \frac{2-e}{2}(a-c) \quad (8)$$

For any level of trade costs between zero and  $\hat{t}^C$ , and any degree of product differentiation  $e$ , each firm is selling more in its home market than abroad, because it faces a cost penalty on its foreign sales. As a result, the prices it obtains in equilibrium yield a lower mark-up over cost on its exports than on its home sales. This is the second key result of the model, which Brander and Krugman (1983) called "reciprocal dumping". Because the two markets are symmetric, the dumping margin, the difference between the prices obtained by each firm in its home and foreign markets (where the latter equals the f.o.b. - free on

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<sup>8</sup>We can attribute to oligopolistic competition alone the amount of trade which would occur in the absence of trade barriers if goods were identical: when  $e = 1$ ,  $y = \frac{a-c}{3b}$ . The remainder of trade,  $\frac{a-c}{b(2+e)} - \frac{a-c}{3b}$ , is due to product differentiation, so the share of trade attributable to product differentiation rather than to oligopolistic competition is  $\frac{1-e}{3}$ . This rises from zero (when  $e = 1$ ) to one third (when  $e = 0$ ) as products become more differentiated. This contrasts with models of monopolistic competition under CES preferences, in which the share of intra-industry trade in total trade is independent of the degree of product differentiation. This empirically implausible prediction was first pointed out by Ethier (1982a, Proposition 12). See Bernhofen (2001) for further discussion.

board - price, i.e., the price net of trade costs), equals:

$$p - (p^* - t) = \frac{1}{2 - e}t \quad (9)$$

This is increasing in both  $t$  and  $e$ : dumping is more pronounced the higher are trade costs and the greater the substitutability between goods.<sup>9</sup>

It is natural to consider the implications of this kind of trade for welfare, but a useful preliminary step, which is also of independent interest, is its implications for profits. Focusing on the home firm, its total profits equal the sum of its profits on home sales and on exports. The first are given by (4) while the second equal the foreign firm's profits in the home market (5), because of the symmetry of the model. Substituting in turn from the first-order conditions, these are proportional to home and export sales respectively:  $\pi = bx^2$  and  $\pi^* = by^2$ . Differentiating (6) and (7), the effect of a multilateral change in trade costs on total profits can be shown to equal:

$$\frac{d(\pi + \pi^*)}{dt} = 2bx \frac{dx}{dt} + 2by \frac{dy}{dt} = \frac{2e}{4 - e^2}x - \frac{4}{4 - e^2}y \quad \left\{ \begin{array}{l} < 0 \text{ when } t = 0 \text{ (so } x = y) \\ > 0 \text{ when } t = \widehat{t}^C \text{ (so } y = 0) \end{array} \right. \quad (10)$$

The key finding is that profits are *decreasing* in trade costs at free trade, but *increasing* in them in the neighbourhood of autarky. With linear demands, it follows that profits must be a U-shaped function of trade costs, reaching their maximum in autarky and their minimum above free trade. The intuition for this is straightforward. First, starting from free trade, exports are harmed more by an increase in the firm's own costs than home sales are helped by an equal rise in its rival's costs; hence total sales and profits fall for a small increase in  $t$  at free trade. Second, starting from autarky, exports are initially zero, so a small fall in trade costs has a negligible effect on profits in the export market. By contrast, home sales are initially at the monopoly level, so a small fall in the foreign firm's trade costs has a first-order effect on home-market profits. Hence, overall profits fall for a small reduction in  $t$  at autarky.

Finally, we can consider the effect of changes in trade costs on welfare. Home welfare equals:

$$W = \chi + \Pi \quad (11)$$

where  $\chi$  is home consumer surplus and  $\Pi = \pi + \pi^*$  are the profits of the home firm in both markets. Once again, since we are assuming symmetric trade liberalisation between identical countries, we can make use of the fact that the profits of the home firm in the foreign market are equal to the profits of the foreign firm in the home market.

Consider in turn the components of welfare in (11). Consumer surplus must rise monotonically as trade costs fall. This is because a reduction in trade costs lowers the prices of both goods to home

<sup>9</sup>Article VI of the GATT permits the imposition of an anti-dumping duty not greater in amount than the margin given in (9).

consumers.<sup>10</sup> To this must be added the U-shaped relationship between profits and trade costs already derived. In the neighbourhood of free trade, welfare is clearly falling in trade costs. All that is left is to consider the sum of consumer surplus and profits for a small fall in  $t$  starting in autarky (where  $t = \hat{t}^C$ ). Consumer surplus rises because the price falls, but profits on home sales fall both because the price falls and because sales are reduced. The price effects cancel, so the total fall in profits outweighs the rise in consumer surplus.<sup>11</sup> Thus home welfare (the sum of profits and consumer surplus) is also a U-shaped function of  $t$ , reaching its maximum at free trade but its minimum below the prohibitive level of tariffs, as shown by the curve labelled  $W^C$  in Figure 1. An alternative intuitive explanation for this is that a fall in trade costs from the prohibitive level leads to a procompetitive increase in sales, helping to undo the monopoly distortion; however, it also brings about trade at very high transport costs, which is wasteful. In the neighbourhood of the prohibitive trade cost the latter effect dominates, but at lower trade costs the procompetitive effect is dominant. Note finally that this argument does not apply to tariffs, at least when tariff revenue is fully reimbursed to consumers. In that case, the trade costs are merely a transfer payment, and so the procompetitive effect dominates at all levels of tariffs, and welfare falls monotonically as tariffs rise.<sup>12</sup>

### 2.3 Price Competition

How are the effects of trade liberalisation on trade and welfare affected if firms compete in price rather than quantity? A first issue to be addressed is that the outcome of price competition is fundamentally different from that of quantity competition when home and foreign goods are perfect substitutes ( $e = 1$ ). This feature is not peculiar to a trading economy, but rather a reflection of the highly competitive nature of price competition in this case. In a closed-economy duopoly, the lowest-cost firm captures the whole market. In an open economy, even an infinitesimal trade cost ensures that no trade occurs. Hence, the key prediction of the Cournot model, cross-hauling of identical goods, does not apply when firms compete on price and goods are identical.<sup>13</sup> However, the other prediction, that trade liberalisation has a competition effect, applies even more strongly. Even though no actual trade may take place in equilibrium, the head-to-head competition between rival firms prevents either of them charging a price greater than their rival's marginal cost inclusive of the trade cost.

The case of price competition with perfect substitutes is an extreme one. By contrast, there is much

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<sup>10</sup>This is intuitively obvious, and easily proved using the first-order conditions and the expressions for output (6) and (7). These yield:  $\frac{dp}{dt} = \frac{d(bx)}{dt} = \frac{e}{4-e^2} > 0$  and  $\frac{dp^*}{dt} = 1 + \frac{d(by)}{dt} = \frac{2-e^2}{4-e^2} > 0$ .

<sup>11</sup>With consumer surplus denoted by  $\chi = u(x, y) - px - p^*y$ , the change in consumer surplus is  $d\chi = -x dp - y dp^*$ , which equals  $-x dp$  in the neighbourhood of autarky where imports  $y$  are zero. Profits on exports are also zero in the neighbourhood of autarky. As for profits on home sales,  $\pi = (p - c)x$ , the change in this is  $d\pi = (p - c)dx + x dp$ . In the neighborhood of autarky,  $d\chi + d\pi = (p - c)dx$  which is negative as the tariff falls.

<sup>12</sup>This qualifies the statement made in Neary (2009), p. 242, footnote 25.

<sup>13</sup>Strictly speaking, this is only true for positive trade costs. Cross-hauling can occur when goods are identical ( $e = 1$ ) and trade is unrestricted ( $t = 0$ ), although the volume of trade is indeterminate without additional assumptions. One natural case is where consumers buy first from their home firm, so trade is zero even with no trade costs. An alternative case is where consumers are indifferent and purchase half and half from each firm, so cross-hauling constitutes a high proportion of trade.

greater similarity between price and quantity competition in the more plausible case where goods are imperfect substitutes. To solve for the Bertrand equilibrium in this case, we need to use the direct demand functions, which can be obtained by inverting the system in (2) and (3):

$$x = \frac{1}{b(1-e^2)} [(1-e)a - (p - ep^*)] \quad (12)$$

$$y = \frac{1}{b(1-e^2)} [(1-e)a - (p^* - ep)] \quad (13)$$

For the moment consider only interior equilibria in which both firms export positive quantities. We will return to corner solutions later. The first-order conditions for the optimal choice of prices are  $p - c = b(1 - e^2)x$  for the home firm and  $p - c - t = b(1 - e^2)y$  for the foreign firm. These can be solved for the Bertrand-Nash equilibrium prices:

$$p = \frac{(1-e)a + c}{2-e} + \frac{e}{4-e^2}t \quad (14)$$

$$p^* = \frac{(1-e)a + c}{2-e} + \frac{2}{4-e^2}t \quad (15)$$

These in turn can be combined with the direct demand functions to obtain the equilibrium quantities under Bertrand competition:

$$x = \frac{1}{b(1+e)(2-e)} \left[ a - c + \frac{e}{(1-e)(2+e)}t \right] \quad (16)$$

$$y = \frac{1}{b(1+e)(2-e)} \left[ a - c - \frac{2-e^2}{(1-e)(2+e)}t \right] \quad (17)$$

As in the Cournot case, imports equal the home firm's sales at free trade and are decreasing in trade costs, falling to zero when trade costs reach the threshold level which sets (17) equal to zero:

$$\widehat{t}^B = \frac{(1-e)(2+e)}{2-e^2}(a-c) \quad (18)$$

For trade costs strictly between zero and  $\widehat{t}^B$ , and any value of  $e$  less than one, there is reciprocal dumping just as in Cournot competition. In this case the dumping margin equals:

$$p - (p^* - t) = \frac{1+e}{2+e}t \quad (19)$$

This is lower than in the Cournot case, provided  $e$  is strictly positive, reflecting the more competitive nature of price competition; and, as in the Cournot case, it is increasing in both  $e$  and  $t$ .

Profits and welfare also behave quite similarly to quantity competition for trade costs between zero and  $\widehat{t}^B$ . Using the first-order conditions for prices, maximised profits are equal to  $b(1 - e^2)x^2$  and

$b(1 - e^2)y^2$ . Total profits for the home firm are then equal to the sum of these, and their behaviour as trade costs change can be shown to equal:

$$\frac{d(\pi + \pi^*)}{dt} = 2b(1 - e^2) \left[ x \frac{dx}{dt} + y \frac{dy}{dt} \right] \propto ex - (2 - e^2)y \quad \begin{cases} < 0 \text{ when } t = 0 \text{ (so } x = y) \\ > 0 \text{ when } t = \hat{t}^B \text{ (so } y = 0) \end{cases} \quad (20)$$

Once again, therefore, profits are a U-shaped function of trade costs. This in turn, combined with the fact that consumer surplus is monotonically decreasing in trade costs, implies that welfare is U-shaped in  $t$ , for the same reasons as in the Cournot case.

However, unlike under Cournot competition this is not the end of the story. Even when trade costs are too high for exports to take place, they may not be too high to prevent the threat of exports from affecting domestic firms' behaviour. Recall from (18) that  $\hat{t}^B$  is the prohibitive level of trade costs under Bertrand competition. Substituting this into (16) shows that the home firm's output is  $x = (a - c)/b(2 - e^2)$  at this level of trade costs, which is above the unconstrained monopoly output level,  $x^M = (a - c)/2b$ . However, the home firm does not have an incentive to raise its price, since its rival would then make positive sales, so lowering the home firm's profits.<sup>14</sup> In this sense, we can describe the equilibrium as one where the home firm is constrained by the threat of potential competition. As the trade costs rise further the home firm has greater scope to raise its price. Only when trade costs reach the prohibitive level under Cournot competition, as given by (8) in section 2.2, can the home firm behave as an unconstrained monopolist. At intermediate levels of trade costs,  $\hat{t}^B \leq t \leq \hat{t}^C$ , the home firm chooses a price at which the foreign firm is just unable to produce. In this region the home firm's output is:<sup>15</sup>

$$x = \frac{a - c - t}{be} \quad (21)$$

which is clearly falling in  $t$ . Combining this with (16), which applies in the region  $0 \leq t \leq \hat{t}^B$ , home sales are an inverted-V function of trade costs.

Finally, consider the level of welfare in this region of potential though not actual competition from imports. Welfare in the absence of trade is consumer surplus plus home profits. This can be written as  $W = (a - c)x - \frac{1}{2}bx^2$ . Totally differentiate this to get:

$$dW = (a - c - bx)dx. \quad (22)$$

It is then clear from (21) and (22) that welfare is falling in trade costs in the region  $\hat{t}^B \leq t \leq \hat{t}^C$ . Hence, unlike the Cournot case, under Bertrand competition trade liberalisation starting from autarky initially

<sup>14</sup>For further details see Clarke and Collie (2003).

<sup>15</sup>To see this, find the level of  $p$  that sets imports equal to zero for any given  $p^*$ . From (13) with  $y = 0$ , this is:  $p = \frac{p^* - (1 - e)a}{e}$ . In this region, with  $\hat{t}^B \leq t \leq \hat{t}^C$ , the foreign firm is just kept out of the market so the incipient price of imports is simply their unit cost:  $p^* = c + t$ . Eliminating prices  $p$  and  $p^*$  from these two equations and the demand function  $p = a - bx$  yields (21).

raises welfare: the home firm is disciplined by the threat of trade, without any trade taking place, and hence without any socially wasteful transport costs being incurred.<sup>16</sup>

The locus labelled  $W^B$  in Figure 1 summarises the relationship between welfare and the level of trade costs under Bertrand competition. (The figure is drawn for an intermediate value of the substitution parameter  $e$ ; 0.8 in this case.) Welfare in autarky is at the monopoly level, where the mode of competition with the foreign firm is irrelevant, so  $W^B$  and  $W^C$  coincide. As  $t$  falls (moving to the left away from  $\hat{t}^C$ ), the home firm's profit-maximising strategy is to lower its price thereby raising output and welfare even though no imports actually occur. Below the threshold level  $\hat{t}^B$ , imports become profitable, and have the same effect as in Cournot competition, generating a U-shaped relationship between welfare and  $t$ . However, as shown by Clarke and Collie (2003), the level of welfare never falls below the autarky level. So, while trade liberalisation may lower welfare in a local sense, opening up to trade can never induce net losses from trade as in the Cournot case.

To summarise the Bertrand case, it differs from Cournot in that the key prediction of cross-hauling of identical goods no longer applies. On the other hand, the other main finding, that trade imposes a competition effect, is enhanced rather than weakened. Even if no trade actually occurs, it may still induce more competitive behaviour by the domestic firm, so raising welfare. As trade costs fall further, actual imports occur, and welfare is a U-shaped function of trade costs as in the Cournot case. However, the level of welfare never falls below the autarky level: in this respect too, the competition effect of trade is stronger under Bertrand competition than under Cournot.

## 2.4 Repeated Interaction and Collusion

So far we have shown that once trade costs fall below some critical level firms will invade each others markets. However, the increased competition between the firms will reduce their profits. Could firms decide to collude by refraining from exporting to each others market? Clearly such a collusive arrangement will not be possible to sustain in a one-shot non-cooperative game setting. However, it has been shown by several authors that if the game is repeated infinitely then whether or not such a collusive arrangement can be sustained will depend on the degree of impatience of the firms.<sup>17</sup>

Both the quantity setting and the price setting games we have examined above have a prisoner's dilemma character, in the sense that the firms would collectively do better if they could collude and share the markets, but they have a unilateral incentive to deviate from such an agreement. Assume that the game is repeated infinitely and that the firms have an identical discount factor  $\delta$ . If a firm deviates from collusion (cheats) it will be punished in the future. We will follow most of this literature and assume that if a firm cheats its rival will never again cooperate with it. This is a so-called "grim

<sup>16</sup>This equilibrium resembles those with explicit entry-deterrence behaviour, as in Dixit (1980) or Fudenberg and Tirole (1984). However, unlike those cases, here the firms move simultaneously in a one-shot game.

<sup>17</sup>See for instance Pinto (1986), Fung (1991, 1992), Lommerud and Sørgaard (2001) and Ashournia, Hansen and Hansen (2008).

trigger strategy” and it implies that a period of cheating is followed by reversion to the Nash equilibrium in each period forever after.

Given that its rival chooses the collusive action, a firm must weigh the one-period gain from cheating against the lower profits in all subsequent periods in the future. The less impatient are firms, the less valuable will be the short-term gains from cheating and the more they will be concerned with the loss of profits in the infinite punishment phase. There is a critical threshold discount factor  $\hat{\delta}$ , above which collusion can be sustained. This critical discount factor depends (among other things) on the level of trade costs. Tacit collusion supported by grim trigger strategies is possible for any discount rate  $\delta$  above the threshold level, which is defined by:

$$\hat{\delta} \equiv \frac{\pi^D - \pi^J}{\pi^D - \pi^N} \quad (23)$$

where  $\pi^J$  is per-period profit for a firm when both firms collude (i.e., engage in joint profit maximization),  $\pi^N$  is per-period profit for a firm under non-cooperation, and  $\pi^D$  is the one-period profit of defecting from the collusive agreement when the rival keeps to the tacit agreement. The ranking of these per-period profits is:  $\pi^D > \pi^J > \pi^N$ .

The simplest special case is that of Cournot competition with identical products. In this case, first studied by Pinto (1986), collusion implies that the firms do not export and behave as monopolists in their own markets. If collusion breaks down, the firms play Cournot in both markets, just as in Section 2.2. A reduction in  $t$  increases  $\pi^D$ , the short-run profitability of defecting from the collusive agreement. This is because the gains from invading the rival’s market are larger the lower are trade costs. A fall in  $t$  also influences a firm’s profits in the punishment phase  $\pi^N$ . However the effect is small relative to the effect on  $\pi^D$  and it is non-monotonic. As we saw in Section 2.2 (see equation (20)), this non-monotonicity arises from the fact that a reduction in trade costs raises profits on export sales but increases competition from the rival in the home market. With homogeneous-product quantity-setting firms, the increased short-run profitability of the cheating dominates. Hence, trade liberalization increases  $\hat{\delta}$  and thus reduces the range of  $\delta$  over which collusion can occur and so has an unambiguously pro-competitive effect.

The unambiguously beneficial effect of trade liberalization on competition has recently been challenged by Ashournia, Hansen and Hansen (2008) who show that this result is sensitive to the assumption of identical products.<sup>18</sup> Following earlier work by Fung (1991) they show that colluding firms will not in general refrain from entering each others’ home markets. Given a taste for variety on the part of consumers and provided that transport costs are not too high, the profits of the cartel can be increased by selling both of the different varieties in the two markets. The collusive outputs in the home market are:

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<sup>18</sup> Lommerud and Sørsgard (2001) demonstrate that this result is also reversed under Bertrand competition with homogeneous products.

$$bx = \frac{(1-e)(a-c) + et}{2(1-e^2)}, \text{ and } by = \frac{(1-e)(a-c) - t}{2(1-e^2)} \quad (24)$$

Hence there is intra-industry trade in a collusive equilibrium provided that  $t < \hat{t}^T \equiv (1-e)(a-c)$ . This threshold is below the prohibitive trade cost under Cournot given in (8). When trade costs are below  $\hat{t}^T$  so that trade occurs under collusion, then a lowering of trade costs will lower the critical threshold level of the discount factor thus making collusion easier. The intuition for this surprising result is that trade liberalisation raises firms' profitability in the presence of collusive trade while it leaves profits unchanged when firms do not trade under collusion. Thus when there is trade under collusion there is an additional reason why trade liberalisation strengthens the incentive to cooperate. This is sufficient to make trade liberalisation anti-competitive in the presence of collusive trade.<sup>19</sup>

### 3 Strategic Trade and Industrial Policy

#### 3.1 A General Strategic Trade Model

In their seminal paper on strategic trade policy Brander and Spencer (1985) developed a model in which it is optimal to subsidize exports. They consider an oligopolistic setting in which pure profits are earned in equilibrium, and an export subsidy can be used to shift these rents from foreigners to home residents.

In their model Brander and Spencer assume that the firms play Cournot and that quantities are strategic substitutes, so that the firms' reaction functions are negatively sloped. However, it was soon demonstrated that the strategic trade argument for an export subsidy is very sensitive to changes in these key assumptions. Eaton and Grossman (1986) showed that when firms compete in a Bertrand manner and prices are strategic complements then an export tax is optimal.<sup>20</sup> We will now present these contrasting results using the unifying framework of a general strategic trade model that allows for both quantity and price competition. This is a slightly modified version of a model first presented by Brander (1995).

Assume that a home and foreign firm export to a third market. Only the home government is policy-active.<sup>21</sup> The "third market" assumption implies that the interests of consumers do not enter the home country's welfare function and this allows us to focus on the strategic interaction between the firms in its purest form. The home and foreign firms play a Nash game in actions  $A$  and  $B$  respectively. These actions may be either outputs or prices. The advantage of setting up the model in this more general way is that we do not need to specify whether firms compete on quantities or prices. Firms' profits depend

<sup>19</sup>Fung (1991) also examines cartel stability under collusive trade. However, he does not discuss the role of trade liberalisation.

<sup>20</sup>Throughout this section, our discussion of Cournot competition holds whether products are homogeneous or differentiated. By contrast, in the Bertrand case, we need to assume that products are sufficiently differentiated such that an interior equilibrium exists.

<sup>21</sup>Multilateral subsidy games will be discussed later.

on their own and their rival's actions and on the home government's export subsidy. Thus the home firm's profit function is:

$$\Pi(A, B, s) = \pi(A, B) + sx(A, B), \quad (25)$$

where  $\pi$  represents operating profits (sales revenue net of production costs) and  $sx$  is subsidy income. The foreign firm is not subsidized and its profits are given by

$$\pi^*(A, B). \quad (26)$$

The home government and the two firms play a two-stage game. In the first stage the government sets the per unit subsidy  $s$  (which could be negative). In the second stage the firms simultaneously choose their market actions. Solving for the sub-game perfect Nash equilibrium we begin by looking at stage 2.

Taking the per unit subsidy as given, the first-order conditions for the firms' market actions are:

$$\Pi_A(A, B, s) = \pi_A(A, B) + sx_A(A, B) = 0, \quad (27)$$

and

$$\pi_B^*(A, B) = 0, \quad (28)$$

where subscripts denote partial derivatives. The partial derivative  $x_A$  of home output  $x$  with respect to the home action  $A$  is positive and equal to unity if the market action is output, while it is negative and equal to the slope of the home firm's demand curve  $x_p$  if the action is price. Equation (28) implicitly defines the foreign firm's reaction function, giving  $B$  as a function of  $A$ . This function will play an important role below.

We now consider the first stage in which the home government sets the subsidy anticipating how this will affect second-stage actions. We will assume that the subsidies are financed by non-distortionary lump-sum taxes. Since all output is exported, home welfare is just the home firm's profits net of subsidy payments:

$$W(A, B) = \Pi(A, B, s) - sx(A, B) = \pi(A, B). \quad (29)$$

Totally differentiate this and make use of the home firm's first-order condition to get:

$$dW = -sx_A dA + \pi_B dB. \quad (30)$$

The optimal subsidy is then:

$$s^o = (x_A)^{-1} \pi_B \frac{dB}{dA}, \quad (31)$$

where  $dB/dA$  is the slope of the foreign firm's reaction function. The sign of the optimal subsidy depends

on the signs of  $\pi_B$ ,  $x_A$  and  $dB/dA$ . The term  $\pi_B$  is the cross-effect of the foreign firm's market action on the home firm's profits, and we follow Brander in saying that the actions are "friendly" if this term is positive. When actions are unfriendly the foreign action reduces home profits. Outputs under Cournot competition are unfriendly ( $\pi_B < 0$ ) while prices under Bertrand competition are friendly ( $\pi_B > 0$ ). However, the derivative  $x_A$  is negative when prices are the strategic variable while it is positive (equal to unity) when firms are choosing quantities. Hence regardless of whether firms play Cournot or Bertrand the combined term  $(x_A)^{-1}\pi_B$  is negative. Thus the sign of the optimal subsidy turns on the slope of the foreign reaction function  $dB/dA$ . Outputs are typically strategic substitutes under Cournot competition, giving rise to an incentive to subsidize. However, prices are typically strategic complements under Bertrand competition, giving rise to an incentive to tax exports.

Clearly the Cournot and Bertrand cases differ in detail. In Cournot (assuming outputs are strategic substitutes), the optimal policy is a subsidy, which shifts profits from the foreign to the home firm, and lowers price so consumers in the third country gain. By contrast, in Bertrand (assuming prices are strategic complements), the optimal policy is a tax, which shifts profits from the home to the foreign firm, and raises prices of both goods so consumers in the third country lose. Nevertheless, there is an important sense in which the two cases are formally identical. In both, the home government uses its superior commitment power to bring about an equilibrium which the home firm cannot attain on its own. That equilibrium is identical to the Stackelberg equilibrium which would prevail if the home firm were (arbitrarily) assumed to be able to choose its action before the foreign firm. It is as if the home government transfers its first-mover advantage to the home firm.

### 3.2 The Robustness of Export Subsidies

While, as we have seen, the optimal policy towards an exporting firm is sensitive to the nature of competition, it can also be affected by other factors. For instance, even under Cournot competition with strategic substitutes, the presence of more home firms can change the optimal policy from a subsidy to a tax.<sup>22</sup> This is because the presence of more home firms introduces a terms-of-trade argument for intervention that must be balanced against the strategic trade motive. Another issue is the social cost of raising government revenue. The argument for a subsidy is weakened when we allow for the possibility that the cost of raising the necessary revenue to finance the subsidy is increased by the distortionary effects of taxation. (See for instance Neary (1994) and Neary and Leahy (2004).) A final qualification to the case for export subsidies is that an expansion of one home firm may draw resources away from oligopolistic firms in other sectors. As Dixit and Grossman (1986) show, the case for subsidisation must then be qualified to rest on the desirability of subsidising one sector relative to all others. In an extreme case, if a symmetric group of oligopolistic sectors draw on a common fixed factor, say skilled labour,

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<sup>22</sup>This was first pointed out by Dixit (1984).

then subsidy rents would be fully captured by that factor, and laissez-faire is the optimal policy. For all these reasons, the fact that the policy recommendations are so sensitive to the assumptions implies that governments need to know quite a lot about a particular industry in order to design the optimal intervention.

So far we have assumed that only the home government intervenes. An obvious extension is to allow for both governments to be policy active. The most natural way to model this is to assume that the home and the foreign governments choose their subsidies simultaneously in the first stage and then the firms choose their market actions  $A$  and  $B$  in the second stage. What difference does this make? In one important sense multilateral intervention makes no difference. If the firms' reaction functions are negatively sloped then each country still has a unilateral incentive to subsidize and if they are positively sloped then each has an incentive to tax. However, a unilateral incentive to subsidize runs counter to the collective interest of countries to reduce exports and thus improve the terms of trade: as Brander and Spencer (1985) showed, the game between countries is a prisoner's dilemma, at least when the countries are symmetric, in that intervention by both countries lowers their welfare. By contrast, if the firms' reaction functions are upward-sloping, the policy game with symmetric countries yields an outcome closer to the joint optimum.<sup>23</sup>

### 3.3 The Robustness of Investment Subsidies

While the strategic trade argument for an export subsidy is highly sensitive to whether firms engage in quantity or price competition, the strategic investment policy argument for a subsidy is much more robust. We will now demonstrate that, although ambiguous in principle, the case for strategic investment subsidies is reasonably robust in practice.<sup>24</sup>

Consider a setup like that in Section 3.1 above in which a home and a foreign firm export to a third market. As before the firms choose actions  $A$  and  $B$ . However, now assume the home and foreign firms also choose investment levels  $k$  and  $k^*$  respectively before the market actions are set. We do not need to be very specific regarding the form of the investment carried out by the firms. The investment could be in capital or in process R&D, in which case it leads to a reduction in the firm's production costs. It could also be in marketing or product quality, which shifts the demand function it faces. In addition the investment spending of each firm may affect the profits of its rival because of R&D or other spillovers. The government of the home country is policy active and sets an investment subsidy  $\sigma$  (but no export

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<sup>23</sup>See Helpman and Krugman (1989), p. 111. Further applications of such policy games under both Cournot and Bertrand competition are considered by Collie (2000, 2002).

<sup>24</sup>Our presentation here follows Leahy and Neary (2001). Spencer and Brander (1983), Bagwell and Staiger (1994), Maggi (1996) and Neary and Leahy (2000) among others have also shown in different contexts that an investment subsidy is typically optimal when a domestic oligopolist faces foreign rivals and an export subsidy is unavailable.

subsidy) before the firms decide on their investment levels. The profits of the home firm are:

$$\Pi(k, k^*, A, B, \sigma) = \pi(k, k^*, A, B) - \sigma k, \quad (32)$$

where  $\sigma k$  represents the firm's subsidy income. The foreign firm does not receive a subsidy and its profit function is represented by:

$$\pi^*(k, k^*, A, B). \quad (33)$$

In the final stage of the game the firms choose their market actions taking the investments and the subsidies as given. The resulting first-order conditions do not depend directly on the investment subsidy:

$$\pi_A(k, k^*, A, B) = 0 \quad \text{and} \quad \pi_B^*(k, k^*, A, B) = 0. \quad (34)$$

From these we can obtain the Nash equilibrium in actions  $A(k, k^*)$  and  $B(k, k^*)$  which depend on the levels of investment. We can use the equilibrium level of the actions to eliminate  $A$  and  $B$  in the profit functions. The resulting "reduced-form" operating profit functions are distinguished by hats:

$$\widehat{\pi}(k, k^*) = \pi[k, k^*, A(k, k^*), B(k, k^*)] \quad \text{and} \quad \widehat{\pi}^*(k, k^*) = \pi^*[k, k^*, A(k, k^*), B(k, k^*)], \quad (35)$$

for the home and foreign firms respectively.

We turn now to the second stage of the game in which the firms simultaneously choose their investment levels given the subsidy and anticipating how the investments will affect the subsequent equilibrium in actions. The home firm maximizes the following reduced-form total profit function, equal to operating profit plus subsidy revenue:

$$\widehat{\Pi}(k, k^*, \sigma) = \widehat{\pi}(k, k^*) + \sigma k. \quad (36)$$

As for the government in the home country, it wishes to maximise:

$$\widehat{W}(k, k^*) = \widehat{\Pi}(k, k^*, \sigma) - \sigma k = \widehat{\pi}(k, k^*). \quad (37)$$

It is clear by inspection that the reduced-form profit and welfare functions in (36) and (37) have the same form as the corresponding functions (25) and (29) in Section 3.1. Hence we can immediately determine the optimal subsidy:

$$\sigma^o = \widehat{\pi}_{k^*} \frac{dk^*}{dk}. \quad (38)$$

As before, the sign of the optimal subsidy depends on the signs of the friendliness term  $\widehat{\pi}_{k^*}$  and on the

slope of the foreign reaction function  $dk^*/dk$ . The slope of the reaction function can be written as:

$$\frac{dk^*}{dk} = -\frac{\widehat{\pi}_{k^*k}^*}{\widehat{\pi}_{k^*k^*}^*}. \quad (39)$$

The denominator is negative from the foreign firm's second-order condition for profit maximisation. Therefore the slope of the reaction function depends on the sign of  $\widehat{\pi}_{k^*k}$ , which indicates whether foreign investment is a strategic substitute ( $\widehat{\pi}_{k^*k}^* < 0$ ) or strategic complement ( $\widehat{\pi}_{k^*k}^* > 0$ ) for home investment. Hence, we can say that the optimal strategic industrial policy is an investment subsidy if and only if an increase in investment by one firm has the same qualitative effect on its rival's profits in total and at the margin: i.e., if and only if  $\widehat{\pi}_{k^*}$  and  $\widehat{\pi}_{k^*k}^*$  have the same sign. With simple functional forms these two concepts tend to have the same sign. As we show in Leahy and Neary (2001), we can expect that the optimal policy will be a subsidy because there is a presumption that unfriendliness ( $\widehat{\pi}_{k^*} < 0$ ) and strategic substitutability ( $\widehat{\pi}_{k^*k}^* < 0$ ) will be found together as will friendliness ( $\widehat{\pi}_{k^*} > 0$ ) and strategic complementarity ( $\widehat{\pi}_{k^*k}^* > 0$ ). So, although the general expression for the subsidy in (38) seems to indicate that not much can be said about the likelihood that subsidization will be the optimal policy, this turns out to be the case for most functional forms.

### 3.4 Multilateral Investment Subsidy Games

As we have just seen, governments have a unilateral incentive to use rent-shifting investment subsidies. This remains the case when we extend the model to allow for the governments of an arbitrary number of countries to choose their investment subsidies simultaneously. However, such subsidy wars among exporters can give rise to a prisoner's dilemma. In that case, all the exporting countries would be better off if they agreed to ban investment subsidies altogether. However, if investment is in R&D and this generates international spillovers then investment subsidies may be friendly to other countries. We will compare welfare when governments choose investment subsidies with welfare in the non-intervention regime.

We extend the model of the previous subsection to a symmetric oligopolistic industry with  $n$  identical firms, each of which is located in one of  $n$  countries, and sells on a single outside market with no tariffs or transport costs. Once again, the game consists of three stages. In the first stage, subsidies are set either by national governments or by a supra-national authority. Then, as in earlier sub-sections, the firms choose in turn their investments and market actions. The model used is a version of the multi-country multi-firm model in Leahy and Neary (2009). Collie (2005) and Haaland and Kind (2006, 2008) consider similar issues in the context of R&D subsidies, though in relatively special models.<sup>25</sup>

Modify equation (36) slightly to extend the notation to cover many firms. A typical firm maximizes

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<sup>25</sup>Besley and Seabright (1999) present a related but different approach to international competition which takes the form of state aids to industry.

the following reduced-form total profit function:

$$\widehat{\Pi}^i(k^i, \mathbf{k}^{-i}, \sigma^i) = \widehat{\pi}^i(k^i, \mathbf{k}^{-i}) + \sigma^i k^i. \quad (40)$$

where variables in bold denote vectors, so  $\mathbf{k}^{-i}$  is the vector of investments by firms other than firm  $i$ . We continue to assume that the firms export to a third country so that consumer surplus does not enter the welfare function. (The consequences of relaxing this assumption are discussed in detail in Leahy and Neary (2009).) The government in country  $i$  wishes to maximise:

$$\widehat{W}^i(k^i, \mathbf{k}^{-i}) = \widehat{\Pi}^i(k^i, \mathbf{k}^{-i}, \sigma^i) - \sigma^i k^i = \widehat{\pi}^i(k^i, \mathbf{k}^{-i}) \quad (41)$$

Aggregate welfare of the  $n$  countries is:

$$\widehat{W}(\mathbf{k}) = \sum \widehat{\pi}^i(k^i, \mathbf{k}^{-i}) \quad (42)$$

We consider three different regimes which we will refer to as laissez-faire ( $L$ ), non-cooperative intervention ( $N$ ) and cooperative intervention ( $C$ ) respectively. The laissez-faire equilibrium arises when all subsidies  $\sigma^i$  are zero, and can be thought of as arising from a commitment to non-intervention on the part of the  $n$  countries' governments. In the non-cooperative intervention case, countries play a Nash game in subsidies, each seeking to maximise national welfare. Finally, the cooperative equilibrium occurs when a supra-national authority chooses a uniform subsidy to maximise the countries' aggregate welfare, which is simply the sum of their individual welfare levels. This regime yields the highest level of welfare and we use it as a benchmark with which to compare the other two regimes.

In the laissez-faire regime the typical firm maximises (40) with  $\sigma^i$  set at zero. The first-order condition is  $\widehat{\pi}_i^i = 0$ . It proves useful to introduce a function  $m^L(\kappa)$  which is the marginal return to investment net of marginal investment costs under laissez-faire evaluated at a symmetric level of investment,  $\kappa$ . Thus the first-order condition under laissez-faire can be rewritten as  $m^L(\kappa^L) = \widehat{\pi}_i^i = 0$ .

In the Non-Cooperative regime the typical government chooses its subsidy to maximise national welfare (41). The typical government has one instrument (its investment subsidy) with which it can target the investment level of its firm. It is very convenient to see the government as using its subsidy to control its own firm's investment with the other firms' investments adjusting according to their reaction functions. This yields the first-order condition:

$$m^N(\kappa^N) = \widehat{\pi}_i^i + (n-1)\widehat{\pi}_j^i \frac{dk^j}{dk^i} = 0 \quad (43)$$

where  $m^N$  is the net marginal return to investment in the non-cooperative case. Likewise, in the cooper-

ative regime the supra-national authority can be seen as choosing all the investment levels to maximise aggregate welfare (42). The first-order condition is:

$$m^C(\kappa^C) = \widehat{\pi}_i^i + (n-1)\widehat{\pi}_i^j = 0 \quad (44)$$

where  $m^C$  is the net marginal return to investment in the cooperative case

We now wish to compare the levels of investment in the different regimes. To do this we must compare the net marginal returns to investment in the different regimes. Naturally we need to be cautious as  $m^L(\kappa^L)$ ,  $m^N(\kappa^N)$  and  $m^C(\kappa^C)$  are evaluated at different symmetric investment levels. However, we can compare the different net marginal returns to investment at any common point. We show in Leahy and Neary (2009) that provided the rankings of marginal returns to investment are the same in all three regimes and some other stability assumptions are made then the ranking of symmetric equilibrium investment levels ( $\kappa$ ) across the three regimes is the same as the ranking of the marginal returns to investment. A comparison of  $m^L$  and  $m^N$  at any common point yields:

$$m^N(\kappa) - m^L(\kappa) = (n-1)\widehat{\pi}_j^i \frac{dk^j}{dk^i} \quad (45)$$

This is a generalization of the two-firm case considered in the earlier section. It shows that the investment levels will be higher when governments intervene than when they do not provided that  $\widehat{\pi}_j^i$  (the friendliness term) and  $\frac{dk^j}{dk^i}$  (which is positive if and only if investments are strategic complements) have the same sign. This is also the same condition as the one that determines the sign of the non-cooperative investment subsidy. So, as explained earlier, there is a presumption that  $m^N - m^L$  is positive and thus that the governments will give positive subsidies and that  $\kappa^N > \kappa^L$ .

Is it in the countries collective interest to subsidize investment? To answer this question we must compare  $m^C$  and  $m^L$ . This yields:

$$m^C(\kappa) - m^L(\kappa) = (n-1)\widehat{\pi}_i^j \quad (46)$$

which is positive if and only if investments are friendly. If there are no positive spillovers then this is negative and so it is in the interests of the group of countries to use a tax to reduce the level of investment. However if there are sufficiently strong spillovers that investments raise rivals' profits then the cooperative subsidy is positive and  $\kappa^C$  is bigger than  $\kappa^L$ . The sign of the friendliness term also determines whether or not the non-cooperative investment level is too high from the point of view of the collective:

$$m^C(\kappa) - m^N(\kappa) = (n-1)\widehat{\pi}_j^i \left(1 - \frac{dk^j}{dk^i}\right) \quad (47)$$

The right-hand side depends only on the sign of  $\widehat{\pi}_j^i$  as  $1 - \frac{dk^j}{dk^i}$  is always positive due to stability consid-

erations as we show in Leahy and Neary (2009).

		$\widehat{\pi}_i^j$	
		– Unfriendly	+ Friendly
$\widehat{\pi}_{ij}^i$	– Strategic substitutes	$\kappa^N > \kappa^L > \kappa^C$	$\kappa^C > \kappa^L > \kappa^N$
	+ Strategic complements	$\kappa^L > \kappa^N > \kappa^C$	$\kappa^C > \kappa^N > \kappa^L$

Table 1: Rankings of Investment Levels in Different Equilibria

The investment rankings in the different equilibria are reported in Table 1. As noted in Section 3.3, there is a presumption that unfriendliness and strategic substitutability are found together, as are friendliness and strategic complementarity. Hence we can focus on the diagonal entries in the table. In the top left-hand entry, where investments are unfriendly and strategic substitutes, the level of investment is highest under non-cooperation and lowest under cooperation. The cooperative investment level is always the one that maximises the welfare of the group of countries. If we assume that welfare is concave in  $\kappa$  then, since  $\kappa^L$  is closer to  $\kappa^C$  than is  $\kappa^N$ , governments acting alone over-subsidise: welfare is higher under laissez-faire than under non-cooperative subsidy setting. This case is more likely to prevail if positive spillovers are low and the firms compete very intensely (goods are close substitutes). By contrast, in the bottom right-hand entry, where investments are friendly and strategic complements, the level of investment is highest under cooperation and lowest under laissez-faire. In this case the individual governments do not subsidise enough from the perspective of the collective. This case is more likely to hold if beneficial spillovers are high and/or firms do not compete too intensely.

### 3.5 Trade and Industrial Policy Towards Dynamic Oligopoly

In this subsection we consider an extension of the strategic trade and investment model to an indefinite (though finite) number  $T$  of time periods. However, we return to the setup with one home and one foreign firm and one policy-active government. In each period  $t$ , each firm takes an action, choosing the value of some variable,  $A_t$  for the home firm and  $B_t$  for the foreign firm. This specification encompasses all those cases considered so far: in each period the decision variables might be output, price, R&D or marketing. In a further departure from previous sub-sections, we allow for the possibility that the policy-active government can set subsidies in more than one time period.

The firms' profits depend on a vector of their own actions and a vector of their rival's actions and on all the home government's subsidies. The home firm's profit function is:

$$\Pi(\mathbf{A}, \mathbf{B}, \mathbf{s}) = \pi(\mathbf{A}, \mathbf{B}) + S(\mathbf{A}, \mathbf{B}, \mathbf{s}), \quad (48)$$

where  $\mathbf{A}$  and  $\mathbf{B}$  are the vectors of the home and foreign firm's actions respectively and  $\mathbf{s}$  is the vector of subsidies. As before, the firm's gross profits  $\Pi$  are made up of profits net of subsidy income  $\pi$  and its subsidy income  $S$ . In many applications, the subsidy income is linear in the firm's decision variables, so that  $S^t = s_t a_t$  where  $S^t$  is subsidy income in period  $t$ . Examples of this include an R&D subsidy or an output subsidy under Cournot competition. By contrast, as we have seen in Subsection 3.1, subsidy income depends in a more complicated way on the subsidy rate in the case of an output subsidy under Bertrand competition. It is clear that equation (48) is a  $T$ -period generalisation of equation (25). The foreign firm's profits are now given by

$$\pi^*(\mathbf{A}, \mathbf{B}). \quad (49)$$

which is similarly a  $T$ -period generalisation of equation (26).

Each firm now has  $T$  first-order conditions, one for each period. These can be written in vector notation as:

$$\left( \frac{d\Pi}{d\mathbf{A}} \right)' = \Pi'_A + \Pi'_B \frac{d\mathbf{B}}{d\mathbf{A}} + \Pi'_s \frac{d\mathbf{s}}{d\mathbf{A}} = 0, \quad (50)$$

and

$$\left( \frac{d\pi^*}{d\mathbf{B}} \right)' = \pi'^*_B + \pi'^*_A \frac{d\mathbf{A}}{d\mathbf{B}} = 0, \quad (51)$$

where a prime denotes the transpose of a vector. It is instructive to compare these with the corresponding first-order conditions when the firms choose an action in one period only. (See Subsection 3.1 above.) Apart from the obvious difference that these are now vectors rather than scalars the key difference is the presence of strategic terms. An action chosen by a firm before the other firm or the government chooses its action may affect the value of that action. (These effects are captured by the matrices  $d\mathbf{B}/d\mathbf{A}$ ,  $d\mathbf{s}/d\mathbf{A}$  and  $d\mathbf{A}/d\mathbf{B}$ .) This in turn affects the profits of the firm in a manner that depends on whether the affected action is friendly or unfriendly.

The home welfare function:

$$W(\mathbf{A}, \mathbf{B}) = \Pi(\mathbf{A}, \mathbf{B}, \mathbf{s}) - S(\mathbf{A}, \mathbf{B}, \mathbf{s}) = \pi(\mathbf{A}, \mathbf{B}). \quad (52)$$

is a  $T$ -period generalisation of (29). When does the government set its subsidies in this  $T$ -period game? One possibility is that all the subsidies are set at the very start of the game before any of the actions of the firms are chosen. In that case we can say that the government has superior *intertemporal* commitment power to the home firm. (Note then that a subsidy labelled  $s_t$  is chosen in period 1 but the subsidized action  $A_t$  occurs in period  $t$ .) Another possibility is that the subsidies are actually set in the period in which they become effective. Our setup allows for both possibilities and for any of the cases in between. However, we do impose the following minimum structure on the  $T$ -period game. We assume that within

time periods the firms play a Nash game, setting  $A_t$  and  $B_t$  simultaneously, but that if the government subsidizes the period  $t$  activities of its firm then the corresponding subsidy  $s_t$  is always chosen before  $A_t$  and  $B_t$ . (However, it is not necessarily chosen before *every* action by the firms.) Thus we say that the government always has superior *intratemporal* commitment power to the home firm.

To obtain the optimal subsidies, totally differentiate (52) to get a necessary condition for welfare maximisation:

$$dW = \pi'_A d\mathbf{A} + \pi'_B d\mathbf{B} = \mathbf{0}. \quad (53)$$

As we show in Neary and Leahy (2000) it is possible to solve the foreign first-order condition equations for generalised reaction functions, which express the foreign firm's actions as functions of all of the home firm's:  $\mathbf{B} = \tilde{\mathbf{B}}(\mathbf{A})$ . In differential form this is  $d\mathbf{B} = \tilde{\mathbf{B}}_A d\mathbf{A}$ . Use this to eliminate  $d\mathbf{B}$  in (53). We can also use the home firm's first-order conditions and the fact that  $\Pi_A = \pi_A + S_A$  to eliminate  $\pi_A$  in (53). This yields the following expression for the optimal subsidies:

$$S'_A = \pi'_B \tilde{\mathbf{B}}_A - \Pi'_B \frac{d\mathbf{B}}{d\mathbf{A}} - \Pi'_s \frac{ds}{d\mathbf{A}}. \quad (54)$$

When we compare this expression to (31), which gives the optimal subsidy in the one-period strategic trade model, we see that the first term is simply a dynamic generalisation of the rent-shifting effect in the static strategic trade model. Algebraically this term is obtained by multiplying the friendliness term  $\pi_B$  by the slope of the foreign reaction function  $\tilde{\mathbf{B}}_A$ . The remaining terms on the right-hand side are new in a dynamic setting and reflect the fact that the government must correct for the home firm's strategic behaviour.<sup>26</sup>

To obtain more concrete results consider a two-period example in which the government cannot commit to its subsidies in advance of the time period in which they become effective. Thus  $s_t$  is chosen in period  $t$  before  $A_t$  and  $B_t$ , and the game now consists of four stages. From equation (54) the optimal first-period subsidy in this case is:

$$S_{A_1}^1 + \rho S_{A_1}^2 = (\pi_{B_1}^1 + \rho \pi_{B_1}^2) \tilde{B}_{11} + \rho \pi_{B_2}^2 \tilde{B}_{21} - \left( \Pi_{B_2} \frac{dB_2}{dA_1} + \Pi_{s_2} \frac{ds_2}{dA_1} \right), \quad (55)$$

where  $\pi^t$  refers to period  $t$  operating profit,  $\rho$  denotes the discount factor, and the rent-shifting and strategic correction terms are written in full. In period 2 the government's problem is now particularly

<sup>26</sup>The first two terms on the right-hand side of (54) may appear to be very similar except in sign. Both consist of a friendliness term multiplied by the slope of a foreign reaction function. Moreover,  $\Pi_B - \pi_B = S_B = \mathbf{0}$  in the many applications in which the subsidy income is linear in the firm's decision variables. However, the matrices  $\tilde{\mathbf{B}}_A$  and  $d\mathbf{B}/d\mathbf{A}$  differ in an important respect which reflects the government's superior commitment power. The matrix  $\tilde{\mathbf{B}}_A$  gives the derivatives of foreign actions with respect to home actions from the perspective of the home government. This differs in general from the matrix  $d\mathbf{B}/d\mathbf{A}$  in which the derivatives are from the perspective of the home firm. The difference between the two reflects the fact that within any time period the home and foreign firm choose their actions simultaneously, so all elements on and above the principal diagonal of the matrix  $d\mathbf{B}/d\mathbf{A}$  are zero; whereas the home government always has superior commitment power (at least intratemporally), so some or all of the corresponding elements in the matrix  $\tilde{\mathbf{B}}_A$  are non-zero.

simple. With  $A_1$  and  $B_1$  already determined, it faces a standard static problem and the optimal subsidy is given by the static rent-shifting formula  $S_{A_2}^2 = \pi_{B_2}^2 \tilde{B}_{22}$  which can be rewritten as (31) above. Note that neither firm can play strategically against its rival in the final stage of the game and so the government only needs to correct firm strategic behaviour in period 1 with adjustments to the first-period subsidy.

To take a specific example, suppose that the firms play Cournot for two periods and that a firm's marginal cost in period 2 is a decreasing function of period-1 output due to learning by doing. (See Leahy and Neary (1999).) Then the term  $\Pi_{B_2} \frac{dB_2}{dA_1}$  will be positive as firm 1 strategically overproduces in period 1 to reduce its rival's output in period 2. As seen in (55) this will require the government to reduce the first-period subsidy to correct for this. Furthermore if the period-2 subsidy  $s_2$  is chosen after the period-1 action  $A_1$ , then the firm will overproduce to gain a higher period-two subsidy. (The term  $\Pi_{s_2} \frac{ds_2}{dA_1}$  will be positive.) Anticipating this, the government will further reduce the first-period subsidy.

In this example, the home firm's overproduction in period 1 illustrates what Fudenberg and Tirole (1984) call "Top Dog" behaviour: because a higher action by the home firm in period 1 reduces the rival firm's period-2 profits, and period-2 actions are strategic substitutes, the home firm has an incentive to behave more aggressively in period 1. Fudenberg and Tirole extend this insight to present a full "animal spirits" taxonomy of behaviour in games of this kind. Such behaviour in turn justifies a policy intervention, since the home firm's aggressive action consumes real resources. In this example, a lower subsidy is warranted to deter the overproduction. In the terminology of Neary and Leahy (2000), the government should intervene to "restrain" the "Top Dog". The same paper extends this idea to show that Fudenberg and Tirole's "animal spirits" taxonomy of strategies by firms implies a corresponding "animal training" taxonomy of optimal policy responses by governments.

## 4 Trade in General Oligopolistic Equilibrium

### 4.1 From Partial to General Equilibrium<sup>27</sup>

So far, all the models considered have focused on a single industry only. They can be given a general-equilibrium foundation, though only under special assumptions. It is instructive to begin by spelling these out, and then considering how they may be relaxed.

As already noted in Section 2.1, utility functions such as (1) defined over consumption levels of a single industry can be rationalised if the upper-tier utility function is quasi-linear:

$$U = x_0 + u(x) \tag{56}$$

Here  $x_0$  is the consumption of the "outside good", which is really a composite commodity defined over all

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<sup>27</sup>This sub-section draws on Neary (2003a).

the other goods in the economy, which are assumed to be produced under perfect competition. As before,  $x$  is the consumption of the output of the oligopolistic sector. (For simplicity we assume in this section that goods within each sector are homogeneous.) Maximising (56) subject to a budget constraint, it can be seen that the marginal propensity to consume  $x$  is zero: all income effects fall on the outside good, so the demand function for  $x$  can be considered independently of the level of income. In practice the price of the outside good is often normalised to equal one, and it is then called the “numéraire good”, though this is just a convenient choice of measuring rod rather than a primitive property.

To move from the quasi-linear utility function (56) to the partial-equilibrium welfare function (11), we first make use of the identity between national expenditure and national income:

$$x_0 + px = wl_0 + (wl + \Pi) \quad (57)$$

Here  $l_0$  and  $l$  denote employment levels in the two sectors. (This is fully consistent with any number of factors of production, provided their relative prices are given.) Assuming that the same wages are paid in all sectors, we can invoke the full-employment condition  $l_0 + l = L$  to rewrite (57) as an equality between national expenditure and national product at factor cost  $wL$  plus profits  $\Pi$ :

$$x_0 + px = wL + \Pi \quad (58)$$

Finally, use this to eliminate consumption of the numéraire good  $x_0$  from (56):

$$U = wL + \chi + \Pi \quad \text{where:} \quad \chi \equiv u(x) - px \quad (59)$$

Equation (59) shows that the quasi-linear utility function (56) can be reexpressed as the sum of three components:  $wL$  is national product valued at factor cost;  $\chi \equiv u(x) - px$  is consumer surplus in the non-numéraire sector; and  $\Pi$  is profits in that sector. Hence, provided  $w$  can be taken as given (i.e., provided the non-numéraire sector is small in factor markets relative to the numéraire one), utility and welfare equal simply the sum of consumer surplus and profits, just as in (11).

A similar derivation was used by Brander and Spencer (1984, pp. 198-9) to justify their claim that models of strategic trade policy have valid general-equilibrium underpinnings.<sup>28</sup> Their conclusion is worth quoting in full: “The essential question is not whether a model is partial or general equilibrium but whether the industry in question is large enough to give rise to income effects, cross-substitution effects in demand and factor price effects.” While we fully agree on the substance, we also believe that it is convenient to have a single shorthand term to refer to the very special case of general equilibrium

<sup>28</sup> As Feenstra and Rose (2000, p. 11) point out: “Brander and Spencer (1985) ... arose out of an attempt to convince Ron Jones that their earlier paper on international R&D rivalry [Spencer and Brander (1983)] worked in a general equilibrium setting.”

where we can ignore income effects and inter-sectoral substitution effects on the demand side, and cost changes on the factor-market side. Rather than inventing a new term, it seems natural to use the label “partial equilibrium” for the case where the industry is not large enough to give rise to the latter effects.

The substantive question remains: is it justifiable to make these “partial equilibrium” assumptions? There are clearly many contexts where it is. In industrial organisation, for example, it is natural to have a partial-equilibrium focus: to understand the workings of a single market, it makes sense to ignore the wider context. And as previous sections have shown, there are a great many issues in international trade which can be illuminated by partial-equilibrium models. Nevertheless, many of the central questions in international trade involve comparisons between sectors, and links between goods and factor markets. This is true, for example, of the determinants of trade patterns, the economy-wide gains from trade, and the effects of trade on income distribution. A full understanding of such questions requires a framework which allows for multiple sectors and which explicitly models the links between goods and factor markets, in other words, a general-equilibrium framework which does not rely on the special assumptions listed above.

However, embedding oligopoly models in general equilibrium has generally been viewed as posing severe technical problems. This arises from the perception that a general-equilibrium model of oligopoly should require firms to solve general-equilibrium problems while still playing strategically against each other, a combination which implies extremely complex modelling. For example, Roberts and Sonnenschein (1977) showed that if oligopolists rationally anticipate the effects of their choices on national income, the resulting reaction functions are extremely badly behaved, and even in simple models an equilibrium may not exist. A different problem, highlighted by Gabszewicz and Vial (1972), is that if oligopolists anticipate their impact on the aggregate price level, then the consequences of their actions are sensitive to the deflator used to evaluate the real value of profits.<sup>29</sup> It is true that considerable progress can be made by ignoring these problems (examples include Markusen (1984) and Ruffin (2003)), but this has not met with universal approval.

A consistent approach to modelling oligopoly in general equilibrium requires that firms are “large in the small but small in the large”: playing strategically against a small number of competitors in their own sectors, just like the firms in earlier sections; while at the same time too small in the economy as a whole to influence aggregate variables such as national income or the price level. A natural framework in which to formalise this idea is the continuum-of-sectors model of Dornbusch, Fischer and Samuelson (1977). Originally presented in a competitive framework, with a continuum of firms in each sector, this model can be modified to allow for only a small number of firms producing a homogeneous good in each sector, so allowing for a consistent model of oligopoly in general equilibrium.

A key step in operationalising the “large in the small but small in the large” approach is to specify

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<sup>29</sup>Gabszewicz and Vial (1972) call this outcome a sensitivity to the choice of numéraire.

a tractable specification of preferences. From this perspective, a very desirable feature of preferences is that they are additively separable. This implies that the inverse demand for each good depends only on its own consumption  $q(z)$  and on the marginal utility of income in the economy,  $\lambda$ :  $p(z) = f[q(z), \lambda]$ . (Here  $z \in [0, 1]$  denotes sectors.) Hence  $\lambda$  is a “sufficient statistic” for all the determinants of demand coming from outside the sector. Rationally, firms take  $\lambda$  as given when competing strategically against their rivals in sector  $z$ , whereas it is endogenous in the economy as a whole. The distinction between the demand function with  $\lambda$  parametric and with  $\lambda$  endogenously determined parallels the distinction between “perceived” and “actual” demand functions in the literature on monopolistic competition. Finally, to get closed-form solutions, it is convenient to focus on the special case of additive preferences where the demand function is linear in prices, so it takes the form:  $p(z) = a' - b'q(z)$ , with  $a' \equiv a/\lambda$  and  $b' \equiv b/\lambda$ . In the remainder of this section we sketch this approach, following Neary (2002b, 2003a), and discuss some applications and extensions.

## 4.2 Specialisation Patterns in International Oligopoly

To understand the model it is useful to begin by taking a firms’-eye view, focusing on equilibrium in individual sectors with wages and the marginal utility of income taken as parametric. We assume that firms engage in Cournot competition on an integrated world market. Following Neary (2003a), we assume that firms differ between countries but not within. So in the home country there are  $n$  firms, each with unit cost  $c$ , producing a level of output  $x$ . Similarly in the foreign country, there are  $n^*$  firms, each with unit cost  $c^*$ , producing a level of output  $y$ . (For convenience, we suppress the sector index  $z$  in this sub-section.) The possible equilibrium patterns of international specialisation are then as illustrated in Figure 2, in the space of home and foreign costs.<sup>30</sup> First, if all firms have costs above the maximum price that consumers are willing to pay,  $a'$ , then the good will not be produced in either country, as illustrated by region  $O$ . Next, we can ask what is the equilibrium output of a home firm. Standard calculations show that this equals:

$$x = \frac{a' - (n^* + 1)c + n^*c^*}{b(n + n^* + 1)} \quad (60)$$

Hence, ignoring fixed costs for simplicity, home firms will produce positive output ( $x > 0$ ) if and only if their costs are sufficiently low, such that  $c < \frac{a' + n^*c^*}{n^* + 1}$ . The threshold value of  $c$  defines the locus which separates the  $F$  and  $HF$  regions in Figure 2, where  $F$  has active foreign firms only, while  $HF$  has active firms in both countries. A corresponding argument defines the locus which represents zero output by foreign firms ( $y = 0$ ), separating the  $HF$  and  $H$  regions.

The most interesting of these regions is  $HF$ . We can call it a “cone of diversification”, and it is special to oligopoly. Under perfectly competitive assumptions, the model would be identical to that of Dornbusch, Fischer and Samuelson (1977), complete specialisation would take place, and so the  $HF$

<sup>30</sup>For an independent development of this figure, see Collie (1991).

region would collapse to the 45° line. By contrast, in oligopoly, high- and low-cost firms coexist in the  $HF$  region. For example, at any point above the 45° line in this cone, home firms have higher costs than foreign firms and therefore (in a free-trade equilibrium) they have lower output.<sup>31</sup> However, they are not driven out of business, because of the barriers to entry which underpin the oligopoly equilibrium. Foreign firms with lower costs are making greater profits, and if entry were free, the number of foreign firms would grow until all home firms had been driven out of business. Thus, entry barriers in the low-cost country serve to cushion high-cost firms from foreign competition under free trade, just as tariff barriers in a perfectly competitive model allow for the coexistence of high and low-cost firms. (See Dornbusch, Fischer and Samuelson (1977), Section III.C).

So far, Figure 2 illustrates all the possible equilibria conditional on production costs and the marginal utility of income  $\lambda$  taken as given. To embed this in general equilibrium, we first invoke the standard Ricardian assumptions about technology and labour markets, relating unit costs in all sectors to local wages and technology. Assume therefore that labour is the only factor of production and that the unit labour requirements for home and foreign firms are fixed, denoted by  $\alpha(z)$  and  $\alpha^*(z)$  respectively. We assume in addition that labour is perfectly mobile within countries, but immobile internationally, and that labour markets are perfectly competitive. Hence the production cost in each sector equals the product of its exogenously-determined unit labour requirement and the national wage rate:

$$c(z) = w\alpha(z) \quad \text{and} \quad c^*(z) = w^*\alpha^*(z) \quad (61)$$

in the home and foreign countries respectively. Next we need to assume that the sectors can be ranked such that home and foreign costs can be directly compared. A sufficient condition for this is that home labour requirements are increasing in  $z$  and foreign labour requirements are decreasing in  $z$ :  $\alpha'(z) > 0$  and  $\alpha^{*'}(z) < 0$ .<sup>32</sup> For given wages in both countries, we can then express the cost of production in each sector at home as a decreasing function of the corresponding cost abroad.<sup>33</sup> This is illustrated by the downward-sloping locus in Figure 2. In the case shown, this implies that there are three kinds of sectors, with the boundaries between them denoted  $\tilde{z}^*$  and  $\tilde{z}$ . In all sectors for which  $z$  is less than  $\tilde{z}^*$ , only home firms make non-negative profits; while in all sectors for which  $z$  is greater than  $\tilde{z}$ , only foreign firms make non-negative profits. The third kind of sectors are those in the cone of diversification, with values of  $z$  lying between  $\tilde{z}^*$  and  $\tilde{z}$ , in which both home and foreign firms are active. These threshold sectors,  $\tilde{z}$  and  $\tilde{z}^*$ , which are endogenously determined in general equilibrium, demarcate the extensive margins of production in the home and foreign countries respectively. Note that the configuration illustrated in Figure 2 is only one possible outcome. For example, the equilibrium value of  $\tilde{z}$  could equal one, in which

<sup>31</sup>Note that, even with different numbers of firms at home and abroad, the locus along which outputs are the same is the 45° line. To see this, equate equation (60) to the corresponding equation for the foreign firm.

<sup>32</sup>This condition is much stronger than necessary, but very convenient. For further discussion, see Neary (2002b).

<sup>33</sup>Formally, this involves combining the two equations in (61) to eliminate  $z$ :  $c = w\alpha \left[ \alpha^{*-1} \left( \frac{c^*}{w^*} \right) \right]$ .

case home firms would be active in all sectors; similarly, the equilibrium value of  $\tilde{z}^*$  could equal zero, in which case foreign firms would be active in all sectors.

So far the wage rates have been taken as exogenous. Their equilibrium values are implied by assumptions already made, with the additional assumption (natural in a trade model) that total labour supplies are fixed in each country. Thus, in the home country, the equilibrium wage rate adjusts to equate supply of and demand for labour:

$$L = \int_0^{\tilde{z}} n\alpha(z)x(z)dz \quad \text{where:} \quad x(z) = \begin{cases} \frac{a'-c}{b(n+1)} & \text{for } z \in [0, \tilde{z}^*] \\ \frac{a'-(n^*+1)c+n^*c^*}{b(n+n^*+1)} & \text{for } z \in [\tilde{z}^*, \tilde{z}] \end{cases} \quad (62)$$

The aggregate demand for labour is simply the integral of the demands from all sectors with active home firms: in other words, firm output  $x(z)$  times its unit labour requirement  $\alpha(z)$  times the number of firms  $n$ . The only complication is that the expression for firm output differs between sectors. In sectors with  $z \in [0, \tilde{z}^*]$ , foreign firms cannot compete, so home firms face only domestic competition; while sectors with  $z \in [\tilde{z}^*, \tilde{z}]$  lie in the cone of diversification, so both home and foreign firms are active and the output of a typical home firm is given by (60). An exactly analogous equation equates demand and supply of labour in the foreign country. Hence we have four equations in total, two labour-market equilibrium equations plus two equations specifying zero output for each of the threshold sectors, which combine to determine simultaneously the four endogenous variables: the home and foreign wage rates and the values of the threshold sectors.

### 4.3 Autarky versus Free Trade: Welfare, Income Distribution and Trade Patterns

A natural question which arises in this model is the comparison between autarky and free trade. To facilitate this, it is convenient to assume that countries are symmetric and always produce all goods (so the  $\{c, c^*\}$  locus lies strictly inside the  $HF$  region).<sup>34</sup> The assumption of full diversification precludes the complete specialisation in production which drives the gains from trade in a competitive model. However, there are other sources of gain from trade in oligopoly. First, domestic firms face more competition in free trade than in autarky, which reduces their mark-ups, lowering prices to consumers in all sectors. Second, comparative advantage still operates, even though complete specialisation does not occur. In sectors where home firms are more efficient, they expand their scale of operations, while foreign firms contract; and conversely in sectors where foreign firms are more efficient. As a result, labour is reallocated from low- to high-productivity sectors, generating a further gain from trade.

Thus, comparative advantage and pro-competitive effects combine to raise welfare. However, where

<sup>34</sup>The fact that countries are symmetric does not mean that they are identical. In particular, while the average labour productivity over all sectors is the same in both countries, there is scope for comparative advantage differences:  $\alpha(z) = \alpha^*(1-z)$  and  $\int_0^1 \alpha(z) dz = \int_0^1 \alpha^*(z) dz$ , but in general  $\alpha(z) \neq \alpha^*(z)$ .

income distribution is concerned, they work in opposite directions. Note that, although there is only one primary factor of production in this Ricardian model, the persistence of pure profits allows the consideration of income distribution. Moving from autarky to free trade, the competition effect tends to squeeze profits, as increased demand for labour bids up wages. By contrast, specialisation according to comparative advantage implies that resources are reallocated towards the more productive sectors. With a fixed number of firms, this process tends to benefit profit recipients, as workers are laid off more in less productive sectors than they are absorbed in more productive ones. As a result, the gains from comparative advantage accrue to profit recipients, and it is even possible that they can outweigh the positive effects of greater competition, leading to a fall in the share of wages in free trade relative to autarky.

Of course, because of oligopoly, there are “missing gains from trade”: if barriers to entry were removed, the two countries would specialise completely and welfare would be higher. In the same way, oligopoly provides a potential explanation for “missing trade”.<sup>35</sup> The volume of trade is reduced relative to a perfectly competitive trading equilibrium on both the supply and demand sides. Because welfare is lower, the demand for all goods including imports is reduced. And because of oligopolistic barriers to entry, output of each sector is also lower than it would be in the competitive case. It follows that trade volumes are less than they would be if the barriers to entry were removed.

#### 4.4 Extensions and Applications

Models of oligopoly in general equilibrium have been applied to a range of issues. Grossman and Rossi-Hansberg (2010) develop a model similar to that described above, but assuming that firms compete on price rather than on quantity, which they apply to consider the role of external economies. The assumption of a continuum of sectors allows for a clean analysis of the properties of the model, without the discontinuities found in classic treatments of external economies such as Ethier (1982b), where firms are large in the economy as a whole as well as in their own market. A different approach to modelling the mode of competition between firms is adopted by Neary and Tharakan (2006). Building on Kreps and Scheinkman (1983) and Maggi (1996), they assume that firms first invest in capacity and then compete on price. If the cost advantage of investing in capacity is sufficiently large, then the outcome of this two-stage game resembles that of a one-stage Cournot game where firms compete only in quantities. Maggi considered only a single industry in partial equilibrium, where the advantage of investing in capacity was exogenous and determined by technology alone. By contrast, in the general-equilibrium model of Neary and Tharakan, sectors differ in the cost advantage of investing in capacity, and capacity requires a different mix of factors from production. As a result, relative factor prices play a role in determining

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<sup>35</sup>See also Ruffin (2003). The “mystery of the missing trade”, the fact that world trade is less than we would expect from international differences in factor endowments, was first highlighted by Treffer (1995). Other possible explanations are explored by Davis and Weinstein (2001).

the extent of competition in the economy, and factor prices are themselves determined endogenously in general equilibrium. As a result, the model allows for the endogenous determination of the mix of sectors between those exhibiting more and less competitive, or Bertrand and Cournot behaviour.

Intersectoral differences in factor mix can also provide insights into the impact of international trade on relative wages, as shown by Neary (2002a). In both perfectly and monopolistically competitive models, increased foreign competition impacts on domestic firms only via changes in the prices they face, but empirical studies have failed to find a sufficiently large effect of import prices. This has led many researchers to conclude that rises in the skill premium, the higher wage enjoyed by skilled relative to unskilled workers, are due to skill-biased technological progress rather than increased competition and trade from low-wage countries. However, models of oligopoly introduce the possibility of non-price interaction between firms. An extreme example of this in Neary (2002a) is where domestic firms are induced to engage in what Wood (1994) calls “defensive innovation” even though no imports actually occur. The source of this is the threat of trade (as imports become potentially more competitive) which encourages home firms to engage in strategic investment to deter entry. Provided investment is relatively skill-intensive, this in turn leads to an increase in the skill premium.

In the same vein, models of oligopoly in general equilibrium have been shown to shed light on particular issues which cannot be considered in either competitive general-equilibrium or oligopolistic partial-equilibrium models. Neary (2003b) considers a unilateral increase in the number of firms in each sector as an improvement in the economy’s competitive advantage, and shows how this interacts with comparative advantage: the economy gains as it specialises in those sectors in which it is relatively more efficient, though the higher wage induced by greater competition between firms causes marginal sectors to cease production. Bastos and Kreickemeier (2009) explore the implications of unionisation in a subset of sectors, and show that it can reverse the conclusions of partial-equilibrium models. Because the outside option of unionised workers is endogenous in general equilibrium, they show that union wages may increase with firm entry and may be higher in free trade than in autarky. Finally, models of oligopoly make it possible to explore the implications of endogenous changes in market structure. Neary (2007) shows that trade liberalisation in the model of the last subsection creates incentives for cross-border mergers. Moreover, the model predicts that such mergers will generate flows of foreign direct investment that take place in the same direction as trade flows: home firms in sectors which enjoy a comparative advantage will also have a greater incentive to take over smaller less productive foreign firms. This is in contrast with standard models of greenfield foreign direct investment which predict counterfactually that trade and foreign direct investment are always substitutes.

## 5 Conclusion

In this chapter, we have given a selective survey of the theory of international trade under oligopoly, concentrating on three topics: oligopoly as an independent determinant of trade, as illustrated by the reciprocal-markets model of Brander (1981); oligopoly as an independent rationale for government intervention, as illustrated by strategic trade and industrial policy in the third-market model of Spencer and Brander (1983) and Brander and Spencer (1985); and the challenges and potential of embedding trade under oligopoly in general equilibrium.

Naturally, space constraints have forced us to omit many important topics which have also been considered in the literature. For example, our discussion of strategic trade policy concentrated on the third-market model and ignored policies towards imports, both tariffs and quantitative restrictions. These were first considered by Brander and Spencer (1984) and Krishna (1989) respectively, and the general issues of strategic trade policy in the reciprocal-markets model are surveyed by Brander (1995). We have paid no attention to strategic trade policy under uncertainty, which has been addressed by Cooper and Riezman (1989) and Dewit and Leahy (2004); nor under asymmetric information, which has been explored by Collie and Hviid (1993) and Brainard and Martimort (1997). We have also ignored the important topic of competition policy, which arises naturally in an oligopoly context and can be analysed in the same way as strategic trade policy. The possibility of affecting national welfare by controlling the number of domestic firms was first explored by Dixit (1984), and related aspects of competition policy in open-economy oligopoly models have been considered by Horn and Levinsohn (2001) and Francois and Horn (2007). In addition, we have ignored foreign direct investment, at least of the greenfield kind, and given only a brief discussion of one approach to strategic aspects of cross-border mergers in Section 4. These topics are covered in more detail in Chapter 8 of this volume. Finally, we have not considered the implications of oligopoly for preferential trade agreements and international trade negotiations, topics which are attracting increasing attention. (See, for example, Yi (1996) and Mrázová (2010).)

Turning from theory to empirics, oligopoly in trade does not lend itself easily to empirical work, at least using large firm-level data sets of the kind that have become available in the 1990s and 2000s, which have made applied trade theory such an exciting field of research. Most empirical applications of oligopolistic trade models so far have been in the normative area. See for example the papers in Krugman and Smith (1994), as well as Baldwin and Flam (1989), which use calibration methods to quantify the gains and losses from strategic trade policy.<sup>36</sup> The real-world example most often cited in this context is international competition between Airbus and Boeing in the commercial aircraft industry. (See Dixit and Kyle (1985).) Irwin (1991) applies the strategic trade policy framework to a much earlier industry. He uses a duopoly model calibrated with data from the East India spice trade in the early seventeenth century to illustrate the effects of trade policies and institutional arrangements on the rivalry between

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<sup>36</sup>Norman (1990) and Francois and Roland-Holst (1997) provide overviews of this literature.

the English and the Dutch East India companies. As for the positive theory of trade under oligopoly, empirical studies of intra-industry trade patterns arising from oligopolistic competition have been carried out by Bernhofen (1999) and Friberg and Ganslandt (2006). A related paper by Feenstra, Markusen and Rose (2001) shows that a wide range of theories are consistent with a gravity-type equation, and finds empirical results that fit the predictions of the reciprocal dumping model with homogeneous goods and restricted entry.

A frequently heard criticism of oligopolistic trade models is that their predictions are highly sensitive to the mode of competition. Arguably this perception has been overstated. To a large extent, it arose from the early demonstration by Eaton and Grossman (1986) that one of the first and highest-profile results on strategic trade policy, the Brander-Spencer (1985) finding that export subsidies are optimal, is reversed when we move from Cournot to Bertrand competition. Nonetheless, the general case for intervention is the same in both cases: governments can improve national welfare by exercising their superior commitment power relative to domestic and foreign firms. Moreover, as we have seen, the argument for activist investment policies is more robust than that for export policies. Similarly, in the reciprocal markets model, the prediction of cross-hauling of identical goods is sensitive to the mode of competition, at least in the sense that the extreme case of identical products with Bertrand competition and no trade costs leads to an indeterminate pattern of production and trade. However, the pro-competition effect is not at all sensitive; indeed it is stronger with Bertrand competition than with Cournot, because even potential trade encourages the home firm to behave in a more competitive manner.

Another frequently-heard objection to oligopolistic trade models is the assumption of an exogenous number of firms. This can be overcome by allowing entry. Indeed trade models with Cournot competition and free entry have been developed (see for instance Venables (1985)) but these treat the number of firms as a continuous variable. As a result, free entry ensures that there are zero profits in equilibrium. Because these models ignore the so-called integer problem (the technical difficulties arising from the requirement that the number of firms must be an integer), their predictions are similar to those from models of monopolistic competition (or even perfect competition, if goods are homogeneous). If the integer problem is not ignored, then profits continue to be earned in most equilibria and so the key features of oligopoly survive. However, models incorporating these features have yet to be developed.<sup>37</sup> For the present, a defence of the relevance of oligopolistic models with fixed numbers of firms can fall back on their realism in many real-world applications. Ignoring entry at least of large firms is very plausible for the short run in most markets, and even over longer time horizons in many markets, where the major players have shown great persistence over time, notwithstanding the spread of globalisation.

In conclusion, a key contribution of oligopoly in trade theory is its focus on central features of the real world: the persistence of pure profits and the strategies adopted by firms to raise them. Indeed the

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<sup>37</sup>Some possible approaches to this problem are sketched in Neary (2010).

importance of profits can hardly be underestimated. They are key to the results of the reciprocal-markets model, starting with the pathbreaking finding by Brander (1981) that intra-industry trade can arise from firms' incentives to capture foreign monopoly rents. Profits are also the essential focus of strategic trade policy, not in the sense that optimal policy necessarily implies profit-shifting towards domestic firms (for example, if firms compete on price, then the optimal policy implies taxing a home firm which in effect shifts profits from it towards its foreign competitor), but rather that the motivation for policy arises from the desire to raise profits net of taxes and subsidies, which in the third-market model is identical to social welfare. Finally, in general equilibrium, the persistence of profits adds a new dimension to discussions of income distribution: aggregate gains from trade can coexist with redistribution away from productive factors (labour in our example) towards profit recipients.

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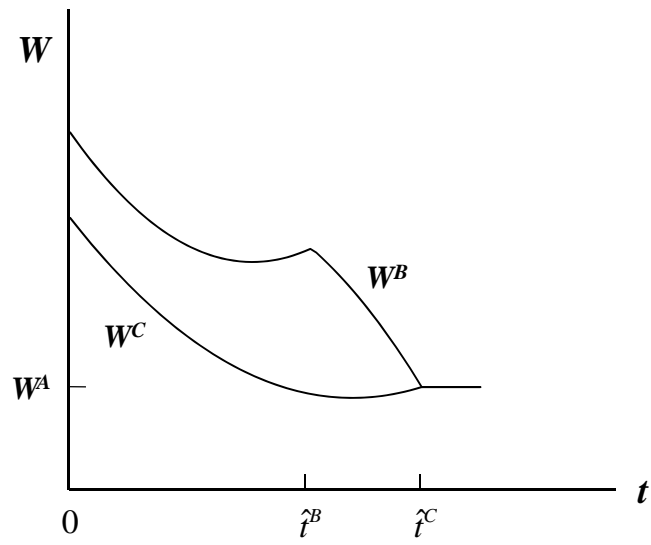
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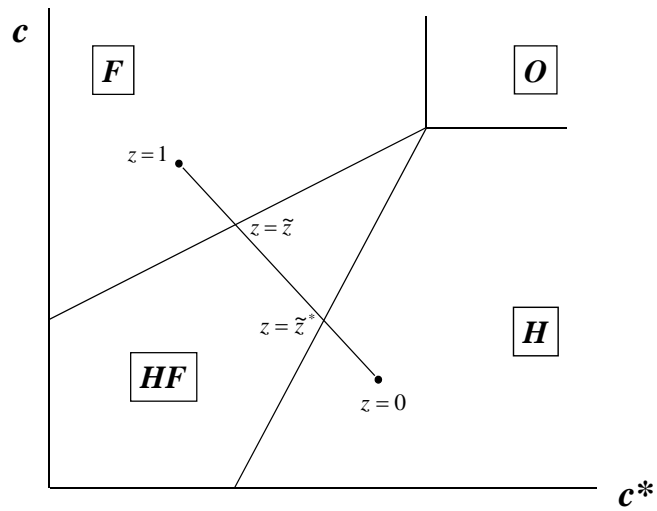
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**Figure 1: Welfare and Trade Costs under Cournot and Bertrand Competition**



**Figure 2: Equilibrium Production Patterns for a Given Cost Distribution**