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*Tacit Collusion over Foreign Direct Investment
under Oligopoly*

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Abstract

A two-country model of the FDI versus export decisions of firms is analysed. The analysis considers both the Cournot duopoly and the Bertrand duopoly models with differentiated products. It is shown that the static game is often a prisoners' dilemma where both firms are worse off when they both undertake FDI. To avoid the prisoners' dilemma, in an infinitely-repeated game, the firms can collude over their FDI versus export decisions. Then, a reduction in trade costs may lead firms to switch from exporting to undertaking FDI when trade costs are relatively high. Also, collusion over FDI may increase welfare.

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1. Introduction

In recent decades, there has been a rapid growth in foreign direct investment (FDI) and most of this FDI has been horizontal FDI where both the source and the host are developed countries.[1] There is even intra-industry FDI between developed countries where firms in the same industry are undertaking FDI in their competitors' home markets. An intriguing question is why has FDI grown rapidly in an era when trade costs have been reduced by trade liberalisation. Intuition suggests that a reduction in trade costs (transport costs and/or import tariffs) will increase the profitability of exporting relative to the profitability of undertaking FDI. In the theoretical literature on FDI, it is generally the case that a reduction in trade costs would only cause firms to switch from undertaking FDI to exporting. Although Brainard (1997) provides empirical evidence to support the proximity-concentration hypothesis, this still leaves unanswered the question of why there has been a rapid growth of FDI in an era of trade liberalisation. To answer this question, this paper will present a model where a reduction in trade costs may actually lead firms to switch from exporting to undertaking FDI. This will occur when trade costs are relatively high whereas conventional wisdom prevails when trade costs are relatively low, and hence the relationship between trade costs and FDI need not be monotonic.

The model presented in this paper builds upon the existing theoretical literature that started with Hortsmann and Markusen (1987) and Smith (1987) where FDI is viewed as a strategic investment in models of intra-industry trade under Cournot duopoly based upon Brander (1981) and Brander and Krugman (1983). Two firms each located in a separate country may either export to their competitor's market or undertake FDI. In a static game, the choice depends upon the trade costs incurred by exporting and the fixed cost of undertaking FDI with firms more likely to undertake FDI when the trade costs are high and/or the fixed cost of undertaking FDI is low. When a firm undertakes FDI, the result is to intensify competition in its competitor's market and thereby reduce the profits of the competitor in its home market. Therefore, when both firms undertake FDI, the outcome of the game is often a prisoners' dilemma where both firms make lower profits when they both undertake

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[1] For reviews of the stylized facts about FDI see chapter one of Markusen (1982) and chapter one of Barba Navaretti and Venables (2004).

FDI than when they both export. The innovation in this paper is to consider an infinitely-repeated version of this static game where firms can avoid the prisoners' dilemma by tacitly colluding over their choice of undertaking FDI or exporting. Realising their strategic interdependence, the firms implicitly agree that both will export rather than undertaking FDI and this can be sustained by the threat that if one firm undertakes FDI then the other will retaliate by also undertaking FDI. First, it is shown that collusion over FDI can be sustained by Nash-reversion trigger strategies as in Friedman (1971) for a given discount factor if the fixed cost of undertaking FDI is sufficiently high. Secondly, it is shown that a reduction in trade costs may reduce the incentive to collude and thereby may lead the firms to switch from exporting to undertaking FDI if the trade cost is sufficiently high. Thirdly, it is shown that it is possible that collusion over FDI may increase the welfare of the countries when the trade cost is an import tariff and even when the trade cost is a transport cost. Finally, the robustness of the analysis is checked by considering the case of Bertrand competition using an extension of the model of intra-industry trade under Bertrand duopoly of Clarke and Collie (2003).

The extensive theoretical literature on FDI as a strategic investment under oligopoly started with Horstmann and Markusen (1987) and Smith (1987).[2] Horstmann and Markusen (1992) and Rowthorn (1992) consider symmetric two-country models where the market structure is endogenous with the firms choosing whether or not to have a factory in each country. In these models, the existence of multinational firms can arise endogenously, but a feature of these models is the possibility of multiple equilibria. The model presented in this paper has a similar symmetric structure, but the firms are assumed to have already established factories in their home markets, and their choice is purely between exporting to the foreign market or undertaking FDI in the foreign market. This simplifying assumption avoids the complications that arise from multiple equilibria, and allows the infinitely-repeated game to be analysed in a tractable manner. In Motta (1992), a potential multinational firm has already established a factory in its home market and it competes with a potential local entrant in the foreign country. Then, a foreign tariff may lead the multinational to choose not to invest in the foreign market as the tariff may induce entry by the local firm, and

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[2] For a broader survey of both the theoretical and empirical literature on multinational firms and FDI, see Caves (2007).

therefore a tariff may have an unconventional effect. Motta and Norman (1996), Norman and Motta (1993) and Neary (2002) have shown that economic integration (a reduction in trade costs within a trade bloc) may increase FDI. It should be noted that in this paper there is a reduction in all trade costs that is equivalent to multilateral trade liberalisation rather than preferential trade liberalisation. Recently, Baldwin and Ottaviano (2001) have provided an explanation for the co-existence of reciprocal intra-industry trade and reciprocal intra-industry FDI. The literature on FDI under oligopoly has generally used static game theory models, but an exception is Leahy and Pavelin (2003) who use an infinitely-repeated game, where firms can tacitly collude over outputs, to explain the follow-my-leader FDI observed by Knickerbocker (1973). This paper does not consider collusion over outputs (or prices) but only collusion over the choice of undertaking FDI or exporting.[3]

Section two presents the static game theory model of FDI under Counot duopoly, and the infinitely-repeated game is presented in section three. The static game theory model of FDI under Bertrand duopoly is presented in section four and section five presents the infinitely-repeated game. Finally, the conclusions are in section six.

2. The Cournot Duopoly Model

In this symmetric model, there are two countries, labelled A and B, and there are two firms, labelled one and two, that produce differentiated products. Firm one has incurred a sunk cost to design its product and to build a factory in country A. Symmetrically, firm two has incurred a sunk cost to design its product and to build a factory in country B. It is assumed that firm one is owned by shareholders who are resident in country A, and firm two is owned by shareholders who are resident in country B. The firms play a two-stage game that is infinitely repeated and the discount factor for both firms is $\delta \in [0,1]$. At stage one, they each independently choose whether to export to the other country, which incurs a trade cost (a transport cost and/or an import tariff) of k per unit exported, or to undertake FDI by building a factory in the other country, which incurs an amortized fixed cost of G per period. Then, at the second stage, the firms compete as Cournot duopolists in the two markets,

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[3] There is also a related literature that considers how trade costs affect the sustainability of multimarket collusion over outputs and prices; see, Bond and Syropoulos (2008) who analyse collusion as in Bernheim and Whinston (1990) in the Brander and Krugman (1983) model of intra-industry trade.

which are assumed to be segmented. Both firms have a marginal cost of c whether they produce in the factory in their home country or, if they undertake FDI, in the factory in the foreign country. In each country, there is a representative consumer with preferences that can be represented by identical, quadratic, quasi-linear utility functions that yield linear demand functions for the differentiated products of the two firms. For country A, the utility function is:

$$U_A = \alpha(x_{1A} + x_{2A}) - \frac{\beta}{2}(x_{1A}^2 + x_{2A}^2 + 2\phi x_{1A} x_{2A}) + z_A \tag{1}$$

where x_{1A} is the consumption of the product of firm one, x_{2A} is the consumption of the product of firm two, and z_A is the consumption of the numeraire good in country A. The numeraire good is produced by a perfectly competitive industry with constant returns to scale technology. The parameter α is the maximum willingness to pay of the consumers, β is inversely related to the size of the market, and ϕ is the degree of product substitutability that ranges from $\phi = 0$ when the products are independent to $\phi = 1$ when the products are perfect substitutes. Utility maximisation by the representative consumer yields the inverse demand functions in country A:

$$p_{1A} = \alpha - \beta(x_{1A} + \phi x_{2A}) \qquad p_{2A} = \alpha - \beta(\phi x_{1A} + x_{2A}) \tag{2}$$

The utility function and demand functions are defined symmetrically for country B, and denoted by subscript B rather than A. Consider the market in country A, when firm two chooses to export, the marginal cost of firm one will be c and the marginal cost of firm two will be $c + k$. Therefore, the operating profits (before the fixed cost) of the firms will be $\pi_{1A} = (p_{1A} - c)x_{1A}$ and $\pi_{2A} = (p_{2A} - c - k)x_{2A}$. The usual derivations for a Cournot duopoly yield the outputs, prices and profits of the two firms, where the superscript E denotes that firm two is exporting to country A:

$$
\begin{aligned}
x_{1A}^E &= \frac{(2-\phi)(\alpha-c) + \phi k}{\beta\Omega}, & x_{2A}^E &= \frac{(2-\phi)(\alpha-c) - 2k}{\beta\Omega}, \\
p_{1A}^E &= c + \frac{(2-\phi)(\alpha-c) + \phi k}{\Omega}, & p_{2A}^E &= c + k + \frac{(2-\phi)(\alpha-c) + 2k}{\Omega}, \\
\pi_{1A}^E &= \frac{1}{\beta\Omega^2}\big[(2-\phi)(\alpha-c) + \phi k\big]^2, & \pi_{2A}^E &= \frac{1}{\beta\Omega^2}\big[(2-\phi)(\alpha-c) - 2k\big]^2,
\end{aligned}
\tag{3}
$$

where $\Omega = 4 - \phi^2 > 0$. The exports of firm two to country A and the profits of firm two from exports will be zero if the trade cost is prohibitive, $k \geq \bar{k} \equiv (2 - \phi)(\alpha - c)/2$. If the trade cost is prohibitive then the firm one produces the monopoly output and earns monopoly profits in country A, which is the same as the outcome under autarky. Symmetry of the model implies that: $x_{1B}^E = x_{2A}^E$, $x_{2B}^E = x_{1A}^E$, $p_{1B}^E = p_{2A}^E$, $p_{2B}^E = p_{1A}^E$, $\pi_{1B}^E = \pi_{2A}^E$ and $\pi_{2B}^E = \pi_{1A}^E$, where, for country B variables, the superscript E denotes that firm one is exporting to country B.

When firm two chooses to undertake FDI, the marginal cost of both firms will be c. Therefore, the operating profits (before the fixed cost) of the firms will be $\pi_{1A} = (p_{1A} - c)x_{1A}$ and $\pi_{2A} = (p_{2A} - c)x_{2A}$. The usual derivations for a Cournot duopoly yield the outputs, prices and profits of the two firms, where the superscript F denotes that firm two is undertaking FDI to supply country A:

$$x_{1A}^F = x_{2A}^F = \frac{(\alpha - c)}{\beta(2 + \phi)} \qquad p_{1A}^F = p_{2A}^F = \frac{\alpha + (1 + \phi)c}{2 + \phi} \qquad \pi_{1A}^F = \pi_{2A}^F = \frac{(\alpha - c)^2}{\beta(2 + \phi)^2} \qquad (4)$$

Comparing prices in (3) and (4) shows that FDI intensifies competition since the prices set by both firms are lower when firm two undertakes FDI to supply country A than when it exports to country A, which reduces the profits of firm one. Symmetry of the model implies that: $x_{1B}^F = x_{2B}^F = x_{1A}^F$, $p_{1B}^F = p_{2B}^F = p_{1A}^F$, and $\pi_{1B}^F = \pi_{2B}^F = \pi_{1A}^F$, where, for country B variables, the superscript F denotes that firm one is undertaking FDI in country B.

Since each firm can choose either to export or to undertake FDI, there are four possible cases to consider. The model is symmetric so the profits of the firms will also be symmetric. Denote the operating profits (before the fixed cost) of a firm from sales in the two countries as: Π_{EE} when both firms choose to export; Π_{FE} when the firm chooses to export and its competitor chooses to undertake FDI; Π_{EF} when the firm chooses to export and its competitor chooses to undertake FDI; and Π_{FF} when both firms choose to undertake FDI. Hence, using (3) and (4), the operating profits of the firms from sales in the two countries are:

$$\Pi_{EE} = \pi_{1A}^{E} + \pi_{1B}^{E} = \pi_{2A}^{E} + \pi_{2B}^{E}, \qquad \Pi_{FE} = \pi_{1A}^{E} + \pi_{1B}^{F} = \pi_{2A}^{F} + \pi_{2B}^{E},$$
$$\Pi_{EF} = \pi_{1A}^{F} + \pi_{1B}^{E} = \pi_{2A}^{E} + \pi_{2B}^{F}, \qquad \Pi_{FF} = \pi_{1A}^{F} + \pi_{1B}^{F} = \pi_{2A}^{F} + \pi_{2B}^{F}. \tag{5}$$

In the static game, when its competitor chooses to export, undertaking FDI is profitable for a firm if $\Pi_{FE} - G > \Pi_{EE}$ and, when its competitor chooses to undertake FDI, undertaking FDI is profitable if $\Pi_{FF} - G > \Pi_{EF}$. As markets are segmented, the decision of the firm is actually independent of the choice of its competitor, and undertaking FDI is a dominant strategy for both firms if the fixed cost of FDI is less than the critical value $\bar{G} \equiv \Pi_{FE} - \Pi_{EE} = \Pi_{FF} - \Pi_{EF}$:

$$\bar{G} = \frac{4k}{\beta\Omega^2}\left[(2-\phi)(\alpha-c)-k\right] \tag{6}$$

Clearly, this is a concave quadratic in the trade cost k that is increasing in the trade cost up to the prohibitive trade cost, $k = \bar{k}$. The critical value of the fixed cost of FDI is shown in figure one as a function of the trade cost for the parameter values: $\alpha = 50$, $\beta = 1$, $c = 14$, with $\phi = 9/10$ in figure 1a and with $\phi = 1/2$ in figure 1b. Undertaking FDI is a dominant strategy for both firms in the region where $G < \bar{G}$ whereas exporting is a dominant strategy for both firms in the region where $G > \bar{G}$. Hence, in this static game, a reduction in trade costs will only lead firms to shift from undertaking FDI to exporting, and will never lead firms to shift from exporting to undertaking FDI.

When both firms undertake FDI they will have higher profits than when they both export if $\Pi_{FF} - G > \Pi_{EE}$, and this will be the case if the fixed cost of FDI is less than $\hat{G} \equiv \Pi_{FF} - \Pi_{EE} = (\Pi_{FE} - \Pi_{EE}) + (\Pi_{FF} - \Pi_{FE})$. The first bracketed term is the profit gain for a firm from undertaking FDI whereas the second bracketed term is the effect on a firm's profits of its competitor undertaking FDI. Using the definition of $\bar{G}$ from (6), $\hat{G}$ becomes: $\hat{G} = \bar{G} + (\Pi_{FF} - \Pi_{FE})$, and then using (3), (4) and (5) the term in brackets is:

$$\Pi_{FF} - \Pi_{FE} = -\frac{\phi k}{\beta\Omega^2}\left[2(2-\phi)(\alpha-c)+\phi k\right] < 0 \tag{7}$$

Since FDI intensifies competition, a firm makes lower profits when its competitor undertakes FDI than when its competitor exports, $\Pi_{FF} < \Pi_{FE}$, and it will always be the case that $\hat{G} < \bar{G}$. Differentiating (7) with respect to the degree of product substitutability, ϕ, yields:

$$\frac{\partial(\Pi_{FF} - \Pi_{FE})}{\partial\phi} = \frac{-2k}{\beta\Omega^3}\left[2(2-\phi)(2-\phi+\phi^2)(\alpha-c)+\phi(4+\phi^2)k\right] < 0 \qquad (8)$$

Therefore, the reduction in profits as a result of a firm's competitor undertaking FDI is increasing in the degree of product substitutability, and hence $(\bar{G} - \hat{G})$ is increasing in the degree of product substitutability. Substituting (6) and (7) into the definition of $\hat{G}$ yields:

$$\hat{G} = \frac{k}{\beta\Omega^2}\left[2(2-\phi)^2(\alpha-c)-(4+\phi^2)k\right] \qquad (9)$$

This is a concave quadratic that has a maximum value when the trade cost is $\hat{k} \equiv (2-\phi)^2(\alpha-c)/(4+\phi^2)$, where $\hat{k} < \bar{k}$ for $\phi > 0$, and it is positive if $k < 2\hat{k}$, where $2\hat{k} < \bar{k}$ if the degree of product substitutability $\phi > 2(\sqrt{2}-1) \approx 0 \cdot 83$. Obviously, the quadratic (9) is increasing in k for $k < \hat{k}$ and decreasing for $k < \hat{k}$. The explanation for this is that profits when both countries choose to export, Π_{EE}, is decreasing in the trade cost when $k < \hat{k}$ and increasing when $k > \hat{k}$. An increase in the trade cost has a negative effect on exports since it increases the marginal cost of the firm whereas it has a positive effect on domestic sales since it increases the marginal cost of the firm's competitor, but the absolute size of the direct effect on exports is larger than the indirect effect on domestic sales. Therefore, when the trade cost is low and the price-cost margins are similar in the two markets then the negative effect on exports will dominate the positive effect on domestic sales, whereas when the trade cost is high and the price-cost margin on domestic sales is much higher than on exports then the positive effect on domestic sales will dominate the negative effect on exports.

Profits will be higher when both firms undertake FDI than when both export in the region in figure one where $G < \hat{G}$. In the region where $\hat{G} < G < \bar{G}$, the static game is a prisoners' dilemma where undertaking FDI is the dominant strategy for both firms, but profits are lower when both firms

undertake FDI than when they both export as a result of more intensive competition and the firms incurring the fixed cost of undertaking FDI. Comparing figure 1a when the products are close substitutes and figure 1b, it can be seen that the outcome is more likely to be a prisoners' dilemma when the products are close substitutes, as expected given (8), since this is when competition will be most intense.

3. The Infinitely-Repeated Cournot Duopoly Game

As is well known, firms can avoid the prisoners' dilemma problem by tacitly colluding when the game is infinitely repeated. Friedman (1971) showed that Nash reversion trigger strategies can sustain a collusive outcome as a subgame perfect Nash equilibrium in an infinitely repeated game. The preferred outcome where both firms choose to export could be sustained by the threat of reversion to the Nash equilibrium where both firms undertake FDI if the discount factor is sufficiently high. It is assumed that the firms only collude over the undertaking FDI versus exporting decision, and that the firms choose outputs as Cournot duopolists in the second stage of the game. The equilibrium of this infinitely-repeated game will be a subgame-perfect Nash equilibrium as the firms are using Nash equilibrium strategies in all subgames. Both firms choosing to export is a Nash equilibrium if the present discounted profits from collusion (both firms choosing to export) exceed the present discounted value of profits from cheating (choosing to undertake FDI when the competitor has chosen to export) for one period followed forever thereafter by the Nash equilibrium profits (when both firms choose to undertake FDI):

$$\frac{1}{1-\delta}\Pi_{EE} > \left(\Pi_{FE} - G\right) + \frac{\delta}{1-\delta}\left(\Pi_{FF} - G\right) \tag{10}$$

The collusive outcome can be sustained as a Nash equilibrium if the fixed cost of FDI is greater than the critical value obtained by rearranging (10), which yields:

$$G^*\left(\delta\right) = \left(1-\delta\right)\left(\Pi_{FE} - \Pi_{EE}\right) + \delta\left(\Pi_{FF} - \Pi_{EE}\right) = \left(1-\delta\right)\bar{G} + \delta\hat{G} \tag{11}$$

The critical value G^* is a convex combination of $\bar{G}$ and $\hat{G}$ where the weights depend upon the discount factor. When the discount factor is equal to zero, the critical fixed cost is $G^* = \bar{G}$ and

when the discount factor is one, the critical value of the fixed cost is $G^* = \hat{G}$. Thus, as one would expect, this means that when $\delta = 1$ the collusive equilibrium can be sustained whenever the static game is a prisoners' dilemma, $G > \hat{G}$. Since $\hat{G} < \overline{G}$, the critical value of the fixed cost in the infinitely repeated game is lower than in the static game if the discount factor is greater than zero, $\delta > 0$, and it is decreasing in the discount factor. Substituting (5) into (11), yields the critical fixed cost of FDI in terms of the parameters of the model:

$$G^*(\delta) = \frac{k}{\beta\Omega^2}\left[2(2-\phi)(2-\phi\delta)(\alpha-c)-(4+\phi^2\delta)k\right] \tag{12}$$

It is shown in figure two as a concave quadratic function of the trade cost for a number of discount factors $\delta \in \{0, 1/3, 2/3, 1\}$ using the same parameter values as in figure one with $\phi = 9/10$ in figure 2a and $\phi = 1/2$ in figure 2b. In the region between $G^*(\delta)$ and $\overline{G}$, the collusive outcome where both firms export can be sustained as a Nash equilibrium in the infinitely-repeated game whereas both firms would undertake FDI in the static game. Clearly, a larger discount factor makes it easier to sustain the collusive outcome where firms choose exporting rather than undertaking FDI. This leads to the following proposition:

Proposition 1: *Under Cournot duopoly, the collusive outcome where both firms export can be sustained as a subgame perfect Nash equilibrium in the infinitely-repeated game if the fixed cost of FDI is greater than the critical value G^*, and the critical value is decreasing in the discount factor, $\partial G^* / \partial \delta < 0$.*

Before considering the welfare effects of collusion, it is worthwhile to analyse how trade costs affect the sustainability of collusion as this has an interesting implication for the relationship between trade costs and FDI. To understand how the critical value of fixed cost of FDI depends upon the trade cost, differentiate (12) with respect to k, which yields:

$$\frac{\partial G^*}{\partial k} = \frac{2}{\beta\Omega^2}\left[(2-\phi)(2-\phi\delta)(\alpha-c)-(4+\phi^2\delta)k\right] \tag{13}$$

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For low trade costs the derivative will be positive, but for a sufficiently high trade costs the derivative is negative. The derivative is negative if the trade cost is greater than:

$$k^* = \frac{(2-\phi)(2-\phi\delta)}{4+\phi^2\delta}(\alpha-c) \qquad (14)$$

This critical value of the trade cost is equal to the prohibitive trade cost, $k^* = \bar{k}$, when the discount factor is $\delta = 0$, and it decreases to $k^* = \hat{k}$ when $\delta = 1$, where $\hat{k} < \bar{k}$ for $\phi \in [0,1]$. In figures 2a and 2b, the critical fixed cost G^* is decreasing to the right of the curve labelled k^*k^* that joins the maxima of G^* and that represents k^* as an implicit function of the discount factor. Hence, in the shaded regions in figures 2a and 2b, if there is a regime switch as a result of a reduction in trade costs then firms will shift from exporting to undertaking FDI. For example, in figure 2a when the discount factor is $\delta = 2/3$, a reduction in trade costs may shift the equilibrium from E (where both firms export) to F (where both firms undertake FDI). Comparing figures 2a and 2b, it seems that this will happen for a wider range of values of the transport cost when the products are close substitutes. This leads to the following proposition:

Proposition 2: *Under Cournot duopoly, if the trade cost $k > k^*$ then the critical value of the fixed cost G^* is decreasing in the trade cost, $\partial G^*/\partial k < 0$, and a reduction in trade costs may lead the firms to switch from exporting to undertaking FDI.*

When the trade cost is sufficiently high, a reduction in trade costs makes it harder for the firms to sustain the collusive outcome where both firms export, and may lead to a switch to the outcome where both firms undertake FDI. This is because when the trade cost is sufficiently high a reduction in trade costs will reduce the profitability of collusion where both firms export, Π_{EE}; increase the profitability of cheating (undertaking FDI while the competitor exports), Π_{FE}; and not affect the profitability in the Nash equilibrium, Π_{FF}. This result, which never occurs in the static game, might provide an explanation for the increase in FDI in an era when multilateral trade liberalisation has reduced trade costs.

When firms collude over prices or outputs, the effect is unambiguously to reduce welfare by increasing the deadweight loss from oligopoly, but the welfare effects of collusion over FDI turn out to be more ambiguous. The welfare effects will differ depending upon whether the trade cost is a transport cost involving a real resource cost or an import tariff where the tariff revenue accrues to the governments. First, consider the case when the trade cost is a transport cost then the welfare of a country is given by the sum of consumer surplus and the profits of its firm. When collusion occurs, $G > G^*(\delta)$, the firms will both export rather than both undertake FDI, and the welfare of a country when both firms export is:

$$W_{EE}^R = \frac{\beta}{2}\left[\left(x_{1A}^E\right)^2 + \left(x_{2A}^E\right)^2 + 2\phi x_{1A}^E x_{2A}^E\right] + \Pi_{EE} \tag{15}$$

The first expression is consumer surplus given the quasi-linear utility function (1) for country A, but symmetry implies that consumer surplus is the same in both countries, and the superscript R denotes a real trade (transport) cost. In the static game, if $G < \bar{G}$, then both firms undertake FDI, and the welfare of a country when both firms undertake FDI is:

$$W_{FF}^R = \frac{\beta}{2}\left[\left(x_{1A}^F\right)^2 + \left(x_{2A}^F\right)^2 + 2\phi x_{1A}^F x_{2A}^F\right] + \Pi_{FF} - G \tag{16}$$

Subtracting (16) from (15) then using (3), (4) and (5) yields the welfare effect of collusion over FDI, the difference in welfare between the collusive equilibrium where both firms export and the static equilibrium where both firms undertake FDI: $\Delta W^R = W_{EE}^R - W_{FF}^R$:

$$\Delta W^R = G - \frac{k}{2\beta\Omega^2}\left[2(3+\phi)(2-\phi)^2(\alpha-c) - (12-\phi^2)k\right] \tag{17}$$

The collusive outcome where the firms export rather than undertake FDI reduces the intensity of competition and leads to higher prices, but the firms do not incur the fixed cost of FDI. Hence, the welfare effect of collusion over FDI will be positive (negative) if the fixed cost of FDI is more (less) than:

$$G^R = \frac{k}{2\beta\Omega^2}\left[2(3+\phi)(2-\phi)^2(\alpha-c) - (12-\phi^2)k\right] \tag{18}$$

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This is a concave quadratic in the trade cost, k, that is shown in figure three for the same parameter values as in figures one and two with $\phi = 9/10$ in figure 3a and with $\phi = 1/2$ in figure 3b. Since collusion over FDI can only occur when the fixed cost of FDI $G < \bar{G} = G^*(\delta = 0)$, it is informative to compare G^R with $\bar{G}$, which can be done by subtracting (6) from (18) to obtain:

$$G^R - \bar{G} = \frac{k}{2\beta\Omega}\left[2(1-\phi)(\alpha-c)-k\right] \tag{19}$$

This is a concave quadratic in the trade cost, k, that is equal to zero when the trade cost is zero and positive (negative) if the trade cost $k < (>)k^R \equiv 2(1-\phi)(\alpha-c)$, where $k^R < (>)\bar{k}$ if $\phi > (<)2/3$. Hence, if the products are not close substitutes, $\phi < 2/3$ as in figure 3b, then $G^R > \bar{G}$ for all trade costs, $k \in \left[0, \bar{k}\right]$, and if the firms collude over FDI then there will be welfare losses for both countries. However, if the products are close substitutes, $\phi > 2/3$ as in figure 3a, then there is the possibility of a welfare gain from collusion over FDI if the fixed cost of FDI $G > G^R$, but this will only be the case if the trade cost $k > k^R$. A welfare gain from collusion over FDI occurs in region R in figure 3a, which includes the case when the trade cost is prohibitive. This leads to the following proposition:

Proposition 3: Under Cournot duopoly, with real trade (transport) costs, there will be a welfare gain from collusion over FDI if $G > G^R$, which will only be the case if $\phi > 2/3$ and $k > k^R$. Otherwise there will be a welfare loss.

The counterintuitive possibility of a welfare gain from collusion over FDI arises because the loss of consumer surplus is outweighed by the increase in profits and not having to incur the fixed cost of FDI when both firms export rather than undertake FDI. This happens when the products are close substitutes and the trade cost is sufficiently high. Then, the strategic incentive to invest in FDI is large and the negative effect on the profits of the firm's competitor is large. The collusive outcome where both firms export not only avoids the prisoners' dilemma from FDI for the firms but also for the countries.

When the trade cost is an import tariff rather than a transport cost, the tariff revenue will accrue to the government in the importing country and will contribute to the welfare of the country. Hence, the welfare of a country when both firms export is given by consumer surplus, the profits of its firm, and tariff revenue: $W_{EE}^T = W_{EE}^R + kx_{2A}^E$, where the superscript T denotes a tariff. Since there is no tariff revenue when both firms undertake FDI, the welfare of a country when both firms undertake FDI is: $W_{FF}^R = W_{FF}^T$. Therefore, the welfare effect of collusion over FDI with a tariff is $\Delta W^T = W_{EE}^T - W_{FF}^T$:

$$\Delta W^T = G - \frac{k}{2\beta\Omega^2}\left[2(2-\phi)^2(\alpha-c)+(4-3\phi^2)k\right] \tag{20}$$

Hence, the welfare effect of collusion over FDI will be positive (negative) if the fixed cost of FDI is more (less) than:

$$G^T \equiv \frac{k}{2\beta\Omega^2}\left[2(2-\phi)^2(\alpha-c)+(4-3\phi^2)k\right] \tag{21}$$

This is a convex quadratic in the trade cost, k, that is shown in figure three with $\phi = 9/10$ in figure 3a and with $\phi = 1/2$ in figure 3b. Note that $G^T = G^R$ at the prohibitive trade cost, $k = \bar{k}$, as tariff revenue is zero since there are no imports. Since collusion over FDI can only occur when the fixed cost of FDI $G < \bar{G} = G^*(\delta = 0)$, it is informative to compare G^T with $\bar{G}$, which can be done by subtracting (6) from (21) to obtain:

$$G^T - \bar{G} = \frac{-k}{2\beta\Omega}\left[2(\alpha-c)-3k\right] \tag{22}$$

This is a convex quadratic in the trade cost, k, that is zero when the trade cost is zero and will be negative (positive) if the trade cost $k < (>)k^T \equiv 2(\alpha-c)/3$, where $k^T < \bar{k}$ if $\phi < 2/3$. If the products are close substitutes, $\phi > 2/3$ as in figure 3a, then $G^T < \bar{G}$ for all trade costs, $k \in [0, \bar{k}]$, and there will be a welfare gain (loss) from collusion over FDI if $G > (<)G^T$. When the products are not

close substitutes, $\phi < 2/3$ as in figure 3b, then $G^T < \overline{G}$ for trade costs $k < k^T$, and there will be a welfare gain (loss) if $G > (<)G^T$ whereas if $k > k^T$ then there is a welfare loss.

Also, since collusion over FDI can only occur when the fixed cost of FDI $G > \hat{G} = G^*(\delta = 1)$, it is informative to compare G^T with $\hat{G}$, which can be done by subtracting (9) from (21) to obtain:

$$G^T - \hat{G} = \frac{-k}{2\beta\Omega^2}\left[2(2-\phi)^2(\alpha-c)-(12-\phi^2)k\right] \tag{23}$$

Therefore, $G^T > (<)\hat{G}$ if the trade cost $k > (<)k^S \equiv 2(2-\phi)^2(\alpha-c)\big/(12-\phi^2)$, where $k^S < \overline{k}$ whatever the degree of product substitutability, $\phi \in [0,1]$ as shown in figures 3a and 3b. Hence, with import tariffs, there will always be a welfare gain from collusion if $k < k^S$. This leads to the following proposition:

Proposition 4: *Under Cournot duopoly, with import tariffs, there will be a welfare gain from collusion over FDI if $G > G^T$, which will always be the case for $k \in [0,k^S]$, may be the case for $k \in [k^S,\overline{k}]$ if $\phi > 2/3$ or $k \in [k^S,k^T]$ if $\phi < 2/3$. Otherwise there will be a welfare loss.*

A welfare gain from collusion over FDI occurs in regions R and T in figure 3a, and in region T in figure 3b. The likelihood of a welfare gain from collusion over FDI is greater with import tariffs than with transport costs as transport costs are a real resource cost to the countries. As an illustration of the different welfare effects with transport costs and tariffs, figure four compares welfare in the static game with welfare in the infinitely-repeated game for the same parameters as in previous figures with $\phi = 9/10$, $\delta = 2/3$, and $G = 60$. The critical fixed cost of FDI to sustain collusion $G^*(\delta = 2/3)$ and the fixed cost $G = 60$ are shown in figure 3a. The corresponding welfare in the static and the infinitely-repeated games is shown in figure 4a when the trade cost is a transport cost and in figure 4b when the trade cost is a tariff. In region *I*, both firms export in the static game and in the infinitely-repeated game so there is no collusive outcome and hence no welfare effect from collusion. In region *II*, both firms undertake FDI in the static game while there is a collusive outcome

in the infinitely-repeated game where both firms export. This results in a welfare loss with transport costs in figure 4a and a welfare gain with tariffs in figure 4b. In region *III*, both firms undertake FDI in the static game and in the infinitely-repeated game so there is no collusive outcome and hence no welfare loss from collusion. In region IV, both firms undertake FDI in the static game while there is a collusive outcome in the infinitely-repeated game where both firms export. This results in a welfare loss with both transport costs in figure 4a and with tariffs in figure 4b. Figures 4a and 4b also show how a reduction in trade costs may lead to a switch from exporting to undertaking FDI.

4. The Bertrand Duopoly Model

Models of international trade under imperfect competition are notorious for yielding different results under Bertrand oligopoly than under Cournot oligopoly. Since outputs are strategic substitutes in the Cournot duopoly, firms will 'overinvest' in FDI under Cournot duopoly whereas since prices are strategic complements in the Bertrand duopoly model firms will 'underinvest' in FDI under Bertrand duopoly.[4] Therefore, one might expect significantly different results from the two models so this section will consider the case of Bertrand duopoly when the firms compete in prices rather than Cournot duopoly when the firms compete in outputs. A thorough analysis of international trade in the Bertrand duopoly model in the presence of trade costs is provided by Clarke and Collie (2003), which should be consulted for details of the best-reply functions and the derivations of the boundary solutions. Given the utility function (1), the demand functions facing the two firms in country *A* are:

$$x_{1A} = \frac{1}{\beta(1-\phi^2)}\big[\alpha(1-\phi) - p_{1A} + \phi p_{2A}\big]$$

$$x_{2A} = \frac{1}{\beta(1-\phi^2)}\big[\alpha(1-\phi) + \phi p_{1A} - p_{2A}\big]$$

(24)

Consider the market in country *A* when firm two chooses to export, assuming that there is an interior solution where both firms have positive sales. Then, the usual derivations yield the Bertrand duopoly prices, sales and operating profits of the two firms:

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[4] For an explanation of strategic substitutes and strategic complements, see Bulow et al (1985). In the terminology of Fudenberg and Tirole (1984), a firm would want to be a top dog under Cournot duopoly and a puppy dog under Bertrand duopoly.

$$p_{1A}^E = c + \frac{\left(2-\phi-\phi^2\right)(\alpha-c)+\phi k}{\Omega}, \qquad p_{2A}^E = c + k + \frac{\left(2-\phi-\phi^2\right)(\alpha-c)-\left(2-\phi^2\right)k}{\Omega}$$

$$x_{1A}^E = \frac{\left(2-\phi-\phi^2\right)(\alpha-c)+\phi k}{\beta\left(1-\phi^2\right)\Omega}, \qquad x_{2A}^E = \frac{\left(2-\phi-\phi^2\right)(\alpha-c)-\left(2-\phi^2\right)k}{\beta\left(1-\phi^2\right)\Omega} \qquad (25)$$

$$\pi_{1A}^E = \frac{\left[\left(2-\phi-\phi^2\right)(\alpha-c)+\phi k\right]^2}{\beta\left(1-\phi^2\right)\Omega^2}, \qquad \pi_{2A}^E = \frac{\left[\left(2-\phi-\phi^2\right)(\alpha-c)-\left(2-\phi^2\right)k\right]^2}{\beta\left(1-\phi^2\right)\Omega^2}$$

The exports of firm two to country A will be zero and the profits of firm two from exports will be zero if the trade cost: $k > \underline{k} \equiv \left(2-\phi-\phi^2\right)(\alpha-c)/\left(2-\phi^2\right)$. This is decreasing in the degree of product substitutability from $(\alpha-c)$ when the products are independent, $\phi=0$, to zero when the products are perfect substitutes, $\phi=1$. However, in the Bertrand duopoly model when $k > \underline{k}$, competition from firm two will still affect the price set by firm one and the profits earned by firm one. Then, as explained in Clarke and Collie (2003), there is a boundary solution equilibrium where firm two sets its price equal to marginal cost and its sales are zero. Hence, the Bertrand duopoly prices, sales and operating profits of the two firms are:

$$p_{1A}^E = c + \frac{1}{\phi}\left[k-(1-\phi)(\alpha-c)\right], \qquad p_{2A}^E = c + k$$

$$x_{1A}^E = \frac{1}{\phi\beta}(\alpha-c-k), \qquad x_{2A}^E = 0 \qquad (26)$$

$$\pi_{1A}^E = \frac{(\alpha-c-k)}{\beta\phi^2}\left[k-(1-\phi)(\alpha-c)\right], \qquad \pi_{2A}^E = 0$$

Firm one will set the monopoly price, $p_{1A}^E = (\alpha+c)/2$, and earn monopoly profits if the trade cost $k \geq \overline{k} \equiv (2-\phi)(\alpha-c)/2$, which is the same as the prohibitive trade cost under Cournot duopoly. Then, the outcome in country A is the same as under autarky. Again, symmetry of the model implies that: $x_{1B}^E = x_{2A}^E$, $x_{2B}^E = x_{1A}^E$, $p_{1B}^E = p_{2A}^E$, $p_{2B}^E = p_{1A}^E$, $\pi_{1B}^E = \pi_{2A}^E$ and $\pi_{2B}^E = \pi_{1A}^E$.

When firm two chooses to undertake FDI, both firms have the same marginal cost so the outcome is an interior solution where both firms have positive sales. The usual derivations yield the Bertrand duopoly prices, sales and operating profits of the two firms:

$$p_{1A}^F = p_{2A}^F = c + \frac{(1-\phi)(\alpha-c)}{(2-\phi)} \qquad x_{1A}^F = x_{2A}^F = \frac{(\alpha-c)}{\beta(2-\phi)(1+\phi)}$$

$$\pi_{1A}^F = \pi_{2A}^F = \frac{(1-\phi)(\alpha-c)^2}{\beta(1+\phi)(2-\phi)^2}$$

(27)

As in the Cournot duopoly case, FDI intensifies competition since it leads both firms to set lower prices, which reduces the profits of firm one. Again, symmetry of the model implies that: $x_{1B}^F = x_{2B}^F = x_{1A}^F$, $p_{1B}^F = p_{2B}^F = p_{1A}^F$, and $\pi_{1B}^F = \pi_{2B}^F = \pi_{1A}^F$.

In the static game, undertaking FDI is a dominant strategy for both firms if the fixed cost of FDI is less than the critical value: $\bar{G} = \Pi_{FE} - \Pi_{EE} = \Pi_{FF} - \Pi_{EF}$. Using (25), (26), (27) and (5), it can be shown that:

$$\bar{G} \equiv \begin{cases} \dfrac{k(2-\phi^2)\left[2(2-\phi-\phi^2)(\alpha-c)-(2-\phi^2)k\right]}{\beta(1-\phi^2)\Omega^2} & \text{if } 0 \le k < \underline{k} \\ \dfrac{(1-\phi)(\alpha-c)^2}{\beta(1+\phi)(2-\phi)^2} & \text{if } \underline{k} \le k \le \bar{k} \end{cases}$$

(28)

For $0 \le k < \underline{k}$, this is a concave quadratic that is increasing in the trade cost and, for $k \ge \underline{k}$, it is independent of the trade cost, since the profits from exporting to the other country are zero so a firm will undertake FDI if the operating profits in the other country cover the fixed cost. By comparing (6) and (28), it can be shown that $\bar{G}$ is larger under Cournot duopoly than under Bertrand duopoly as a result of profits being higher under Cournot duopoly than under Bertrand duopoly as Vives (1985) has shown. The critical fixed cost of FDI, $\bar{G}$, is shown in figure five for the same parameters as used in previous figures with $\phi = 9/10$ in figure 5a and $\phi = 1/2$ in figure 5b.

When both firms undertake FDI they will have higher profits than when they both export, $\Pi_{FF} - G > \Pi_{EE}$, and this will be the case if the fixed cost of FDI is less than $\hat{G} \equiv \Pi_{FF} - \Pi_{EE} = \bar{G} + (\Pi_{FF} - \Pi_{FE})$. As in the Cournot duopoly model, it can be shown that $(\Pi_{FF} - \Pi_{FE}) < 0$ as in (7) so $\hat{G} < \bar{G}$, and it can be shown that $\partial(\Pi_{FF} - \Pi_{FE})/\partial\phi < 0$ as in (8) so

$\left(\bar{G}-\hat{G}\right)$ is increasing in the degree of product substitutability. Using (25), (26), (27) and (5) it can be shown that:

$$\hat{G} \equiv \begin{cases} \dfrac{k\left[2\left(2-\phi-\phi^2\right)^2(\alpha-c)-\left(4-3\phi^2+\phi^4\right)k\right]}{\beta\left(1-\phi^2\right)\Omega^2} & \text{if } 0 \leq k < \underline{k} \\[4mm] \dfrac{2(1-\phi)(\alpha-c)^2}{\beta(1+\phi)(2-\phi)^2} - \dfrac{(\alpha-c-k)\left[k-(1-\phi)(\alpha-c)\right]}{\beta\phi^2} & \text{if } \underline{k} \leq k \leq \bar{k} \end{cases} \tag{29}$$

where $k-(1-\phi)(\alpha-c)>0$ for $k>\underline{k}$. This is a concave quadratic for $k<\underline{k}$ that has a maximum value at $\hat{k}\equiv\left(2-\phi-\phi^2\right)^2(\alpha-c)\big/\left(4-3\phi^2+\phi^4\right)$, and is a convex quadratic for $k>\underline{k}$. It is shown along with $\bar{G}$ in figure five with $\phi=9/10$ in figure 5a and with $\phi=1/2$ in figure 5b. By comparing (9) and (29), it can be shown that $\hat{G}$ is larger under Cournot duopoly than under Bertrand duopoly. Also, it can be shown that $\bar{G}-\hat{G}=-\left(\Pi_{FF}-\Pi_{FE}\right)$ is larger under Bertrand duopoly than under Cournot duopoly as the loss of profits when a firm's competitor chooses to undertake FDI rather than to export is larger under Bertrand duopoly than under Cournot duopoly. This implies that the outcome is more likely to be a prisoners' dilemma under Bertrand duopoly than under Cournot duopoly, and this is confirmed by comparing figure five with figure one. Comparison of figures 5a and 5b suggests that the outcome is more likely to be a prisoners' dilemma when the products are close substitutes as would be expected given that $\left(\bar{G}-\hat{G}\right)$ is increasing in the degree of product substitutability.

5. The Infinitely-Repeated Bertrand Duopoly Game

When the Bertrand duopoly game is infinitely-repeated, the firms can tacitly collude by choosing to export rather than undertake FDI so as to avoid the prisoners' dilemma. Since (10) and (11) apply to Bertrand duopoly as well as Cournot duopoly, the collusive outcome can be sustained if the fixed cost of FDI is greater than $G^*(\delta)=(1-\delta)\bar{G}+\delta\hat{G}$. Hence, as $\hat{G}<\bar{G}$, the critical fixed cost of FDI in the infinitely-repeated game is lower than in the static game, $G^*<\bar{G}$, if the discount factor is greater than zero, $\delta>0$, and it is decreasing in the discount factor. Since $\bar{G}$ and $\hat{G}$ are larger

under Cournot duopoly than under Bertrand duopoly, for any given discount factor, $G^*(\delta)$ will be larger under Cournot duopoly than under Bertrand duopoly. Using (25), (26), (27) and (5) in (11), it can be shown that critical value of the fixed cost of FDI is:

$$G^* = \begin{cases} \dfrac{k\left[2\left(2-\phi-\phi^2\right)\left(2-\delta\phi-\phi^2\right)(\alpha-c)-\left(4-4\phi^2+\delta\phi^2+\phi^4\right)k\right]}{\beta\left(1-\phi^2\right)\Omega^2} & \text{if } 0 \le k < \underline{k} \\[4mm] \dfrac{(1+\delta)(1-\phi)(\alpha-c)^2}{\beta(1+\phi)(2-\phi)^2} - \dfrac{\delta(\alpha-c-k)\left[k-(1-\phi)(\alpha-c)\right]}{\beta\phi^2} & \text{if } \underline{k} \le k \le \overline{k} \end{cases} \tag{30}$$

This is concave quadratic for $k < \underline{k}$ and a convex quadratic for $k > \underline{k}$. It is shown in figure six for a range of discount factors using the same parameter values as in previous figures with $\phi = 9/10$ in figure 6a and with $\phi = 1/2$ in figure 6b. This leads to the following proposition:

Proposition 5: *Under Bertrand duopoly, the collusive outcome where both firms export can be sustained as a subgame perfect Nash equilibrium in the infinitely-repeated game if the fixed cost of FDI is greater than the critical value G^*, and the critical value is decreasing in the discount factor, $\partial G^*/\partial\delta < 0$.*

Again, it is worthwhile to consider how trade costs affect the sustainability of collusion over FDI. To understand how the critical value of the fixed cost of FDI depends upon the trade cost, k, differentiate (30) with respect to the trade cost, which yields:

$$\frac{\partial G^*}{\partial k} = \begin{cases} \dfrac{2\left[\left(2-\phi-\phi^2\right)\left(2-\delta\phi-\phi^2\right)(\alpha-c)-\left(4-4\phi^2+\delta\phi^2+\phi^4\right)k\right]}{\beta\left(1-\phi^2\right)\Omega^2} & \text{if } 0 \le k \le \underline{k} \\[4mm] -\dfrac{\delta}{\beta\phi^2}\left[(2-\phi)(\alpha-c)-2k\right] \le 0 & \text{if } \underline{k} < k \le \overline{k} \end{cases} \tag{31}$$

For low trade costs this derivative is positive, but for sufficiently high trade costs this derivative is negative. For $0 \le k \le \underline{k}$, it is negative if the trade cost is greater than:

$$k^* = \frac{\left(2-\phi-\phi^2\right)\left(2-\delta\phi-\phi^2\right)}{4-4\phi^2+\delta\phi^2+\phi^4}(\alpha-c) \tag{32}$$

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This critical value of the trade cost is equal to $\underline{k}$ when $\delta = 0$ and it is equal to $\hat{k}$ when $\delta = 1$. By comparing (14) and (32), it can be shown that k^* is larger under Cournot duopoly than under Bertrand duopoly. The derivative (31) is negative for $\underline{k} < k < \overline{k}$, and therefore $\partial G^* / \partial k < 0$ for $k^* < k < \overline{k}$. In figure six, it can be seen that $\partial G^* / \partial k < 0$ in the shaded region to the right of the $k^* k^*$ locus. Then, if there is a regime switch as a result of a reduction in trade costs then firms will shift from exporting to undertaking FDI as shown by the move from E to F in figure 5a when the discount factor $\delta = 1/6$. Note that this occurs in the region where there is no trade, $\underline{k} < k < \overline{k}$. Although there is no trade, the reduction in trade costs decreases the profits from collusion, $\Pi_{EE} = \pi_{1A}^E$ when there is a boundary solution as in (26), and thereby makes it harder to sustain the collusive outcome. These results lead to the following proposition:

Proposition 6: *Under Bertrand duopoly, if the trade cost $k > k^*$ then the critical value of the fixed cost G^* is decreasing in the trade cost, $\partial G^* / \partial k < 0$, and a reduction in trade costs may lead the firms to undertake FDI rather than export.*

Turning to the welfare effects of collusion over FDI under Bertrand duopoly, consider the case when the trade cost is a real resource cost such as a transport cost. The welfare of the country is given by (15) when both countries export and by (16) when both countries undertake FDI so the welfare effect of collusion is $\Delta W^R = W_{EE}^R - W_{FF}^R$. Then, using (25), (26) and (27) it can be shown that the welfare effect of collusion will be positive (negative) if the fixed cost of FDI is more (less) than:

$$G^R \equiv \begin{cases} \dfrac{k\left[2(1-\phi)(3-2\phi)(2+\phi)^2(\alpha-c)-\left(12-9\phi^2+2\phi^4\right)k\right]}{2\beta(1-\phi^2)\Omega^2} & \text{if } 0 \leq k \leq \underline{k} \\[4mm] \dfrac{(3-2\phi)(\alpha-c)^2}{\beta(1+\phi)(2-\phi)^2} + \dfrac{(\alpha-c-k)\left[(1-2\phi)(\alpha-c)-k\right]}{2\beta\phi^2} & \text{if } \underline{k} \leq k \leq \overline{k} \end{cases} \qquad (33)$$

This is a concave quadratic in the trade cost for $0 \leq k \leq \underline{k}$, and a convex quadratic for $\underline{k} \leq k \leq \overline{k}$. It is shown in figure seven for the same parameter values as in previous figures with $\phi = 9/10$ in figure 7a and with $\phi = 1/2$ in figure 7b. To see how the region where collusion is possible,

$\hat{G} < G < \overline{G}$, is divided by G^R into regions where there are welfare gains or losses, consider the intersections of G^R with $\overline{G}$ (note that $G^R > \hat{G}$ for $0 < k < \overline{k}$). For $0 \le k \le \underline{k}$, it can be shown that $G^R < \overline{G}$ if $k > k^R \equiv 2(1-\phi)(\alpha-c)$, where $k^R < \underline{k}$ if $\phi > \phi^R \equiv (\sqrt{17}-1)/4 \approx 0\cdot78$, and that $G^R > \overline{G}$ for $0 \le k \le \underline{k}$ if $\phi < \phi^R$. Since $G^R < (>)\overline{G}$ at $k = \underline{k}$ as $\phi > (<)\phi^R$ and since $\partial G^R / \partial k > 0$ for $\underline{k} \le k \le \overline{k}$, if $\phi > \phi^R$ then $G^R < \overline{G}$ for trade costs greater than $\underline{k}$ and less than:

$$k^U = \left[(1-\phi) + \frac{\sqrt{(1-\phi^2)(2-\phi)\phi^3}}{(1+\phi)(2-\phi)} \right](\alpha-c) \tag{34}$$

where $k^U > \underline{k}$ for $\phi > \phi^R$. Hence, when the products are close substitutes, $\phi > \phi^R$ as in figure 7a, there is a range of values for the trade cost, $k^R < k < k^U$, where there are welfare gains from collusion if the fixed cost of FDI is sufficiently high, $G > G^R$ as in region R in figure 7a. For $\phi < \phi^R$ as in figure 7b, there is no possibility of welfare gains from collusion over FDI and there are always welfare losses. These results lead to the following proposition:

Proposition 7: *Under Bertrand duopoly, with real trade costs, there will be a welfare gain from collusion over FDI if $G > G^R$, which will only be the case if $\phi > \phi^R$ and $k^R < k < k^U$. Otherwise there will be a welfare loss.*

When the trade cost is an import tariff rather than a transport cost then the tariff revenue will accrue to the government in the importing country and will contribute to the welfare of the country when the firms export. The addition of tariff revenue means that the collusive outcome where both firms export is more likely to be superior in terms of welfare to the Nash equilibrium of the static game where both firms undertake FDI. It can be shown that the welfare effect of collusion will be positive (negative) if the fixed cost of FDI is more (less) than:

$$G^T \equiv \begin{cases} \dfrac{k\left[2\left(2-\phi-\phi^2\right)^2(\alpha-c)+(4-3\phi)k\right]}{2\beta\left(1-\phi^2\right)\Omega^2} & \text{if } 0 \le k \le \underline{k} \\[4mm] \dfrac{(3-2\phi)(\alpha-c)^2}{\beta(1+\phi)(2-\phi)^2}+\dfrac{(\alpha-c-k)\left[(1-2\phi)(\alpha-c)-k\right]}{2\beta\phi^2} & \text{if } \underline{k} \le k \le \overline{k} \end{cases} \tag{35}$$

This is a convex quadratic for $0 \le k \le \underline{k}$ while it is equal to G^R, which is also a convex quadratic, for $\underline{k} \le k \le \overline{k}$, and it is shown in figure seven. To see how the region where collusion is possible, $\hat{G} \le G \le \overline{G}$, is divided into regions where there are welfare gains and losses, consider the intersections of G^T with $\hat{G}$ and $\overline{G}$. It can be shown that $G^T <(>)\hat{G}$ as $k <(>)k^S \equiv 2\left(2-\phi-\phi^2\right)^2(\alpha-c)/\left(12-9\phi^2+2\phi^4\right)$. The intersection of G^T and $\overline{G}$ occurs where $0 \le k \le \underline{k}$ for $\phi < \phi^R$ as in figure 7b and where $\underline{k} \le k \le \overline{k}$ for $\phi > \phi^R$ as in figure 7b. It can be shown that $G^T <(>)\overline{G}$ as $k <(>)k^T$, where $k^T \equiv 2\left(1-\phi^2\right)(\alpha-c)/\left(3-2\phi^2\right)$ for $\phi < \phi^R$, and $k^T = k^U$ as in (34) for $\phi > \phi^R$. Hence, there are a range of values for the trade cost $0 \le k \le k^S$ where there are always welfare gains from collusion over FDI and a range of values for the trade cost $k^S \le k \le k^T$ where there will be a welfare gain if the fixed cost of FDI is sufficiently high. There are welfare gains in regions R and T in figure 7a and in region T in figure 7b. This leads to the following proposition:

Proposition 8: *Under Bertrand duopoly, with import tariffs, there will be a welfare gain from collusion over FDI if $G > G^T$, which will always be the case for $0 \le k \le k^S$, may be the case for $k^S < k < k^T$, and will never be the case for $k > k^T$. Otherwise there will be welfare loss.*

As an illustration of the different welfare effects with transport costs and tariffs, figure eight compares welfare in the static game with welfare in the infinitely repeated game for the same parameters as in previous figures with $\phi = 9/10$, $\delta = 1/6$, and $G = 30$. The critical fixed cost of FDI to sustain collusion $G^*(\delta = 2/3)$ and the fixed cost $G = 30$ are shown in figure 7a. The corresponding welfare in the static and the infinitely-repeated game are shown in figure 8a when the trade cost is a transport cost and in figure 8b when the trade cost is a tariff. In region I, both firms export in the static

game and in the infinitely-repeated game so there is no collusive outcome and hence no welfare effect from collusion. In region *II*, both firms undertake FDI in the static game while there is a collusive outcome in the infinitely-repeated game where both firms export. This results in a welfare loss with transport costs in figure 8a and a welfare gain with tariffs in figure 8b. In region *III*, both firms undertake FDI in the static game and in the infinitely-repeated game so there is no collusive outcome and hence no welfare loss from collusion. In region *IV*, both firms undertake FDI in the static game while there is a collusive outcome in the infinitely-repeated game where both firms export. This results in a welfare loss with both transport costs in figure 8a and tariffs in figure 8b. Figures 8a and 8b how a reduction in trade costs may lead to a switch from exporting to undertaking FDI.

6. Conclusions

The export versus FDI decisions of firms have been analysed in a two-country model with differentiated products under both Cournot duopoly and Bertrand duopoly. In the static game, in common with most of the literature, a reduction in trade costs (import tariffs and/or transport costs), can only lead firms to switch from undertaking FDI to exporting as it increases the profitability of exporting relative to undertaking FDI. It was also shown that the static game is often a prisoners' dilemma where both firms make lower profits when they both undertake FDI than when they both export, and this is most likely when the products are close substitutes. This is because undertaking FDI increases the intensity of competition in the competitor's home market. To avoid the prisoners' dilemma, in an infinitely-repeated game, the firms can implicitly collude about their export versus FDI decisions by choosing to export rather than to undertake FDI. It was shown that collusion over FDI can be sustained by Nash-reversion strategies if the fixed cost of FDI is sufficiently high. Then, a reduction in trade costs may lead firms to switch from exporting to undertaking FDI if the trade cost is sufficiently high, as the reduction in trade costs reduces the profitability of collusion over FDI. This counterintuitive result contrasts with the results in most of the literature, and may help to explain why there has been an increase in FDI in an era of trade liberalisation.[5] Also, it was shown that collusion

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[5] It may also explain the observation of Graham (1978) that US firms undertaking FDI in Europe was closely followed by European firms undertaking FDI in the US. If a reduction in trade costs made collusion over

over FDI may increase welfare when trade costs are import tariffs and even when trade costs are real transport costs. This is most likely when the products are close substitutes, when the trade costs and the fixed cost of FDI are high, and when there are import tariffs rather than transport costs.

The results were qualitatively similar under Cournot duopoly and Bertrand duopoly, and this is surprising given that outputs are strategic substitutes under Cournot duopoly and prices are strategic complements under Bertrand duopoly. Since FDI can be viewed as a strategic investment in a fixed cost to reduce marginal costs, firms will overinvest in FDI under Cournot duopoly and underinvest under Bertrand duopoly. Therefore, it is not surprising that collusion over FDI may result in a welfare gain under Cournot duopoly as the firms will overinvest in FDI, but it is rather surprising that the same possibility occurs under Bertrand duopoly. Although the results are qualitatively similar, there are quantitative differences between the results under Cournot duopoly and under Bertrand duopoly. The critical values for the fixed cost of FDI are higher under Cournot duopoly than under Bertrand duopoly since, as Vives (1985) showed, profits are higher under Cournot duopoly than under Bertrand duopoly. Also, the negative effect of FDI by a firm on the profits of its competitor are larger under Bertrand duopoly than under Cournot duopoly since, as Vives (1985) also showed, competition is more intense under Bertrand duopoly than under Counot duopoly.

FDI less profitable then a breakdown of collusion would result in both US and European firms would undertake FDI in their competitors' markets.

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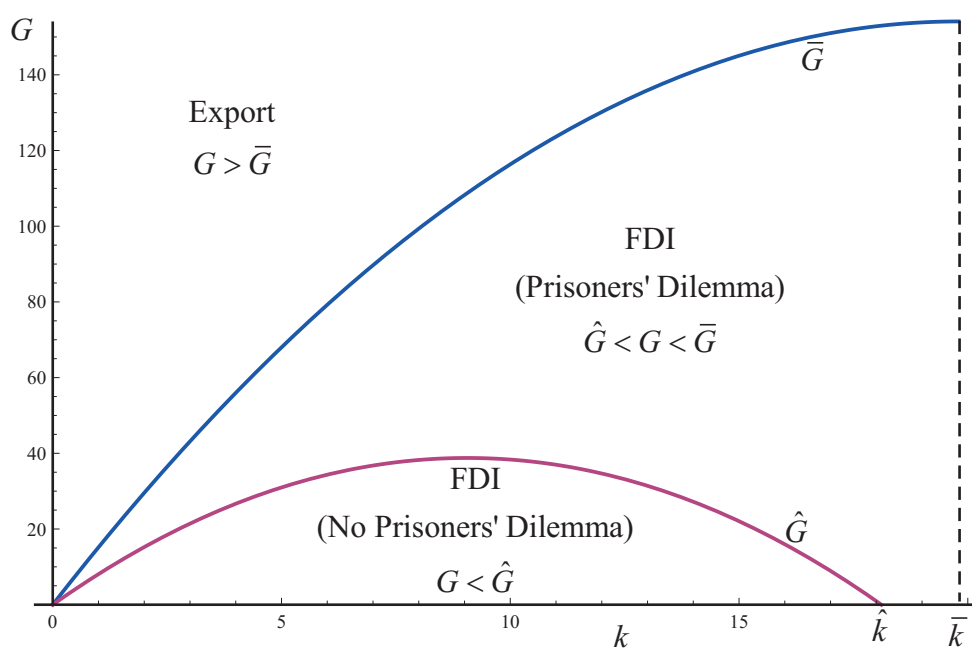
Figure 1a: Static Game under Cournot Duopoly $\left(\phi = 9/10\right)$
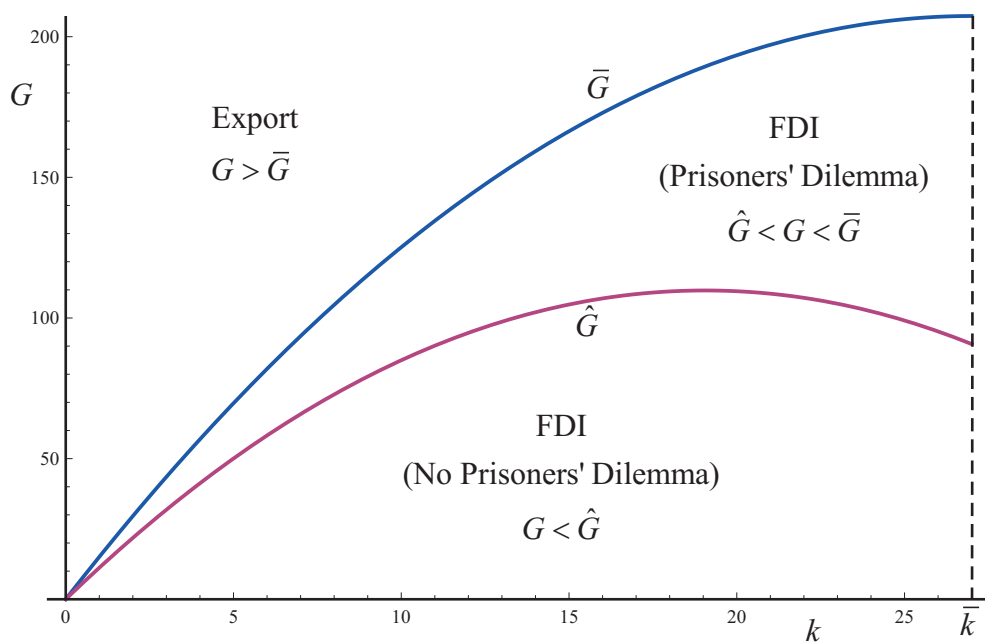
Figure 1b: Static Game under Cournot Duopoly $\left(\phi = 1/2\right)$
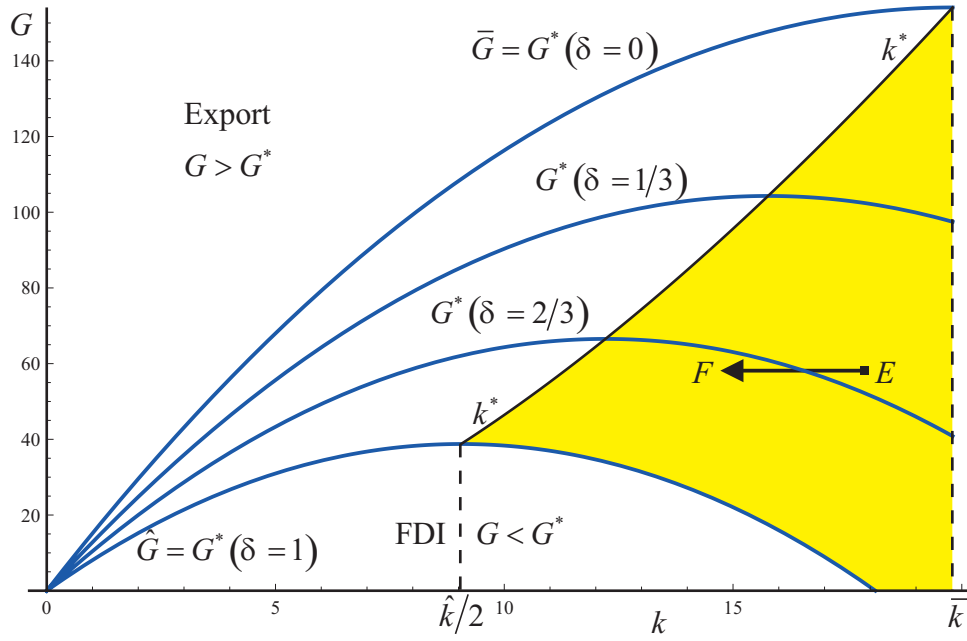
Figure 2a: Infinitely-Repeated Game under Cournot Duopoly $\left(\phi = 9/10\right)$
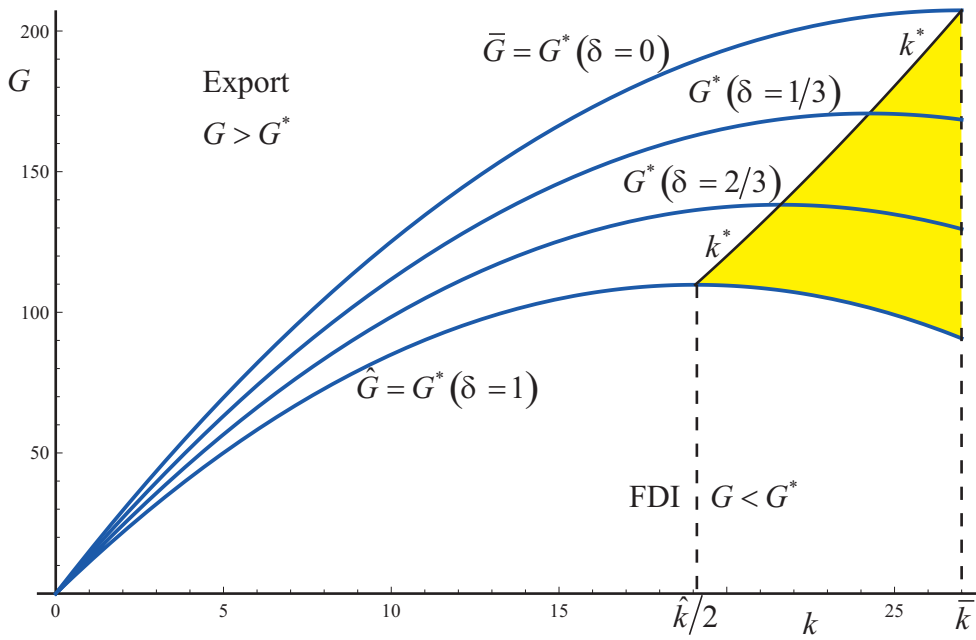
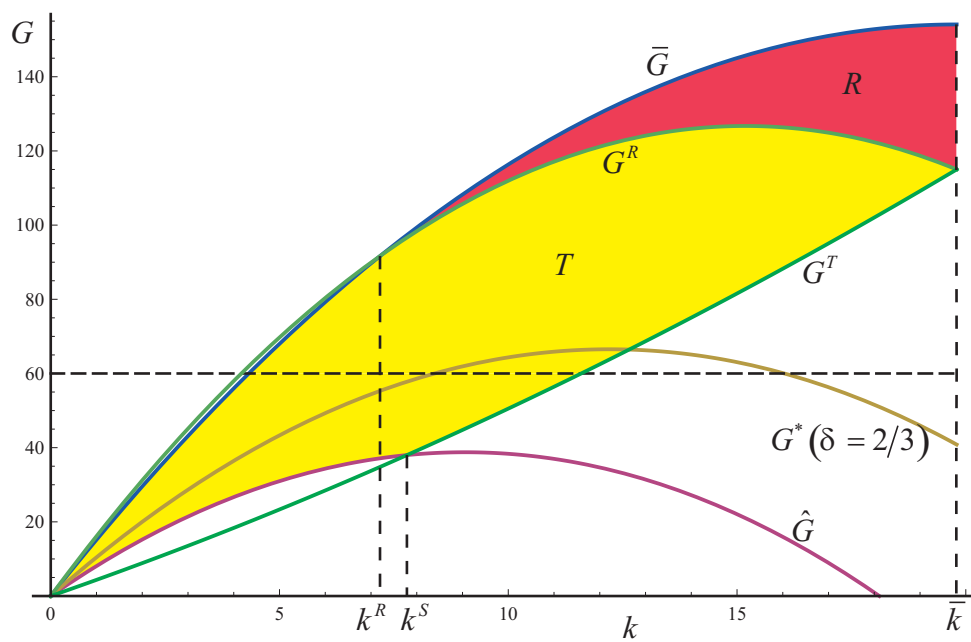Figure 2b: Infinitely-Repeated Game under Cournot Duopoly $\left(\phi = 1/2\right)$

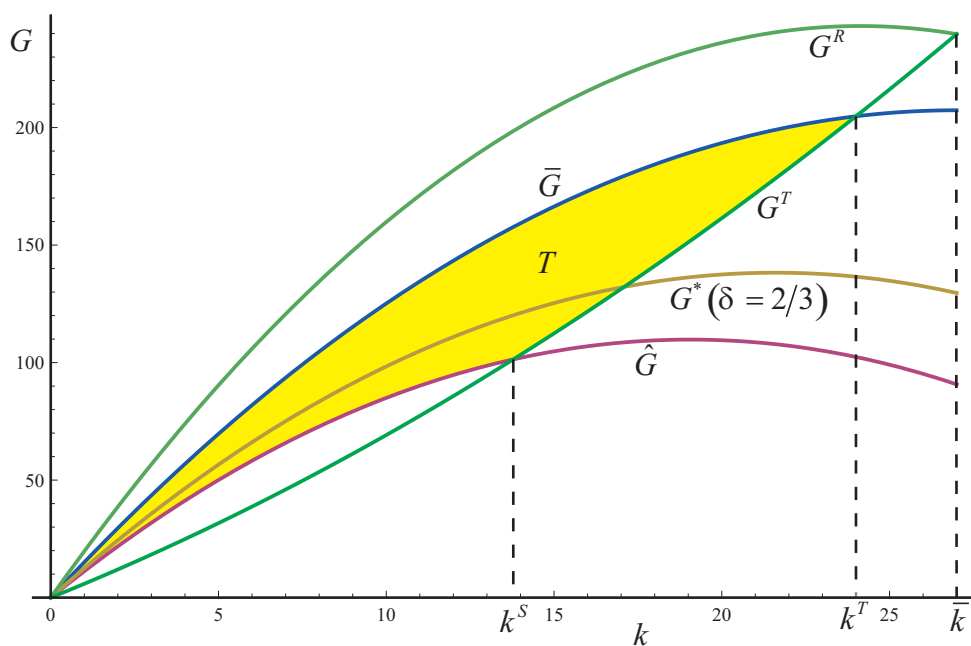Figure 3a: Welfare Effects of Collusion under Cournot Duopoly $\left(\phi = 9/10\right)$

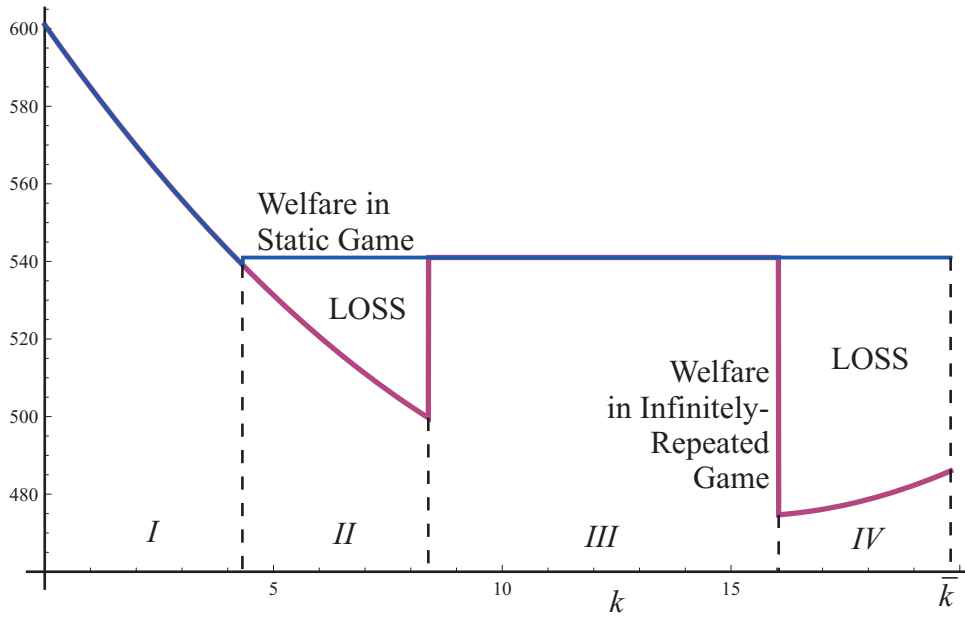Figure 3b: Welfare Effects of Collusion under Cournot Duopoly $\left(\phi = 1/2\right)$

Figure 4a: Transport Costs and Welfare $\left(\phi = 9/10, \delta = 2/3, G = 60\right)$
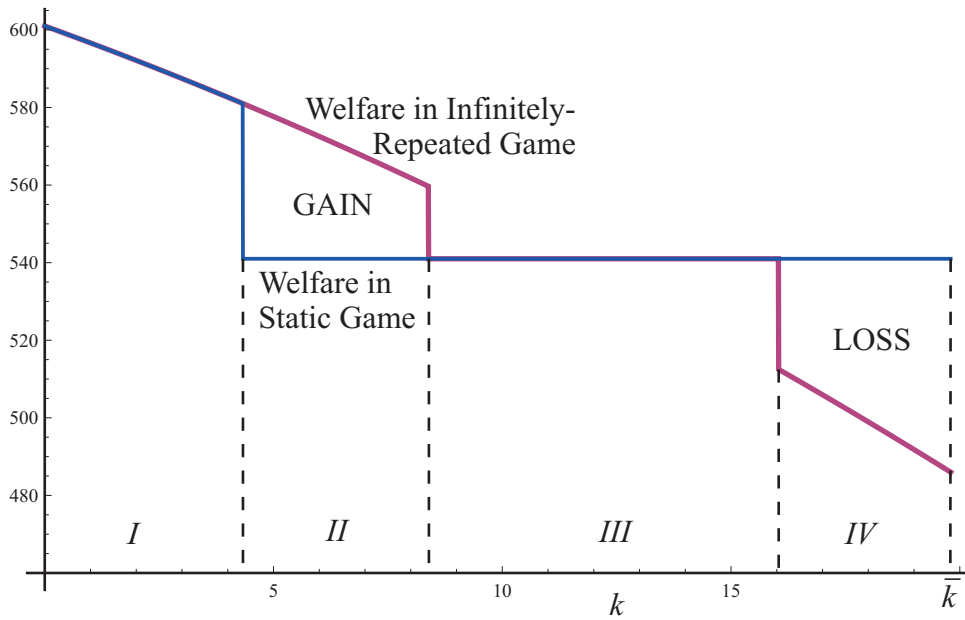
Figure 4b: Tariffs and Welfare $\left(\phi = 9/10, \delta = 2/3, G = 60\right)$
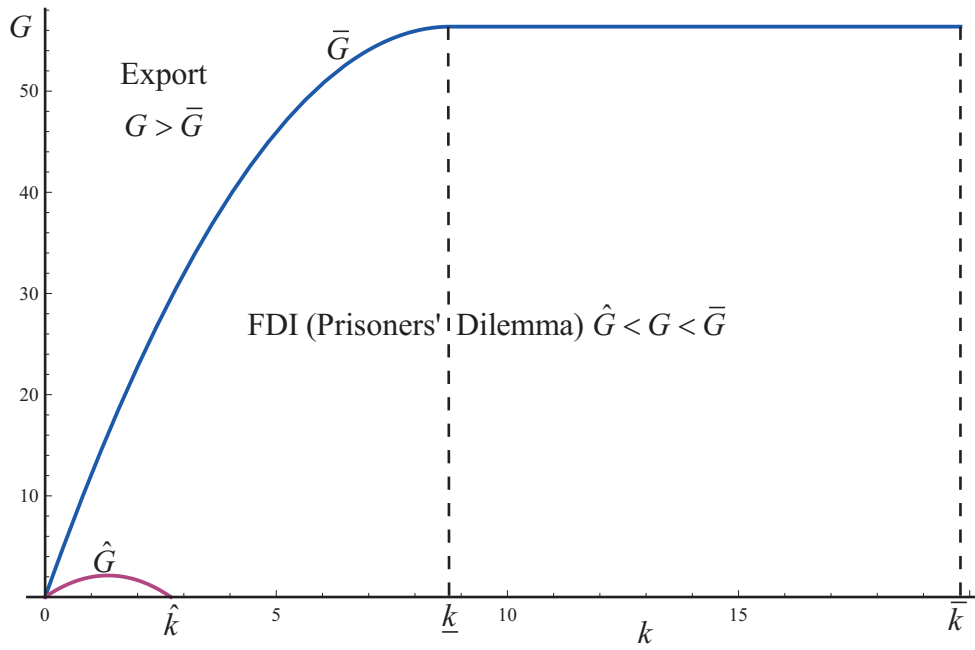
Figure 5a: Static Game under Bertrand Duopoly $\left(\phi = 9/10\right)$
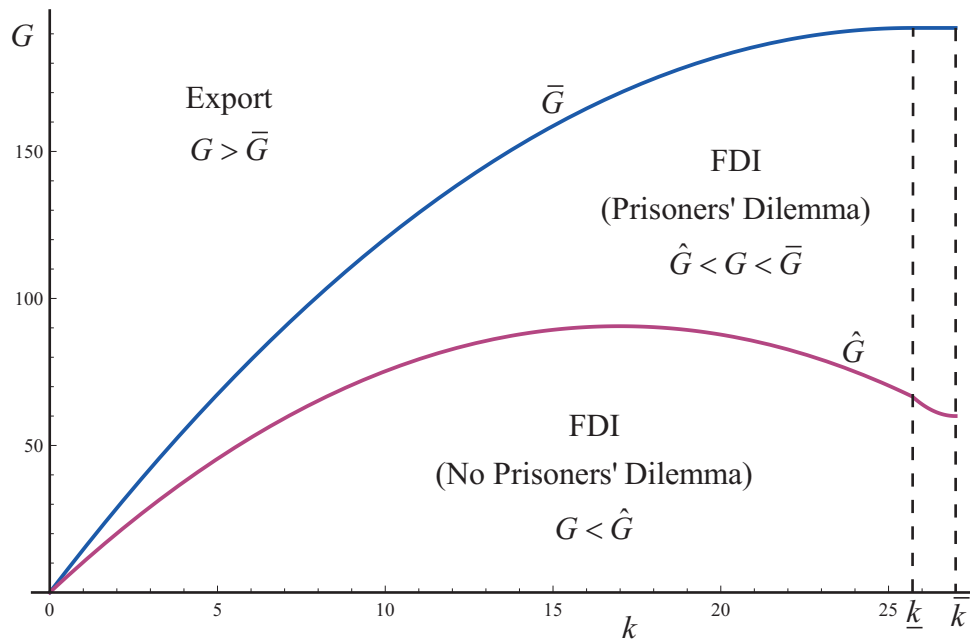
Figure 5b: Static Game under Bertrand Duopoly $\left(\phi = 1/2\right)$
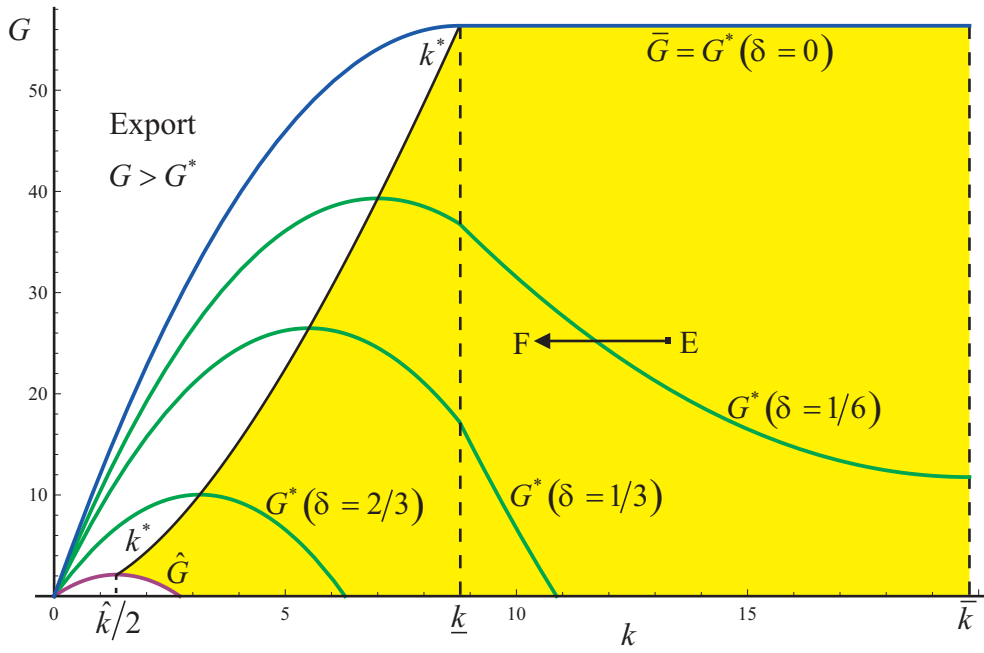
Figure 6a: Infinitely-Repeated Game under Bertrand Duopoly $\left(\phi = 9/10\right)$
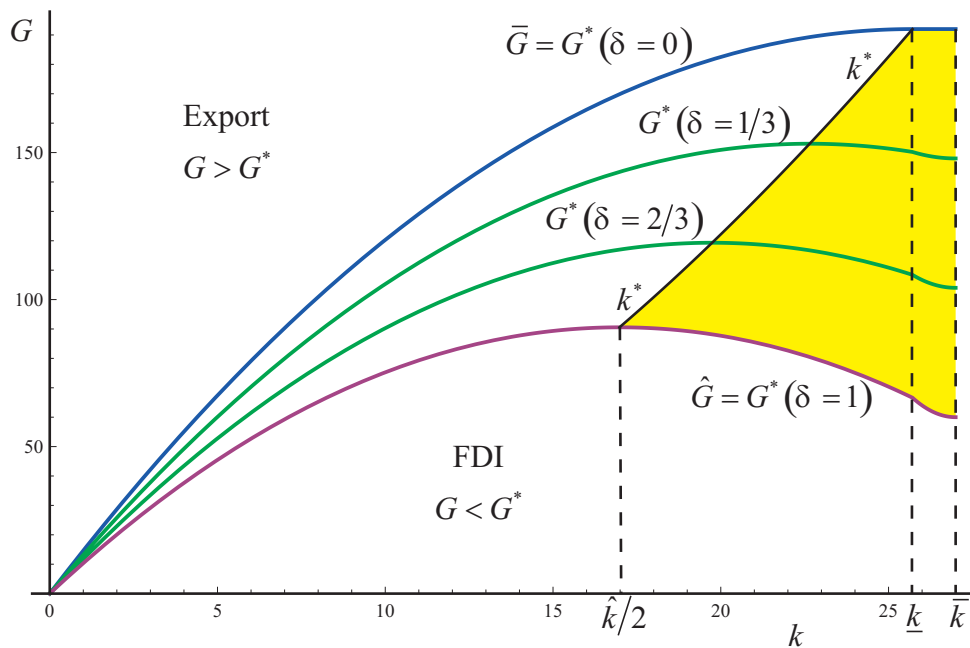
Figure 6b: Infinitely-Repeated Game under Bertrand Duopoly $\left(\phi = 1/2\right)$
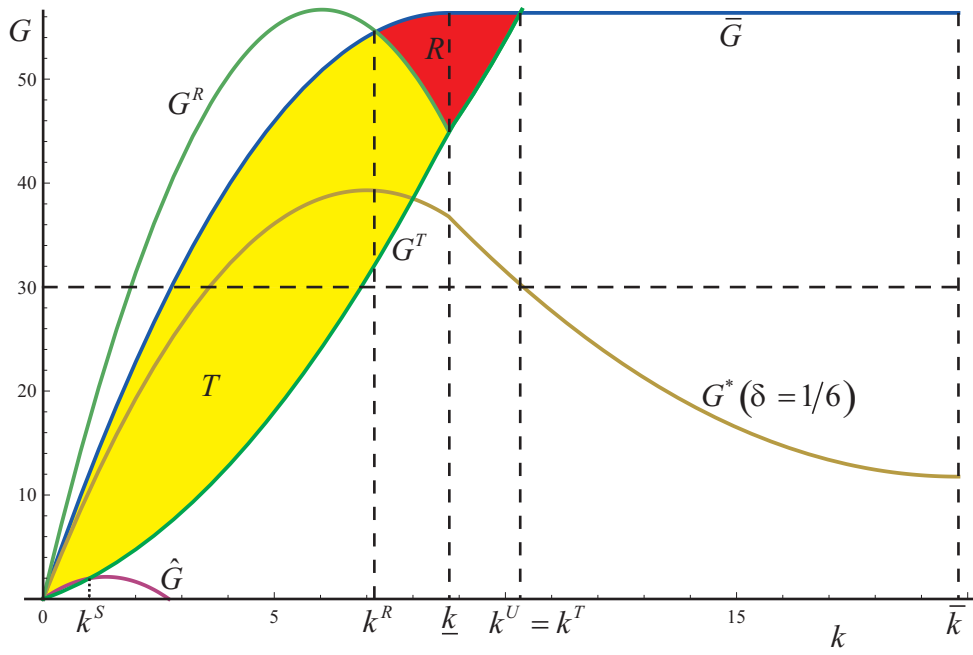
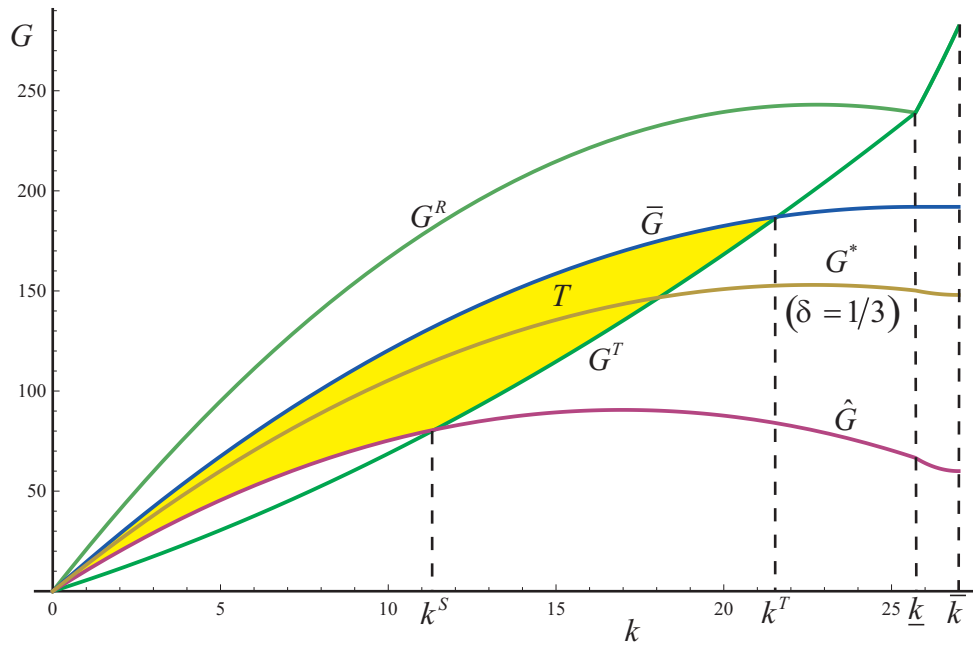Figure 7a: Welfare Effects of Collusion under Bertrand Duopoly $\left(\phi = 9/10\right)$

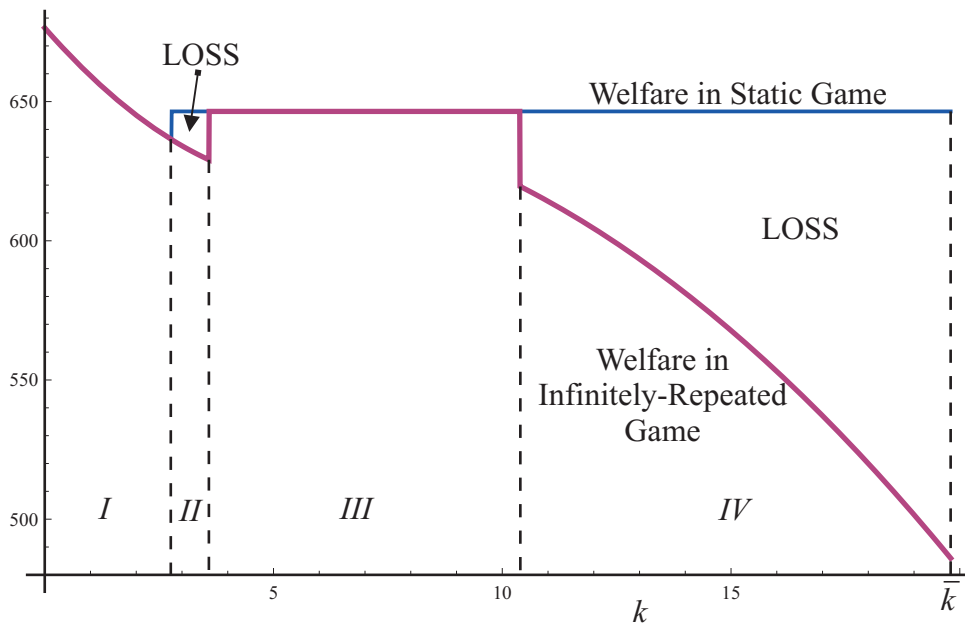Figure 7b: Welfare Effects of Collusion under Bertrand Duopoly $\left(\phi = 1/2\right)$

Figure 8a: Transport Costs and Welfare $\left(\phi = 9/10, \delta = 1/6, G = 30\right)$
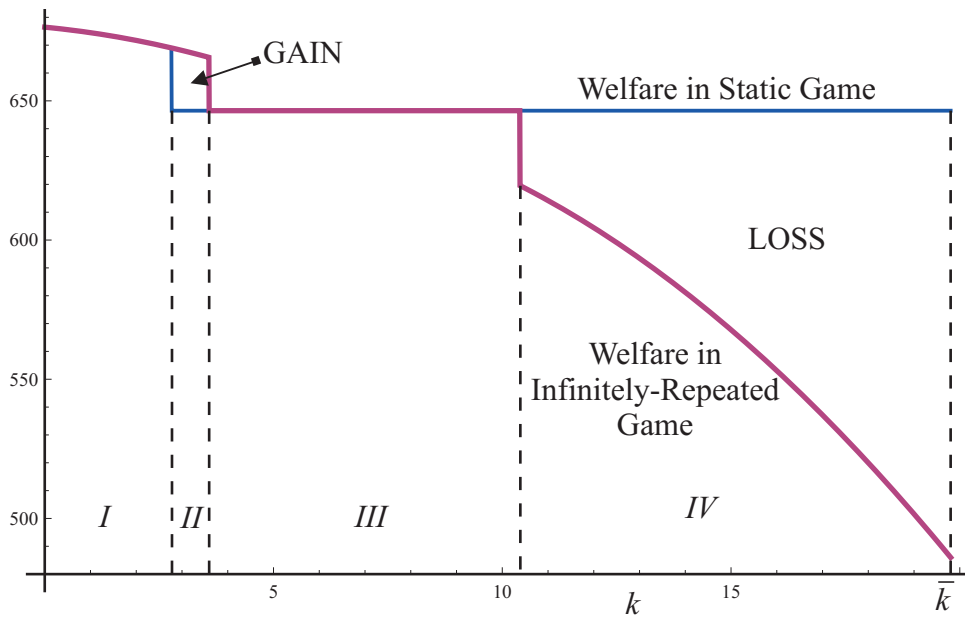

Figure 8b: Tariffs and Welfare $\left(\phi = 9/10, \delta = 1/6, G = 30\right)$