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TACIT COLLUSION UNDER DESTINATION- AND ORIGIN-BASED COMMODITY TAXATION

Andreas Haufler
Guttorm Schjelderup*

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CESifo
Poschingerstr. 5
81679 Munich
Germany
Phone: +49 (89) 9224-1410/1425
Fax: +49 (89) 9224-1409
http://www.CESifo.de

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Abstract

The paper employs a standard model of dynamic price competition to study how international principles of value-added taxation affect the stability of collusive agreements when producers in an international duopoly agree not to export into each others's home market and tax rates differ across countries. In this framework, tacit collusion may be more likely to break up under either the destination or the origin principle, depending on the relation between costs of production and market size. A robust result is that tax rate harmonization increases the likelihood of tacit collusion under both tax principles considered.

Keywords: Commodity taxation, dynamic price competition

JEL Classification: H7, L1

Andreas Haufler
Department of Economics
University of Göttingen and CESifo
Platz der Göttinger Sieben 3
37073 Göttingen
Germany
e-mail: ahaufle@uni-goettingen.de

Guttorm Schjelderup
Institute of Economics
Norwegian School of Economics and Business Administration and CESifo
Helleveien 30
5045 Bergen-Sandviken
Norway
e-mail: Guttorm.Schjelderup@nhh.no

1 Introduction

The completion of the European Union's internal market has had the explicit aim of fostering competition and efficiency in the Union (see Smith and Venables, 1988). At the same time the abolition of internal border controls has profound implications for indirect taxation by EU member states since the conventional administration of the destination principle with border tax adjustments is no longer possible. In general, these complications for value-added taxation in the European Union were seen as the price that was to be paid for the improved working of goods and services markets. The solution found for value-added taxation in the EU was to leave the destination principle in place for transactions between registered traders, whereas cross-border purchases by final consumers are taxed in the country of origin. This, however, turns the current scheme of value added taxation in Europe into a hybrid between destination and origin taxation and has revived old proposals to tax all intra-Community trade under the origin principle. Furthermore, the EU has agreed on a common minimum rate for value-added taxation (VAT) in order to limit the extent of private cross border shopping, and a complete harmonization of VAT rates is currently under discussion (European Commission, 1996). Given the rapid spread of value-added taxation worldwide (see Cnossen, 1998), these issues also have a policy relevance for other integrating regions, such as the Commonwealth of Independent States, or the MERCOSUR and the ASEAN countries.

The issues of tax rate harmonization and the choice of commodity tax principle have been discussed in two separate strands in the literature, both assuming almost without exception that product markets are perfectly competitive. A first set of papers has shown that the minimum rate strategy pursued in the European Union can be given some welfare-theoretic justification under both cooperative and non-cooperative tax setting. In the absence of strategic behaviour on the part of governments an approximation of tax rates aligns relative prices across countries and thus, depending on the tax principle in operation, either improves exchange or production efficiency (see Keen, 1989; Frenkel, Razin, Sadka, 1991, Ch. 2). When governments set commodity tax rates non-cooperatively, tax rates will be set too low in at least one of the trading countries (Mintz and Tulkens, 1986) and a minimum rate policy will lead to a strict Pareto improvement when revenue maximization is the policy objective (Kanbur and Keen, 1993).

The second strand in the literature has addressed the issue whether an integrated region like the EU should switch to the origin principle for its internal commodity trade. Given that a pure destination principle is no longer possible in the absence of border controls, a number of writers have argued in favour of a complete switch to the origin principle (see, e.g., Sinn, 1990). This argument is often based on the equivalence between pure origin and destination principles, which holds only if the commodity tax can be levied on all goods at the same rate.[1] However, since important sectors of the economy (banking and insurance, for example) are currently not included in the regular VAT base, a switch from the destination to the origin principle can be expected to have real effects. If markets are perfectly competitive, then – by the production efficiency theorem of Diamond and Mirrlees (1971) – there is a general argument in favour of the destination principle, since it implies that relative price distortions fall on consumer rather than producer prices, and international trade remains based on the principle of comparative advantage.[2]

Only very recently have aspects of imperfect competition been incorporated in the analysis of either tax rate harmonization or the choice of commodity tax principle. Keen and Lahiri (1998) compare the destination and origin principles in a duopoly model where cost structures of the two firms differ. In this setting, they show for a variety of cases under both coordinated and non-coordinated tax setting that the origin principle is likely to dominate from a global efficiency perspective. Keen, Lahiri and Raimondos-Møller (1998) address the issue of tax rate harmonization in a similar framework and show that tax harmonization can be harmful under the origin principle even when it is beneficial under the destination principle. These first findings indicate very clearly that results that have been derived in a framework of perfect competition change substantially when imperfections in product markets are permitted.

These analyses of imperfect competition take the duopolistic market structure as given and the authors do not link the issue of value-added taxation to the European Union's goal of fostering competition between firms in the internal market. This is

[1]For recent overviews of the conditions under which the destination and origin principles are equivalent, see Lockwood (1994) and Genser, Haufler and Sørensen (1995).

[2]Note, however, that the production efficiency theorem only ranks the destination and the origin principle in terms of the achievable world welfare under coordinated tax setting. When taxes are set non-cooperatively (and perfect competition prevails in goods markets) neither of the two tax principles Pareto dominates the other (see Lockwood, 1993).

where the present paper attempts to go one step further by analyzing the interaction between commodity taxation and market structure. The fundamental idea is that the taxation of intra-Community trade and services may in fact be used to support the process of market liberalization and enforce more competitive pricing strategies on the part of firms. More specifically, our analysis focuses on the effects that the choice of a commodity tax principle on the one hand, and a policy of tax rate harmonization on the other, have on the likelihood that a collusive agreement between monopolists in different national markets breaks up.

The importance of implicit collusion in an international framework – which involves cooperation both within a country and across national boundaries – is documented in a number of empirical studies. Slade (1995) studies 10 industries and finds empirical evidence for collusion in all but one of these industries. Strong evidence for international collusion is found in industries such as diamonds, wood pulp, uranium yellowcake, canadian potash, and cement (see also Scherer, 1996). Detailed evidence for semicollusion in the Norwegian cement market has recently been presented by Steen and Sørgard (1999). The political importance of collusion is also witnessed by the many allegations of collusion at an international level, only some of which are taken to court.[3] These cases also reveal the difficulty of addressing collusion by means of conventional competition policy. The reason is that firms seldom go into explicit contractual agreements over price or quantity fixing, but instead rely on secret talks or signalling games in the market. These indirect ways of forming collusive agreements imply that public prosecutors must rely on circumstancial evidence, which is often insufficient as a basis for allegations.

Against this background, the present paper uses a standard model of dynamic price competition and tacit collusion, borrowed from the industrial organization literature (see Tirole, 1988, Chapter 6, for an introduction). The theory of repeated games has meanwhile been applied to a number of international policy contexts, including the 'reciprocal dumping' model of trade (Pinto, 1986), the comparison between tariffs and quotas (Rotemberg and Saloner, 1989), the effects of trade lib-

[3]As a recent example, the competitive regulatory agencies in Denmark, Norway and Sweden have taken coordinated action in bringing to court firms in the plastic pipe and electronics industry for cooperating within national boundaries as well as colluding internationally by creating exclusive national territories. Similar coordinated actions have also been undertaken within the EU in the same industries (see Berlingske Tidende, 7 February, 1999, p.1 and economy section of the same issue).

eralization (Lommerud and Sørgard, 1998), the response of national price levels to exchange rate fluctuations (Froot and Klemperer, 1989) and the comparison between different exchange rate regimes (Meckl, 1996). However, we are not aware that this approach has so far been applied to issues of international taxation.

In our two-country, two-firm model, the national product markets are of equal size and the costs of production for both firms are equal. The only asymmetry thus derives from exogenous differences in national VAT rates in the home countries of the two firms. In this framework, we obtain the following results. First, whether a collusive agreement is more likely to break up under the destination or the origin principle cannot be answered in general, but depends on the relative size of costs of production on the hand and market size on the other. However, in the special case where costs of production are zero we obtain the sharp result that a collusive agreement is always less stable if commodity taxation follows the destination principle. Second, under both the destination and the origin principle a harmonization of tax rates - interpreted as a mandatory tax increase in the low-tax country – is harmful, in the sense that it stabilizes the socially undesirable secret cartel. It is worth emphasizing that all these results are robust with respect to the choice of price (Bertrand) versus quantity (Cournot) competition between firms.

The remainder of the paper is set up as follows. In Section 2 we present the model of dynamic price competition as it applies in our context. Section 3 then discusses the stability of collusive arrangements under the destination principle, considering both price and quantity competition between firms. Section 4 performs the same analysis for the origin principle. Section 5 compares and summarizes our results with respect to both the choice of tax principle and the harmonization of tax rates. Section 6 concludes.

2 The analytical framework

We follow the standard set-up of infinitely repeated games and consider two firms, labelled by $i \in \{1, 2\}$ and located in country 1 and 2, respectively. The two firms produce amounts x_i of an identical and homogenous good. Our analysis is partial equilibrium in the sense that we focus on the imperfectly competitive market (or the two national markets) for good x. Implicitly there is an untaxed, tradeable numeraire good in the background which ensures that taxes have an effect on relative prices.

In our international framework, tacit collusion between the two firms implies that both firms refrain from exporting and each firm is thus a monopolist in its home market. In each period, either firm may find it profitable to defect from this implicit agreement and export to the other market, but it knows that this action will cause future retaliation by the other firm. It is well known that there are a large number of equilibria in this type of repeated game and we assume, as is usual in the literature, that the Pareto optimal equilibrium from the viewpoint of the two firms will be realized in equilibrium (see Tirole, 1988, p. 247).

It is a standard result under this set of assumptions that if firm i defects at all, it will do so in the first period ($t = 0$). If firm i deviates from the cartel solution at $t = 0$ and exports to country j, it will in this period catch firm j by surprise. We call this the *deviation phase* of the game. In the following period(s), however, firm j retaliates by exporting to market i. This is the *punishment phase* of the game. As in most of the policy-oriented literature on repeated games, we assume a *trigger strategy* which implies that firm j will retaliate by exporting to market i in *all* subsequent periods.[4] Hence, if one of the firms defects in period $t = 0$, then duopoly competition will prevail in both markets in $t = 1, 2, ...\infty$. Finally, in line with the assumption that governments cannot effectively 'control' the imperfectly competitive market for good x, we assume that national markets are segmented, i.e., different producer prices can be set in the two national markets under both monopolistic and duopolistic market structures.

In the following, we denote by π_i^M the profits of firm i if it acts as a monopolist in its domestic market, π_i^E are the extra profits in period 0 when the firm defects and exports into the other market, and π_i^D are the total duopoly profits (earned in both markets together) of firm i under mutual export competition. Denoting by δ_i

[4]It is shown in Abreu (1986) and Fudenberg and Maskin (1986) that the trigger strategy is subgame perfect. Lommerud and Sørgard (1998) also analyze a stick-and-carrot strategy where punishment is confined to a limited number of periods. They argue, however, that an attractive feature of the trigger strategy is that it is easy to signal in a setting of tacit collusion, where formal contracts cannot be written. Moreover, the results of Fudenberg and Maskin (1986) imply that if policies have asymmetric effects on players, then the choice of punishment scheme does not qualitatively affect the results, as long as all schemes are symmetric. Since the difference in how the two tax principles work is crucial in our model, the results will be robust to other symmetric strategy specifications, for example a two-phase optimal punishment path (Abreu, 1986, 1988), or renegotiation-proof strategies (Farrell and Maskin, 1989).

the discount factor of firm i ($0 < \delta_i < 1$), defection from the cartel solution will be unprofitable when

$$\frac{\pi_i^M}{1-\delta_i} \geq (\pi_i^M + \pi_i^E) + \left(\frac{\delta_i}{1-\delta_i}\right)\pi_i^D \qquad \forall\, i \in \{1,2\},$$

where we have used the summation rules for infinite series starting at time $t = 0$ and $t = 1$, respectively. The LHS of this inequality gives the discounted sum of monopoly profits in all periods whereas the RHS gives total profits in the defection period 0 (the sum of domestic monopoly profits and profits in the export market) and duopoly profits in both markets thereafter.

Competitive conditions for the two firms are asymmetric in our model due to the assumption of different national tax rates. Hence, it is possible that $\pi_i^M < \pi_i^D$ for one of the two firms. Of course, it will then always be profitable for this firm to leave the collusive agreement, since it will gain not only in the deviation phase but also in the punishment phase of the game. Since we focus only on conditions under which tax policy affects the stability of collusive arrangements, we disregard these cases in the following and assume that $\pi_i^M > \pi_i^D$ holds throughout the analysis. The above inequality can then be rearranged to give the following "stability condition" for the collusive agreement:

$$\theta_i \geq \bar{\theta}_i^{k,m} = \frac{\pi_i^E}{\pi_i^M - \pi_i^D} \qquad \forall\, i \in \{1,2\}. \tag{1}$$

Here, we have introduced $\theta_i \equiv \delta_i/(1-\delta_i)$ as the relative discount factor of firm i, and $\bar{\theta}_i^{k,m}$ denotes the critical value of this factor that just leaves the firm indifferent between staying in the secret cartel and defecting. These critical values depend on both the nature of competition (Bertrand or Cournot, $k \in \{B, C\}$) and the tax principle in operation (destination or origin principle, $m \in \{DP, OP\}$).

Since the gains from defecting accrue in $t = 0$, but the losses due to export competition are felt only later, it is intuitive that the cartel will be more stable, the higher are the firms' relative discount factors θ_i (i.e., the closer the absolute discount factor δ_i is to its maximum value of unity). We will assume in the following that the relative discount factor is the same for both firms ($\theta_1 = \theta_2 = \theta$), an obvious interpretation being that both firms calculate their discount factor from the common market interest rate.[5] The critical values $\bar{\theta}_i$ will, however, differ between the two firms

[5]The important simplifying assumptions underlying our specification are that the discount

when the profit terms in eq. (1) differ because of an underlying asymmetry. The firm with the higher critical value of $\bar{\theta}_i$ will then be the one which is more likely to break the collusive arrangement and hence it is this firm's $\bar{\theta}_i$ that is binding for the stability of the secret cartel.[6] In the following analysis we thus focus on the comparison of the binding critical values of $\bar{\theta}_i$ under different tax principles and different behavioural assumptions concerning duopoly competition. The implication is that the higher is $\bar{\theta}_i$ under a given scenario, the lower is the likelihood that the collusive agreement will be stable, in the sense that only a smaller range of (common) relative discount factors θ sustains the cartel solution.

We introduce ad valorem taxes t_i that each country levies on good x. The focus on ad valorem taxes is motivated by the fact that we are concerned here with value-added taxation.[7] The ad valorem tax rates t_i remain exogenous in our analysis and, importantly, generally differ between countries. Throughout the paper, and without loss of generality, we adopt the convention that country 1 is the high tax country and $t_1 \geq t_2$. Finally, to isolate the role of differences in tax rates, we confine the analysis to the case where both firms incur the same constant marginal cost c per unit produced, and markets in both countries are of equal size.

Before we turn to the separate analyses of the destination and origin principles, we can compute each firm's monopoly profits π_i^M. These are unaffected by the international tax principle in operation because with two monopolies each serving the domestic market only, there is no trade in good x between the two countries. We assume that demand functions in both markets are linear and given by $x_i = a - q_i = a - (1 + t_i)\, p_i$. The parameter $a > 0$ denotes maximum sales at a price of zero and is thus an indicator of market size. Consumer and producer prices

factors are common knowledge and that they are time-invariant. See Martin (1993, ch. 5) for a discussion of the additional effects introduced by discount factors that vary across periods.

[6]If firm j has the higher critical value of $\bar{\theta}$, then firm i ($i \neq j$) could improve the stability of the collusive agreement by offering firm j a new contract (for example a fifty-fifty split of the two markets). Such market sharing, however, poses a problem since it is difficult to detect breach of the agreement. The cost of monitoring, therefore, provides cartels with an incentive to set up exclusive territories, thereby making it easier to detect defection (see Marvel 1982, and Tirole 1988, pp. 183 and 185).

[7]It is well known that, in contrast to the competitive case, specific and ad valorem taxation are not equivalent under imperfect competition. Venables (1986) and, in more detail, Delipalla and Keen (1992) show that ad valorem taxes lead to lower consumer prices and profits in the oligopoly equilibrium than specific taxes.

are denoted by q_i and p_i respectively, and t_i are (country-specific) ad valorem taxes. Introducing common per unit-costs c for both firms, profits in market i are given by

$$\pi_i = p_i x_i - c x_i = (p_i - c)\left[a - p_i (1 + t_i)\right] \qquad \forall\, i \in \{1, 2\}. \tag{2}$$

The monopoly problem can be solved by choosing either the producer price p_i or the quantity sold x_i. In both cases it is straightforward to show that the solution to the maximization problem yields

$$p_i = \frac{1}{2}\left[\frac{a}{(1+t_i)} + c\right], \qquad q_i = \frac{1}{2}\left[a + c\,(1+t_i)\right], \qquad x_i = \frac{a - c\,(1+t_i)}{2} \quad \forall\, i. \tag{3}$$

For positive costs of production, our model implies that taxes are partly shifted into consumer prices, and partly fall on producers. Note, however, that in the special case of zero costs the commodity tax is fully shifted backwards into producer prices and effectively becomes a pure profit tax.

The prices and quantities given by (3) yield monopoly profits of

$$\pi_i^M = \frac{\alpha_i^2}{4\,(1+t_i)} \qquad \forall\, i \in \{1, 2\}, \tag{4}$$

where

$$\alpha_i \equiv a - (1+t_i)\,c > 0 \quad \forall\, i \in \{1, 2\} \tag{5}$$

must be positive for positive sales in country i [see eq. (3)].

It is immediately seen from (4) and (5) that monopoly profits are lower in the high-tax market, given our assumption of identical market size parameters a. This model implication will turn out to be important in what follows.

In the following we derive explicit expressions for the remaining profit terms in eq. (1), i.e., exporting profits π_i^E and duopoly profits π_i^D. These terms depend on both the tax principle in operation and the nature of duopoly competition.

3 The destination principle

Under the destination principle commodity taxes are levied in the country where the good is consumed. This implies that firms located in countries with different commodity tax rates will nevertheless compete in each market on an equal tax footing. We first compute exporting and duopoly profits when price is the strategic variable (Bertrand competition), and then turn to the case of quantity (Cournot) competition.

3.1 Bertrand competition

If firm i deviates from the cartel solution and exports to market j ($j \neq i$), firm j is initially unaware of the breach of agreement. Firm j will therefore continue to set its monopoly price as given by eq. (3). Under price competition, this implies that firm i can capture the whole market in country j by slightly undercutting this price. Since firm i's exports are taxed at the rate t_j under the destination principle, firm i's exporting profits will be (marginally below) the monopoly profits in market j. Hence,

$$\pi_i^{E\,(B,DP)} = \frac{\alpha_j^2}{4(1+t_j)} \qquad \forall\, i, j,\ i \neq j\,, \tag{6}$$

where α_j is given in (5).

When firm j observes that firm i has defected from the cartel, it will respond by exporting to market i and there will then be export competition in both markets. Differences in tax rates do not affect the symmetric cost structure of the two firms under the destination principle. Therefore, price competition means that, in equilibrium, both firms set producer prices equal to marginal costs and profits in the price duopoly are

$$\pi_i^{D\,(B,DP)} = 0 \qquad \forall\, i \in \{1,2\}. \tag{7}$$

We can now substitute (4), (6) and (7) into (1). The critical discount factor, at which firm i is indifferent between defecting and remaining in the secret cartel, is

$$\bar{\theta}_i^{B,DP} = \frac{(1+t_i)}{(1+t_j)} \frac{\alpha_j^2}{\alpha_i^2} \qquad \forall\, i, j,\ i \neq j\,. \tag{8}$$

Given our convention that country 1 is the high tax country, it is immediately seen from (8) that the critical value of firm 1, $\bar{\theta}_1^{B,DP}$, is the higher one.[8] Intuitively it is the firm in the high-tax country 1 which has the greater incentive to defect from the cartel because its gains from defecting are given by the (one-period) monopoly profits in the relatively profitable (low-tax) market 2 while the losses occur in the less profitable home market 1. Hence, $\bar{\theta}_1^{B,DP}$ will be the binding critical value that limits the range of discount factors supporting the secret cartel under the destination principle and Bertrand competition.

[8]Note that for equal tax rates ($t_1 = t_2$), equation (8) reduces to $\bar{\theta} = 1$; from the definition $\theta \equiv \delta/(1-\delta)$ this implies a critical absolute discount factor of $\delta = 1/2$. This reproduces a standard result in symmetric models of repeated price competition (see Tirole, 1988, p. 246).

3.2 Cournot competition

When quantity is the strategic variable and firm i defects from the collusive arrangement, then it will be impossible for this firm to capture the entire export market j. In the case of two suppliers to one market we have to extend the aggregate demand function to get

$$x_j^i + x_j^j = a - q_j \qquad \forall\, i, j,\ i \neq j, \tag{9}$$

where the superscript denotes the supply of firms i, j and the subscript refers to market j. It is easily derived that firm i's profit maximum must generally lie on the reaction curve

$$x_j^i = \frac{\alpha_j - x_j^j}{2} \qquad \forall\, i, j,\ i \neq j. \tag{10}$$

In period 0 firm j will now fix its monopoly *quantity* of $x_j^j = \alpha_j/2$ [see eq. (3)]. Firm i takes this quantity as given and chooses the profit-maximizing supply in its export market from (10); this yields $x_j^i = \alpha_j/4$. Using the aggregate demand function (9), the profit expression (2) and $p_i = q_j/(1+t_j)$ under the destination principle gives exporting profits equal to

$$\pi_i^{E\,(C,DP)} = \frac{\alpha_j^2}{16(1+t_j)} \qquad \forall\, i, j,\ i \neq j\ . \tag{11}$$

Comparing (11) with eq. (6), it is obvious that the maximum profits that can be earned in the deviation phase are reduced under the assumption of quantity competition. However, profits in the duopoly equilibrium also depend on the nature of competition. From the two reaction functions given in (10), the symmetric Cournot equilibrium quantity chosen by each firm in each market is $\alpha_j/3$. Hence total duopoly profits for firm i, aggregated over both markets, are

$$\pi_i^{D\,(C,DP)} = \frac{\alpha_i^2}{9\,(1+t_i)} + \frac{\alpha_j^2}{9\,(1+t_j)} \qquad \forall\, i, j,\ i \neq j\ . \tag{12}$$

Using (4), (11) and (12) in (1), the critical discount factor for firm i is

$$\bar{\theta}_i^{C,DP} = \frac{9\,(1+t_i)\ \alpha_j^2}{4\left[5\,(1+t_j)\ \alpha_i^2 - 4\,(1+t_i)\,\alpha_j^2\right]} \qquad \forall\, i, j,\ i \neq j\ . \tag{13}$$

Again it is easily deduced from (13) that it is the firm in the high-tax country 1 which has the higher critical value of $\bar{\theta}$, and is thus more likely to defect from the secret cartel. The intuition is the same as in the case of Bertrand competition. Under the destination principle, the relative competitiveness of the two firms is unaffected by commodity tax differentials. Any tax asymmetry ($t_i \neq t_j$), however, will affect the relative attractiveness of the two national markets and the firm in the high-tax country will gain more (and lose less) from defecting, as compared to the firm located in the low-tax region.

Finally, recall our assumption that monopoly profits of each firm must always exceed duopoly profits, and hence the denominator in (13) must be positive. This implies a set of restrictions on the values of the exogenous parameters (a, c, t_1, t_2) that will prove useful in the following. In particular, $\bar{\theta}_1^{C,DP} > 0$ is sufficient (but not necessary) to ensure that the following inequalities are met:[9]

$$(1 + t_2) - 4\,(t_1 - t_2) > 0, \tag{14}$$

$$\alpha_1 - 4c\,(t_1 - t_2) > 0. \tag{15}$$

Condition (14) restricts tax rates in the two countries to be "not too different" and condition (15) states that market size must be sufficiently large, relative to unit costs, in order to ensure that the model is well behaved.

4 The origin principle

Under the origin principle, commodities are taxed in the country of production, but are exempted from tax in the importing country. Hence tax differentials now affect the relative competitiveness of the two firms in each market.

4.1 Bertrand competition

If firm i defects from the cartel and exports to market j it can again capture the entire market by slightly undercutting firm j. The difference to the previous section is that firm i will now base its pricing decision on the monopoly *consumer* price charged by firm j which, from equation (3), is equal to $[a + c(1 + t_j)]/2$. Given that the tax rate applicable to firm i's sales to market j is t_i, the maximum producer price that firm i can charge is $[a + (1 + t_j)\,c]/[2\,(1 + t_i)]$. From (3), demand in country j

[9] Condition (14) follows from $5(1+t_2) - 4(1+t_1)$ and condition (15) is derived from $5\alpha_1 - 4\alpha_2$, using $\alpha_1 - \alpha_2 = -c(t_1 - t_2)$ from (5). Since $\alpha_1 < \alpha_2$ and $t_1 > t_2$ these conditions are weaker than the assumption that $\bar{\theta}_1^{C,DP} > 0$, and hence are necessarily fulfilled if this assumption is met.

is $\alpha_j/2$. Hence, using (5), maximum profits from exporting are equal to

$$\pi_i^{E\,(B,OP)} = \frac{[\alpha_i + c\,(t_j - t_i)]\,\alpha_j}{4(1+t_i)} \qquad \forall\, i, j,\ i \neq j\,. \tag{16}$$

In contrast to eq. (6) it is now the tax rate in the defecting firm's home country, rather than the tax rate in the foreign market, which determines the profitability of exporting. In the duopoly equilibrium, the high-tax firm 1 sets price equal to marginal cost and makes zero profits. This implies consumer prices of $c(1+t_1)$ in both markets and allows the low-tax firm 2 to charge a producer price of $c(1+t_1)/(1+t_2)$, leaving a profit margin of $c\,(t_1-t_2)/(1+t_2)$ per unit of output sold in either market. Since, for a consumer price of $c\,(1+t_1)$, demand is $\alpha_1/2$ in *each* of the two markets, duopoly profits for the two firms are given by

$$\pi_1^{D\,(B,OP)} = 0, \qquad \pi_2^{D\,(B,OP)} = \frac{c\,(t_1 - t_2)\,\alpha_1}{(1+t_2)}. \tag{17}$$

Note from eq. (17) that the tax advantage for firm 2 disappears when producer prices are zero. Since zero is the Bertrand equilibrium price in the absence of production costs, tax differentials are then immaterial in the duopoly equilibrium.

Substituting (4), (16) and (17) into (1) gives critical values of $\bar{\theta}$ that differ for the two firms

$$\bar{\theta}_1^{B,OP} = \frac{[\alpha_1 - c\,(t_1 - t_2)]\,\alpha_2}{\alpha_1^2}$$

$$\bar{\theta}_2^{B,OP} = \frac{[\alpha_2 + c\,(t_1 - t_2)]\,\alpha_1}{\alpha_2^2 - 4c\,(t_1 - t_2)\,\alpha_1}\,. \tag{18}$$

It is not immediately obvious in this case which firm is more likely to defect. Comparing the numerators for $\bar{\theta}_1^{B,OP}$ and $\bar{\theta}_2^{B,OP}$ in (18) the latter is unambiguously larger since the low-tax firm 2 has the higher gains from exporting to the other market. The comparison of the denominators is ambiguous, however, since firm 2 retains some positive profits in the non-cooperative duopoly equilibrium, but it also gives up a higher level of monopoly profits [eq. (4)]. It is shown in Appendix A that firm 1 incurs the higher net loss from defecting (i.e., the denominator is larger in $\bar{\theta}_1^{B,OP}$). Hence, $\bar{\theta}_2^{B,OP} > \bar{\theta}_1^{B,OP}$ holds without ambiguity and it is the firm in the low-tax country 2 which imposes the binding constraint on the stability of the collusive agreement under the origin principle and Bertrand competition.

4.2 Cournot competition

If firm i defects under Cournot competition, it will set its export supply x_j^i knowing that firm j sells $x_j^j = \alpha_j/2$ from (3). In contrast to the destination principle, firm i's reaction curve [cf. eq. (10)] now includes the tax rate of its home country i and is given by $x_j^i = (\alpha_i - x_j^j)/2$. Substituting x_j^j from above yields firm i's optimal output $x_j^i = [\alpha_i + c(t_j - t_i)]/4$. From (9), the consumer price in market j is then $q_i = [a + c(1 + t_j) + 2c(1 + t_i)]/4$ and the producer price that firm i can charge is $p_i = q_j/(1 + t_i)$. This gives profits in the deviation phase equal to

$$\pi_i^{E\,(C,OP)} = \frac{[\alpha_i + c\,(t_j - t_i)]^2}{16(1 + t_i)} \qquad \forall\, i, j,\; i \neq j\,. \tag{19}$$

In the non-cooperative phase, the Cournot equilibrium quantity supplied by firm i is, by the same argument as above, $x_i = [\alpha_i + c(t_j - t_i)]/3$, implying identical consumer prices in both markets equal to $q = [a + c(1 + t_1) + c(1 + t_2)]/3$. Noting again that the producer price obtained by firm i depends on the domestic tax rate t_i, firm i earns total duopoly profits (in both markets together) of

$$\pi_i^{D\,(C,OP)} = \frac{2\,[\alpha_i + c\,(t_j - t_i)]^2}{9(1 + t_i)} \qquad \forall\, i, j,\; i \neq j\,. \tag{20}$$

In the same way as before, we substitute (19), (20) and (4) into (1) to derive the critical discount factor of firm i in this case. This is

$$\bar{\theta}_i^{C,OP} = \frac{9\,[\alpha_i + c\,(t_j - t_i)]^2}{4\left(9\alpha_i^2 - 8\,[\alpha_i + c\,(t_j - t_i)]^2\right)}\,. \tag{21}$$

Appendix A shows that, as under price competition, the critical value of firm 2 is the higher one, and this country's $\bar{\theta}$ is binding for the stability of collusion. The intuition for this result is the same as before: the firm located in the low-tax country 2 has the higher gain from defecting in period 0 and the lower net loss in subsequent periods. Hence, under the origin principle, it is always the more competitive firm 2 that is more likely to break the collusive agreement.

5 Comparison of results

It is now time to summarize and compare the results of our analysis in the previous sections. Table 1 collects the critical levels of $\bar{\theta}_i^{k,m}$ under the destination and the

Table 1: Critical values of $\bar{\theta}_i^{k,m}$

$\bar{\theta}_i^{k,m}$	Destination Principle $\left(\bar{\theta}_1\right)$	Origin Principle $\left(\bar{\theta}_2\right)$
Bertrand	$\frac{(1+t_1)}{(1+t_2)}\frac{\alpha_2^2}{\alpha_1^2}$	$\frac{\left[\alpha_2 + c\left(t_1 - t_2\right)\right]\ \alpha_1}{\alpha_2^2 - 4c\left(t_1 - t_2\right)\alpha_1}$
Cournot	$\frac{9\left(1+t_1\right)\alpha_2^2}{4\left[5\left(1+t_2\right)\alpha_1^2 - 4\left(1+t_1\right)\alpha_2^2\right]}$	$\frac{9\left[\alpha_2 + c\left(t_1 - t_2\right)\right]^2}{4\left(9\alpha_2^2 - 8\left[\alpha_2 + c\left(t_1 - t_2\right)\right]^2\right)}$

where $\alpha_i = \left[a - \left(1+t_i\right)c\right]$ and $\alpha_1 < \alpha_2$

origin principle, and for both Bertrand and Cournot competition [eqs. (8), (13), (18) and (21)]. As previously stated, it is the firm in the high-tax country (country 1, by convention) that is more likely to leave the collusive agreement under the destination principle, whereas under the origin principle, the critical value of firm 2 is the relevant one. Finally, recall our assumption that all entries in Table 1 are positive, and the implied parameter restrictions (14) and (15).

To interpret the values given in Table 1, it is helpful to first consider the symmetric benchmark case where tax rates are equal in both countries ($t_1 = t_2$ and hence $\alpha_1 = \alpha_2$). In this case the critical values of $\bar{\theta}$ for *both* tax principles reduce to 1 under Bertrand competition and to 9/4 under Cournot competition. Two conclusions follow immediately from this special case. First, in the absence of tax differentials the choice of tax principle is immaterial in our framework. Second, tacit collusion is less likely, at least in this symmetric setting, if firms engage in quantity (Cournot) as opposed to price (Bertrand) competition. This result obtains even though the extra profits that can be reaped in the deviation phase from penetrating the other market are generally higher under Bertrand competition (because the defecting firm can capture the entire foreign market). However, in the symmetric scenario, price competition implies that profits in the duopoly equilibrium fall to zero under either the destination or the origin principle. It is this severe effect of competition in the later stages of the game which dominates in equilibrium and "disciplines" the parties, making collusion more likely under price competition.

5.1 Choice of international tax principle

Turning to the implications of our model for tax policy, we first compare the stability of tacit collusion between firms under destination- versus origin-based commodity taxation. This is given in the following proposition.

Proposition 1: *A stable collusive agreement is less likely under the destination principle, as compared to the origin principle, if (i) market size is large and (ii) costs of production are low.*

Proof: This is given in Appendix B for the case of Bertrand competition.[10]

Proposition 1 states that the question whether the origin or the destination principle is more likely to sustain collusive agreements cannot be answered in general. Instead, the results depend on two critical parameters of our model, the unit costs of production c and the market size parameter a. To interpret this result note first that tax differentials generally weaken the stability of the collusive agreement. This is easily seen from Table 1 which shows that the critical values of $\bar{\theta}$ are always at a *minimum* when tax rates are equal. Next, recall from our discussion in sections 3 and 4 that tax differentials have very different effects under the two tax principles. Under the destination principle it is the difference in the profitability of the two markets which is crucial for the incentive to leave the secret cartel. Other things equal, this difference will be magnified when the common market size parameter a is large. Under the origin principle, in contrast, tax differentials change the competitive position of the two firms. Since taxes are levied ad valorem, the absolute cost advantage of the low-tax firm becomes larger when costs of production are high.

It thus follows that the comparison between the critical values of $\bar{\theta}_i^{k,m}$ under the two tax principles will depend on the quantitative magnitudes of two counteracting effects: a large market size parameter a will tend to increase the incentive for the *high-tax firm 1* to defect from the secret cartel, and thus lead to a higher critical value of $\bar{\theta}$ under the destination principle. In contrast, if the cost component c gets large, this increases the incentive for the *low-tax firm 2* to leave the collusive agreement, and thus tends to imply a higher value of $\bar{\theta}$ under the origin principle.

[10]The comparative static analysis used in the proof of Proposition 1 does not yield unambiguous results in the case of Cournot competition. Nevertheless, the simulation results given in Table 2 below suggest that the general statement in Proposition 1 is also true under quantity competition of firms.

Table 2: Numerical comparison of $\bar{\theta}$ for different parameter values

$t_1 = 0.3,\ t_2 = 0.2$

	$\bar{\theta}_1^{B,DP}$	$\bar{\theta}_2^{B,OP}$	$\bar{\theta}_1^{C,DP}$	$\bar{\theta}_2^{C,OP}$
(i) $a = 3,\ c = 0.1$	1.09	1.01	3.86	2.40
(ii) $a = 3,\ c = 0.5$	1.13	1.09	5.29	3.54
(iii) $a = 3,\ c = 1.0$	1.22	1.26	19.26	29.01
(v) $a = 6,\ c = 1.0$	1.13	1.09	5.29	3.54

Table 2 presents the results from some numerical experiments for exogenously chosen tax rates $t_1 = 0.3$ and $t_2 = 0.2$. The simulation results indicate that the statement in Proposition 1 generally applies under either Bertrand or Cournot competition. Under both assumptions concerning the nature of duopoly competition, the destination principle implies the higher critical value of $\bar{\theta}$ if costs of production are relatively low [cases (i) and (ii)]. When c is successively increased the ranking of the two tax principles is reversed [case (iii)], and this switch occurs in a similar parameter range for Bertrand competition on the one hand and Cournot competition on the other.[11] Finally, note from the comparison of cases (ii) and (iv) that doubling both a and c leaves all entries unchanged. Hence it is the relative importance of the cost parameter, in comparison to market size, which determines the results.

A special case of our analysis arises when costs of production are zero in both countries. It is straightforward to show that in this case the comparison between the two tax principles is unambiguous.

Corollary 1: *When costs of production are zero, tacit collusion is less likely under the destination principle, irrespective of the nature of duopoly competition.*

[11] It should be emphasized that changing either the level of tax rates or the tax differential has significant effects on the absolute value of each $\bar{\theta}_i$, but does not critically affect the *difference* between these terms, in which we are interested. Furthermore, note from the comparison of cases (i)–(iii) that, under Bertrand competition, the difference $\bar{\theta}_1^{B,DP} - \bar{\theta}_2^{B,OP}$ is monotonously falling as c is increased. For Cournot competition, however, $\bar{\theta}_1^{C,DP} - \bar{\theta}_2^{C,OP}$ first rises and then falls as c is successively raised. This is the reason why unambiguous comparative static results can be obtained under Bertrand, but not under Cournot competition (cf. footnote 10). Nevertheless, the numerical results in Table 2 indicate that changes in a and c have similar effects under Bertrand and Cournot competition in the parameter range where the switch occurs.

Proof: If $c = 0$, then $\alpha_1 = \alpha_2 = a$. Hence, under Bertrand competition, the entries in Table 1 reduce to $\bar{\theta}_1^{B,DP} = (1 + t_1)/(1 + t_2)$ and $\bar{\theta}^{B,OP} = 1$, where critical values under the origin principle are the same for both firms. Hence, for $t_1 > t_2$, $\bar{\theta}_1^{B,DP} > \bar{\theta}^{B,OP}$. Under Cournot competition, the critical values reduce to $\bar{\theta}_1^{C,DP} = 9(1+t_1)/\{4[5(1+t_2) - 4(1+t_1)]\}$ and $\bar{\theta}^{C,OP} = 9/4$. Since the denominator of $\bar{\theta}_1^{C,DP}$ is positive by assumption, this again implies $\bar{\theta}_1^{C,DP} > \bar{\theta}^{C,OP}$. 2

In comparison to most of the literature on international commodity taxation, Corollary 1 is a surprising and counterintuitive result, since it is usually argued that competition between firms is stronger under the origin principle. In the present setting, however, it turns out that if costs of production are zero, then tax differentials play no role at all under the origin principle. Intuitively, in the absence of production costs, taxes under the origin principle are essentially pure profit taxes [cf. eq. (3)]. The firm in the low-tax country has higher gains from exporting to the other firm's market in the deviation phase, but it also faces higher losses in the punishment phase, because they accrue in its relatively more profitable home market. These effects just compensate each other, implying that tax differentials disappear altogether in the critical values of $\bar{\theta}$ under the origin principle. In contrast, under the destination principle the effects of tax differentials on the gains and losses from defection are mutually reinforcing rather than offsetting. Here, the firm in the high-tax country has more to gain from defecting because it enters the relatively more profitable low-tax market abroad, but the losses in the punishment phase accrue in the relatively less profitable home market.

While we do not carry out an explicit normative analysis in the present paper, a few remarks on the normative implications of our results shall be made here. It is obvious that a stable collusive agreement is undesirable from a social welfare perspective, since it restricts output more, and causes a higher deadweight loss, than if the two firms are engaged in duopoly competition. The difference is particularly visible under Bertrand competition where prices in the duopoly equilibrium are equal to marginal costs and hence are set at the levels that maximize consumer welfare. With Cournot competition, aggregate output in the duopoly equilibrium falls short of the socially optimal level, but it is still unambiguously higher than if both firms act as monopolists in their respective home markets. Therefore, using a simple but conventional welfare measure by adding up consumer surplus, producer profits and tax revenue, a normative interpretation of our results is that we should prefer the tax principle which implies the wider range of discount factors under which duopoly competition will result.

This brief discussion allows to point out the potential contrasts between our results and those of Keen and Lahiri (1998), who argue that the origin principle is the preferred choice in a setting where the market structure is exogenously given by duopoly competition and firms face different cost structures. One core argument in their framework is that national tax rates can be directly targeted at production distortions under the origin, but not under the destination principle. Hence, when tax rates are free to vary internationally, the origin principle – but not the destination principle – is generally able to attain a first-best allocation (Keen and Lahiri, 1998, Proposition 2). In contrast, Proposition 1 above has shown that the comparison between the two tax principles is generally ambiguous in our tacit collusion setting, and a welfare argument in favour of the destination principle can be constructed when costs of production are sufficiently low (Corollary 1). Of course, the nature of our arguments differs from those of Keen and Lahiri, as we focus on induced changes in market structure rather than on production efficiency. Nevertheless our results indicate that the general policy argument in favour of the destination principle that arises from analyses of perfect competition in product markets is not necessarily reversed in the presence of imperfect competition.

Finally, note that our ranking of the destination and the origin principle does not depend on the nature of duopoly competition. This is not a standard result in related analyses that compare the behaviour of firms under price vs. quantity competition. Schjelderup and Sørgard (1997), for example, show that a decentralized multinational sets a transfer price above or below marginal costs, depending on whether strategic interaction with other firms in the market occurs through prices or quantities. Similarly, Lommerud and Sørgard (1998) – in a model of trade liberalization and collusion – find that collusion becomes easier to sustain under Bertrand competition after a reduction in trade costs, while the opposite is true under Cournot competition. In contrast, the strategic incentives faced by the two firms in the present model are qualitatively very similar under price competition on the one hand and quantity competition on the other.

5.2 Tax harmonization

In the following, we interpret tax harmonization as a process where the low-tax country unilaterally increases its VAT rate and thus narrows the tax differential to the high-tax country. This has, for example, been the approach to commodity tax harmonization within the European Union, and it is also a common definition in the literature (see, e.g., Kanbur and Keen, 1993). Hence, we consider the effects of a rise in the tax rate of country 2 (the low-tax country by our convention) on the critical values of $\bar{\theta}_i^{k,m}$, as given in Table 1. The results are summarized in the following proposition:

Proposition 2: *Tax harmonization makes a collusive agreement more likely under both the destination and the origin principle, and for either Bertrand or Cournot competition.*

Proof: See Appendix C.

Proposition 2 is easily understood from our earlier discussion, where we have emphasized that tax differentials are critical in 'destabilizing' the collusive arrangement under both tax principles. Under the destination principle, an increase in t_2 makes exporting into the low-tax country less profitable for the high-tax firm 1, whereas the losses in the punishment phase are unchanged. Hence the incentive to defect is unambiguously reduced. Under the origin principle, an increase in t_2 reduces the competitive advantage that the low-tax firm 2 has, again reducing the gains from exporting. Whether the losses in the punishment phase increase or fall is ambiguous a priori, but we have earlier established that the low-tax country suffers the lower net losses in the punishment phase (see Appendix A). This implies that an increase in t_2 will also raise the losses to firm 2 in the punishment phase, so that the incentive to defect is unambiguously weakened. The only exception under the origin principle arises in the special case of zero costs of production (see Corollary 1). Here the incentive to defect is the same for both firms and is thus not affected by tax rate harmonization.

The robust results summarized in Proposition 2 provide an interesting contrast to the beneficial effects of tax rate harmonization under the assumption of perfect competition in product markets. At a very basic level, tax harmonization aligns either relative consumer prices (under the destination principle) or relative producer prices (under the origin principle), thus improving either international exchange or production efficiency (see, e.g., Frenkel, Razin and Sadka, 1991, ch. 2). For the case of the destination principle, Keen (1989) has furthermore shown that this fundamental argument for an international alignment of tax rates carries over to a second-best setting with many goods and taxes. Keen, Lahiri and Raimondos-Møller (1998) demonstrate that these results must be qualified under the origin principle (but not under the destination principle), if competition is imperfect and firms have different costs of production. In this case, tax harmonization – defined as an approximation of tax rates starting from a non-cooperative Nash equilibrium – is harmful, because it increases the market share of the less efficient firm.[12] In the present setting of tacit collusion, however, the argument against tax harmonization applies equally under the destination principle, and parallels the general case against tax rate harmonization developed in the political economy literature (Brennan and Buchanan, 1980; Siebert and Koop, 1993; see also Edwards and Keen, 1996). In this strand of literature it is usually argued that when governments are not sufficiently disciplined by the political process, then tax competition between governments can play a corrective role that shouldn't be precluded by tax rate agreements. In a similar way, firms behave non-competitively in the present setting of tacit collusion. Tax differentials can correct this market failure by inducing firms to engage in 'exporting wars', and this incentive should not be weakened by an alignment of commodity tax rates between countries.

6 Conclusions

In this paper we have analyzed the effects of alternative commodity tax regimes on the stability of collusive agreements between firms. Such non-competitive behaviour, aimed at maintaining national monopolies, is still present in certain segments of the European industry and the question we have raised here is whether tax policy can help to promote the incentives for firms to leave the collusive arrangement and enter foreign markets. We have asked two distinct questions for tax policy. First, is the destination or the origin principle to be preferred as a means of inducing competition between firms? Second, how is the incentive to leave a secret cartel affected by tax rate harmonization, as currently discussed in the European Union?

[12] A similar argument against tax harmonization under non-cooperative tax setting is also implicit in the analysis of Keen and Lahiri (1998, sec. 5).

The results of our simple model show that the answer to the first of these questions is not clear cut. While first intuition may suggest that the origin principle is more likely to induce firms in low-tax countries to enter foreign markets, our analysis has shown that tax differentials can also have a 'destabilizing' effect on a collusive agreement under the destination principle. In general, tax differentials affect the relative profitability of markets under the destination principle, but the relative profitability of firms under the origin principle. Which of these effects dominates depends on the precise combination of costs of production on the one hand and market size on the other.

Turning to the second policy question, our analysis has led to the unambiguous result that tax harmonization stabilizes socially undesirable secret cartels. This is true under both the destination principle and the origin principle and is intuitively explained by the 'destabilizing' effect that tax differentials have for collusive agreements under both tax principles considered. This result reinforces earlier arguments against tax rate harmonization derived from a political economy perspective and indicates that tax coordination may encourage cartelization not only among governments, but also among firms. If non-competitive behaviour by both governments and firms are seen as relevant features of European economies, then this indeed raises some serious doubts about the medium-term plans of the European Commission to fully harmonize VAT rates in the European Union.

It needs to be stressed, however, that our analysis can at best be seen as a first step in exploring the effects of alternative tax policies on the dynamics of firm interaction in imperfectly competitive markets. Straightforward extensions of our analysis would be to incorporate either differences in market size (unrelated to tax differentials), or differing costs of production for the two firms. In both cases, exogenous tax differentials interact with the additional cost or market size asymmetry.[13] A more fundamental simplification of our model concerns the assumption that tax rates are exogenous. Endogenizing tax rates would allow to analyze the strategic interaction between governments and firms and thus link our framework more closely to the existing literature on tax competition. This is an extension that we hope to do in future work.

[13] The analysis for the case of differences in market size is available from the authors upon request.

Appendix

A. Comparison of $\bar{\theta}_i$ under the origin principle

To show that the low-tax firm 2 will have the higher level of $\bar{\theta}$ under the origin principle, we first consider the case of Bertrand competition. Comparing the numerators (NUM) of the two expressions in (18) gives:

$$NUM\ \left(\bar{\theta}_2^{B,OP}\right) - NUM\ \left(\bar{\theta}_1^{B,OP}\right) = 2ac(t_1 - t_2) + c^2\left[(1+t_2)^2 - (1+t_1)^2\right]$$

$$= 2c(t_1 - t_2)(a - c) - c^2(t_1 - t_2)(t_1 + t_2) = 2c(t_1 - t_2)\left[a - c\left(1 + \frac{t_1 + t_2}{2}\right)\right] > 0,$$

since $t_1 > t_2$ by assumption and the square bracket must be positive for positive sales in both countries [cf. eq. (3)]. Similarly, comparing the denominators (DEN) in equation (18) gives:

$$DEN\ \left(\bar{\theta}_2^{B,OP}\right) - DEN\ \left(\bar{\theta}_1^{B,OP}\right) = \alpha_2^2 - \alpha_1^2 - 4c\,(t_1 - t_2)\,\alpha_1$$

$$= -2ac\,(t_1 - t_2) - c^2\left[(1+t_1)^2 - (1+t_2)^2 - 4(1+t_1)(t_1 - t_2)\right]$$

$$= -2c\,(t_1 - t_2)\left[\alpha_1 - \frac{c}{2}\,(t_1 - t_2)\right] < 0.$$

The squared bracket in this expression is positive from (15). Hence it must be true that $\bar{\theta}_2^{B,OP} > \bar{\theta}_1^{B,OP}$ since it has the larger numerator, but the smaller denominator.

Under Cournot competition, we form the difference $\bar{\theta}_2^{C,OP} - \bar{\theta}_1^{C,OP}$, using the two expressions in (21). Given that negative values in the denominators are excluded by assumption, we get

$$sign\ \left(\bar{\theta}_2^{C,OP} - \bar{\theta}_1^{C,OP}\right) = sign\ (\beta)$$

where

$$\beta = [\alpha_2 + c\,(t_1 - t_2)]^2\left\{9\alpha_1^2 - 8[\alpha_1 - c(t_1 - t_2)]^2\right\}$$
$$-[\alpha_1 - c\,(t_1 - t_2)]^2\left\{9\alpha_2^2 - 8[\alpha_2 + c(t_1 - t_2)]^2\right\}$$

$$= 9\left\{\alpha_1^2[\alpha_2 + c(t_1 - t_2)]^2 - \alpha_2^2[\alpha_1 - c(t_1 - t_2)]^2\right\}$$

$$= 9c(t_1 - t_2)\left\{\alpha_1^2[2\alpha_2 + c(t_1 - t_2)] + \alpha_2^2[2\alpha_1 - c(t_1 - t_2)]\right\} > 0,$$

since the last term must be positive from (15). 2

B. Proof of Proposition 1

To prove Proposition 1 for the case of Bertrand competition, we show that the *difference* in the critical values under the destination and the origin principle is increasing in the market size parameter a and decreasing in unit costs c, i.e.,

$$\frac{\partial\bar{\theta}_1^{B,DP}}{\partial a} - \frac{\bar{\theta}_2^{B,OP}}{\partial a} > 0, \qquad \frac{\partial\bar{\theta}_1^{B,DP}}{\partial c} - \frac{\bar{\theta}_2^{B,OP}}{\partial c} < 0. \tag{A.1}$$

Differentiating $\partial\bar{\theta}_1^{B,DP}$ with respect to a is straightforward:

$$\frac{\partial\bar{\theta}_1^{B,DP}}{\partial a} = \frac{2\alpha_2(1+t_1)(\alpha_1-\alpha_2)}{(1+t_2)\alpha_1^3} = -\frac{2c\,(t_1-t_2)\,(1+t_1)\,\alpha_2}{(1+t_2)\alpha_1^3}\ . \tag{A.2}$$

To differentiate $\partial\bar{\theta}_2^{B,OP}$ with respect to a, note first that the denominator of this fraction can be rewritten as follows:

$$\alpha_2^2 - 4c(t_1-t_2)\alpha_1 = [\alpha_1 - c(t_1-t_2)]^2. \tag{A.3}$$

It is then straightforward to derive

$$\frac{\partial\bar{\theta}_2^{B,OP}}{\partial a} = -\frac{2c\,(t_1-t_2)\,(\alpha_1+\alpha_2)}{[\alpha_1 - c\,(t_1-t_2)]^3}\ , \tag{A.4}$$

where $\alpha_1 + c(t_1-t_2) = \alpha_2$ from (5) has been used.

Partial differentiation with respect to c proceeds analogously. This gives

$$\frac{\partial\bar{\theta}_1^{B,DP}}{\partial c} = \frac{2\alpha_2(1+t_1)[(1+t_1)\alpha_2-(1+t_2)\alpha_1]}{(1+t_2)\alpha_1^3} = \frac{2a\,(t_1-t_2)\,(1+t_1)\,\alpha_2}{(1+t_2)\alpha_1^3}\ , \tag{A.5}$$

and for $\partial\bar{\theta}_2^{B,OP}$ [using (A.3)]

$$\frac{\partial\bar{\theta}_2^{B,OP}}{\partial c} = \frac{2a\,(t_1-t_2)\,(\alpha_1+\alpha_2)}{[\alpha_1 - c\,(t_1-t_2)]^3}\ . \tag{A.6}$$

Combining (A.2) and (A.4) yields

$$\frac{\partial\bar{\theta}_1^{B,DP}}{\partial a} - \frac{\partial\bar{\theta}_2^{B,OP}}{\partial a} = \frac{2c\,(t_1-t_2)\,\Gamma}{(1+t_2)\,\alpha_1^3\,[\alpha_1 - c\,(t_1-t_2)]^3}\ , \tag{A.7}$$

and similarly for (A.5) and (A.6)

$$\frac{\partial\bar{\theta}_1^{B,DP}}{\partial c} - \frac{\partial\bar{\theta}_2^{B,OP}}{\partial c} = \frac{-2a\,(t_1-t_2)\,\Gamma}{(1+t_2)\,\alpha_1^3\,[\alpha_1 - c\,(t_1-t_2)]^3}\ , \tag{A.8}$$

where

$$\Gamma = \alpha_1^3 (\alpha_1 + \alpha_2)(1 + t_2) - (1 + t_1)\alpha_2 [\alpha_1 - c(t_1 - t_2)]^3 \ .$$

The denominators of (A.7) and (A.8) must be positive from (15). Hence, Γ must be positive for (A.1) to hold. A sufficient condition for $\Gamma > 0$ is

$$(\alpha_1 + \alpha_2)(1 + t_2) - (1 + t_1)\alpha_2 > 0 \quad \Longrightarrow \quad \alpha_1 (1 + t_2) - \alpha_2 (t_1 - t_2) > 0.$$

Adding and subtracting $2\alpha_1(t_1 - t_2)$ this can be rewritten as

$$\alpha_1[1 + t_2 - 2(t_1 - t_2)] + [\alpha_1 - c(t_1 - t_2)](t_1 - t_2) > 0,$$

which must be fulfilled from conditions (14) and (15). 2

C. Proof of Proposition 2

We differentiate the four terms $\bar{\theta}_i^{k,m}$ in Table 1 with respect to t_2, using our definition of $\alpha_i \equiv [a - (1 + t_i) c]$, which implies $\partial\alpha_2/\partial t_2 = -c$. Under the destination principle there are no ambiguities because the numerator of both $\bar{\theta}_1^{B,DP}$ and $\bar{\theta}_1^{C,DP}$ is falling in t_2, while the denominator is rising. The analysis for the origin principle and Cournot competition is also straightforward since the numerator is unambiguously falling in t_2 and the denominator is easily shown to increase in t_2, despite the presence of counteracting effects. Finally, under the origin principle and Bertrand competition, we get

$$\frac{\partial\bar{\theta}_2^{B,OP}}{\partial t_2} = \frac{-2c\alpha_1\, DEN - 2c(2\alpha_1 - \alpha_2)\, NUM}{(DEN)^2} < 0.$$

This must be negative since DEN and NUM are positive terms and $(2\alpha_1 - \alpha_2)$ must also be positive. The latter follows from $\alpha_1 - \alpha_2 = -c(t_1 - t_2)$ and $\alpha_1 > c(t_1 - t_2)$ from (15). Hence, we have $\partial\bar{\theta}_i^{k,m}/\partial t_2 < 0 \; \forall \; k \in \{B, C\}, \; m \in \{DP, OP\}$. 2

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