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Multimarket Linkages, Cartel Discipline and Trade Costs

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Multimarket Linkages, Cartel Discipline and Trade Costs

Abstract

We build a model of tacit collusion between firms that operate in multiple markets to study the effects of trade costs. A key feature of the model is that cartel discipline is endogenous. Thus, markets that appear segmented are strategically linked via the incentive compatibility constraint. Importantly, trade costs affect cartel shipments and welfare not only directly but also indirectly through discipline. Using extensive data on international cartels, we find that trade costs exert a negative and significant effect on cartel discipline. In turn, cartel discipline has a negative and significant impact on trade flows, in line with the model.

JEL-Codes: D430, F100, F120, F130, F150, F420, L120, L130, L410.

Keywords: endogenous cartel discipline, competitiveness, multimarket contact, welfare, trade flows, trade costs, trade policy, gravity.

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. . . [M]ultimarket contact can have real effects; in a wide range of circumstances, it relaxes the incentive constraints that limit the extent of collusion. . . . [W]hen multimarket contact does have real effects, these effects are not necessarily socially undesirable. Ultimately, the question of whether multimarket contact does have significant effects must be resolved through empirical research. (Bernheim and Whinston, 1990, p. 22)

1 Introduction

Empirical evidence on recently prosecuted international cartels indicates that their collusive practices have persisted over time and have involved interactions that extend beyond the boundaries of their resident economies.[1] At the same time, innovations in shipping technologies and trade accords (multilateral and/or preferential) have intensified multimarket interactions, causing international trade flows to expand.[2] Do reductions in trade costs affect cartel discipline? If they do, what does that mean for bilateral trade volumes and efficiency? Our principal objective in this paper is to address variants of these issues theoretically and empirically.

Conventional wisdom holds that reductions in trade costs intensify international competition, undermine cartel stability, and improve efficiency. Yet, as noted above, a number of international cartels have thrived despite substantial trade liberalization and globalization. Building on the idea that multimarket contact may facilitate collusion (Bernheim and Whinston, 1990), we develop a segmented-markets, duopoly model with firms interacting repeatedly over time, not only in their own markets but also in third-country markets, to assess the importance of cross-market linkages for the cohesion of cartels. We study the dependence of constrained efficient cartel agreements on trade barriers. Our theoretical analysis reveals that markets that are segmented in static settings become strategically linked under repeated play. The analysis also points out that, when trade costs are low, cartel discipline is strong and further reductions in trade costs enhance it. In the empirical part, we substantiate the presence of this novel relationship and quantify its implications

[1] For example, in 2012 the European Commission fined seven international groups of companies from Taiwan, France, Netherlands, Japan and South Korea for collusive practices in the cathode ray tubes sector. (See *http://europa.eu/rapid/press-release_IP-12-1317_en.htm.)* The European Commission and the United States Department of Justice also charged four firms from Japan and South Korea for price-fixing, customer allocation, and the exchange of confidential information in the nucleotides (food flavor enhancers) sector. (For information on the decision of the European Commission see: *http://europa.eu/rapid/press-release_IP-02-1907_en.htm?locale=en.* The U.S. Department of Justice's decisions are available at: *http://www.justice.gov/atr/cases/f9200/9297.htm*, *http://www.justice.gov/opa/pr/2001/August/435at.htm*, and *http://www.justice.gov/atr/cases/f9300/9301.htm.*) A common feature of the activities of these firms is that their actions also affected third-county markets.

[2] Since the creation of the World Trade Organization in 1995, over 400 agreements facilitating trade trade in both goods or services have been notified to the WTO. (https://www.wto.org/english/tratop_e/region_e/regfac_e.htm).

for bilateral trade flows.

We start with a formal analysis of output deliveries and global profits under Cournot-Nash competition, unconstrained collusion, and optimal deviations from targeted cartel agreements. Focusing on interactions in quantities with trigger strategies that punish deviant behavior with reversion to the Cournot-Nash equilibrium, we then describe the cartel's incentive-compatibility constraint (ICC). Our initial aim is to shed light on the way *internal trade costs* (which separate the home markets of cartel members) and *external trade costs* (which separate their home markets from the markets of third or "outside" countries) condition the sustainability of maximal collusion. The minimum discount factor capable of supporting maximal collusion assumes center stage and we find that its behavior — and, consequently, the stability of maximal collusion — depends on the initial levels of *all* trade costs. Specifically, for any given level of non-prohibitive external trade costs, reductions in internal trade costs undermine the stability of maximal collusion if these costs are sufficiently low but strengthen it if the costs are high. On the other hand, reductions in external trade costs facilitate (undermine) collusion if internal trade costs are low (high).[3] More importantly, by unveiling the conditions on parameters under which the ICC is active, we prepare the ground for a deeper exploration of the determinants of cartel discipline.

In the second step, we solve the cartel's optimization problem and characterize the solution. A distinguishing feature of our approach is that it enables us to express output deliveries, global profits and national welfare levels as functions of trade costs and *cartel discipline*. But cartel discipline, whose measure hinges on the tightness of the ICC, depends on the salient features of national markets, including their relative sizes, trade costs, and firms' time preferences.

We show that, when internal trade costs are sufficiently low, cartel members find it appealing to incur the costs of intra-industry trade as that improves enforcement. Moreover, reciprocal reductions in these costs enhance cartel discipline. Thus, in contrast to much of the existing

[3] A related strand of the existing literature studies the effects of trade policy (in the form of tariffs or quotas) on collusion among domestic and foreign firms, operating in a single market (Davidson, 1984; Rotemberg and Saloner, 1989; Fung, 1992; Syropoulos, 1992; Matschke, 1999). Pinto (1986) extends Brander and Krugman's (1983) model to consider repeated interactions and demonstrates that, for certain values of the discount factor, there will be no trade if firms choose the monopoly output. Lommerud and Sørgard (2001) prove that choosing prices may make multimarket collusion easier to sustain, while the opposite holds for quantity-setting collusion. Akinbosoye et al. (2012) demonstrate that trade liberalization enhances cartel stability when goods are close substitutes and initial trade cost levels are sufficiently high. Ashournia et al. (2013) show that reductions in trade costs could have a pro-collusive effect if the initial level of trade costs is sufficiently low.

literature (which typically abstracts from third-country markets or assumes segmentation), cartel discipline now affects the rest of the world (ROW). But cartel discipline also depends on external trade costs. And, when cross-hauling is present, reductions in external trade costs improve cartel discipline. More generally, the qualitative effect of external trade costs on cartel discipline hinges on the level of internal trade costs and vice versa.

Trade costs also affect cartel shipments and welfare. However, while the direct effects of these costs may be clear, little is known about their indirect effects, channeled through cartel discipline. We find that in the presence of intra-industry trade, cartel discipline is inversely related to both internal trade costs and external trade costs. By placing the endogeneity of cartel discipline front and center, our analysis points out that, when the ICC binds, reductions in internal (resp., external) trade barriers bring about trade diversion. This implies higher consumer prices and lower welfare in ROW. It also generates a familiar trade-off for the home countries of the cartel. Although the deepening of internal (or regional) integration shifts rents from ROW to the cartel-member countries, this integration may affect their welfare levels adversely. This is due to the fact that the incipient improvement in cartel discipline, despite its promotion of cross-hauling, helps sustain a domestic price hike, which reduces consumer surplus. Hence, in the absence of appropriate competition policy, the strengthening of economic integration may reduce world efficiency in the Pareto sense.

A corollary to the above finding is that the absence — or, more starkly, the prohibition — of internal trade may Pareto-dominate a regime of internally free trade of the kind typically encountered in Free Trade Areas and Customs Unions. Still, depending on the characteristics of national markets and the salience of the future, economic integration may prove beneficial to the home countries of cartels. We study the conditions under which this possibility arises and clarify how strategic market linkages and cartel behavior matter.

We also examine how (constrained) collusive outcomes compare to the ones that (hypothetically) arise under unrestrained collusion (i.e., pure monopoly) and Cournot-Nash competition. A seemingly counter-intuitive finding here is that constrained collusion may deliver a higher level of welfare for the cartel countries, both relative to pure monopoly and to the Cournot-Nash equilibrium. The former possibility arises when the welfare gain due to higher consumer surplus more

than offsets the associated reduction in collusive profits under constrained collusion. The latter possibility arises when firms are sufficiently patient and the market in ROW is sufficiently large.

Our theory offers a rich set of predictions that allow us to make several empirical contributions.[4] In the empirical part, we use an extensive novel dataset on international cartels and international trade,[5] and propose a two-step econometric strategy to test some of the key predictions of the theoretical model. Specifically, in the first stage, we test the hypothesis that cartel discipline is inversely related to trade costs using a Cox Proportional Hazard model of cartel duration. The analysis reveals that internal trade costs have a positive and statistically significant effect on the hazard of cartel break up, therefore, supporting the theoretical prediction that these costs are inversely related to cartel discipline. Moreover, we find that the effect of external trade costs on the hazard of collusive dissolution is also positive and highly statistically significant, suggesting that external trade costs are also inversely related to cartel discipline, as predicted by our theoretical model. Our first-stage findings are robust to a series of sensitivity checks.

Encouraged by these results, we use the first-stage estimates to construct several measures of cartel discipline, which we then employ to test the hypothesis that stronger cartel discipline impedes trade. In line with our theory, the second-stage analysis reveals that the effect of cartel discipline on both internal and external cartel shipments is negative and statistically significant. These results imply that stronger collusive discipline obstructs trade both between cartel members and between a cartel exporter and a non-cartel importer (ROW). We also control for the presence of cartels in our empirical specification and obtain a large, positive, and highly statistically significant estimate of their existence on both internal and external trade. This interesting result implies that international cartels may actually enhance welfare, through trade, and we view it as a promising direction for future work. The second-stage results are robust to various sensitivity experiments.

[4]Despite the prominent presence of international cartels in various industries, empirical research in the area remains limited. Most of the related literature focuses either on the determinants of cartel stability (Dick, 1996; Brenner, 2005; Connor and Zimmerman, 2005; Levenstein and Suslow, 2011; Zhou, 2012; and Connor et al., 2013), or on single episodes of collusion, where price and quantity data are readily available (Roller and Steen, 2006; Bejger, 2011, 2012; Harrington et al., 2015; and Connor, 2001). There are also a number of papers that provide a descriptive overview of different cartel practices and characteristics (Connor, 2003; Bolotova et al., 2008; Harrington, 2006; Levenstein and Suslow, 2006 and 2008). Levenstein et al. (2015) study the effects of 7 international cartel break-up cases on prices, industry concentration ratios and the spatial patterns of trade (i.e., on the impact of distance on trade.) Our study of the relations between trade costs, cartel discipline, and trade is novel in this literature.

[5]Our data set covers 173 international cartels over the period 1988-2012 and includes information on the 6-digit Harmonized System product codes for each of the cartelized products. The 6-digit HS codes enable us to match the cartel data with corresponding international trade flows data at the most disaggregated level available (HS 6-digit product level). We offer further details on the data construction an sources in Section 3.2 and in Appendix B.

We have already indicated how our work is related to contributions that emphasize the stability of collusion. One difference from this literature is that our model extends the sphere of a cartel's influence to include third-country markets. Another difference is that our explicit consideration of the ICC helps us determine cartel discipline endogenously as a function of trade costs and other salient market characteristics. Syropoulos (1992) and Bond and Syropoulos (2008) also treated cartel discipline as endogenous. However, the former study did not consider multimarket linkages and cross hauling, while the latter abstracted from third-country markets. Our inclusion of export markets for cartels overlaps with the work of Auqier and Caves (1979) and Brander and Spencer (1984). The key difference is that in our work cartel discipline is endogenous. The welfare part of our analysis is related to Deltas et al. (2012) who find that monopoly may enhance welfare by reducing costly cross-hauling.[6] However, this work differs in model specifics and orientation. Perhaps more importantly, and in sharp contrast to our work, the above contributions do not contain an empirical component.

The rest of the paper is organized as follows. Section 2 presents the segmented-markets duopoly model, describes the ICC and the stability of maximal collusion, unveils the solution to the cartel's optimization problem and introduces our endogenous index of cartel discipline. Then, it proceeds to characterize the net effects of economic shocks on cartel shipments and their implications for welfare. Section 3 contains the empirical component of our analysis. First, it describes the testable hypotheses and the econometric approach. Then, in provides an overview of the data. And, lastly, it summarizes the main results. Section 4 concludes. Appendix A includes technical proofs related to the theoretical analysis. Appendices B and C contain information on data and a series of robustness checks, respectively.

2 Theoretical Analysis

In this section, we first present a duopoly model in which firms interact in quantities over time in three markets/countries, separated by per-unit trade costs. Then, we characterize the global profit functions of the representative firm in the case of Cournot-Nash competition, constrained and unconstrained collusion, and optimal deviation. Next, we proceed to study the constrained

[6] More specifically, focusing on horizontal differentiation à la Hotelling and segmented markets, these authors find that collusion may be "consumer-surplus-enhancing" if trade costs are considerably high — so that the cartel expands the share of the efficiently produced variety by reducing its price to cover the entire market.

optimization problem of the cartel. After examining the stability of maximal collusion, we present our theory of endogenous cartel discipline and describe the strategic linkages that arise across markets. Lastly, we analyze the effects of economic shocks on cartel shipments and national welfare.

2.1 Framework

We consider a world in which two firms, labeled 1 and 2, produce a homogeneous good for sale to the (segmented) markets of three countries indexed by $j \in J \equiv \{1, 2, ROW\}$, where "$ROW$" captures the "rest of the world." Firm i is located in market $i \in I \equiv \{1, 2\}$ and there is no local production of the good in ROW.[7] Without loss of generality, we assume that the marginal cost of manufacturing a good is zero and define t_{ij} to be the per unit trade cost to firm i of shipping its product to market $j \in J$. Moreover, for simplicity, we suppose $t_{ii} = 0$. Trade costs t_{ij} could be interpreted as transportation costs or as import tariffs.[8] Firms interact in quantities.

Denote with q_{ij} the quantity supplied by firm $i \in I$ to market $j \in J$ and define $Q_j \equiv \sum_{i \in I} q_{ij}$. For simplicity and tractability, we assume consumer preferences take the quasi-linear form $U_j = u(Q_j) + q_{0j}$, where q_{0j} captures the consumption of a numeraire good 0 (which is assumed to be produced in positive quantities by perfectly competitive firms) and $u(Q_j) = AQ_j - \frac{1}{2}\beta_j Q_j^2$ in country $j \in J$. Optimization in consumption gives $p_j(Q_j) = \max(0, A - \beta_j Q_j)$, where A and β_j respectively capture the choke-off price and slope of the inverse demand function in j. Since the inverse of β_j can be viewed as the measure of identical consumers with identical preferences in each country j, we interpret it as the inverse of the size of j's market.

The profit function of firm $i \in I$ operating in market $j \in J$ is $\pi_{ij} \equiv \pi_{ij}(q_{ij}, Q_j, t_{ij}) = [p(Q_j) - t_{ij}]\, q_{ij}$. Thus, firm i's global profit is

$$\Pi_i = \sum_{j \in J} \pi_{ij}(q_{ij}, Q_j, t_{ij}), \text{ for } i \in I. \tag{1}$$

Henceforth, we use superscripts "N", "C" and "D" to identify functions associated with the "Cournot-**N**ash" equilibrium, a "**C**ollusive" agreement, and an optimal "**D**eviation" from it, respectively. Moreover, we refer to countries 1 and 2 as the "hosts" of firms or of the cartel. Further,

[7] In the theoretical analysis, we treat ROW as a single entity. However, the model could be modified to consider the possible existence of a competitive fringe of firms without loss of generality.

[8] The key difference between the technology-based and policy-related interpretations of trade costs is that the latter may generate revenues. Due to the partial-equilibrium nature of the model, this distinction is inconsequential for the behavior of firms (but not for welfare).

to simplify notation, we impose the following symmetry conditions:

$$\beta_1 = \beta_2 = 1 \text{ and } \beta = \beta_{ROW}, \tag{C1}$$

$$t = t_{12} = t_{21} \geq 0, \tag{C2}$$

$$\tau = t_{1ROW} = t_{2ROW} \geq 0. \tag{C3}$$

Condition $(C1)$ requires the markets of the cartel hosts to be equally sized and normalizes the measure of this (common) size to unity. We may, therefore, interpret β as an inverse measure of ROW's *relative size*.[9] Condition $(C2)$ imposes symmetry on the trade costs facing exporters to countries 1 and 2, so we may think of t as a measure of their *internal* trade costs. Condition $(C3)$ imposes symmetry on *external* trade costs, captured by τ. As noted earlier, internal trade costs may take the form of tariffs or of transportation costs. We will interpret external trade costs τ as "transportation" costs.[10] As explained below, in addition to bypassing the challenging problem of determining the allocation of market shares between asymmetric cartel members, $(C1)-(C3)$ allow us to treat multimarket collusion as a constrained optimization problem. This approach allows firms to link markets strategically that are seemingly segmented, thereby generating novel insights on the possible effects of PTAs on collusive behavior, trade creation/diversion, and welfare.[11]

$(C1)-(C3)$ ensure the two firms face a symmetric environment that implies: (i) Cournot-Nash quantities satisfy $q_{11}^N = q_{22}^N$, $q_{12}^N = q_{21}^N$ and $q_{1ROW}^N = q_{2ROW}^N$; (ii) best-response functions follow a similar (symmetric) pattern; and (iii) cartel agreements involve identical actions by "mirror-image" firms. We may simplify the notation further by capturing the output decisions of the representative cartel member with $q \equiv (x, y, z)$, where x denotes deliveries to its own market, y exports to the other firm's market, and z exports to ROW. We let $q^N \equiv (x^N, y^N, z^N)$ capture the Nash triple and $q^D \equiv (x^D, y^D, z^D)$ the triple under an optimal deviation from q.

Next, let $\bar{t} \equiv A/2$ and $\bar{\tau} \equiv A$ represent the prohibitive internal and external trade costs. Starting with the Cournot-Nash equilibrium, one can show: $x^N = \min\left(\frac{A+t}{3}, \frac{A}{2}\right)$, $y^N = \max\left(\frac{A-2t}{3}, 0\right)$ and $z^N(\tau, \beta) = \max\left(\frac{A-\tau}{3\beta}, 0\right)$. Thus, if $t < \bar{t}$, reciprocal reductions in internal trade costs $(t \downarrow)$ spur

[9] Parameter β figures prominently in the determination of collusive stability, the impact of collusion on welfare (as compared to Cournot-Nash competition), and the spillover effects of regional economic integration on welfare.

[10] The analysis could be modified to interpret τ as a policy instrument. One possibility is to view τ as a "most favored nation" import tariff imposed by ROW. Alternatively, τ could be interpreted as a uniform export tax imposed by countries 1 and 2 (as would be the case if these countries formed a customs union).

[11] A possible disadvantage is that it does not capture the impact of unilateral changes in trade costs.

internal trade ($y^N \uparrow$), partially displace local supplies ($x^N \downarrow$), and expand domestic output ($Q^N \uparrow$). However, because marginal costs are constant and markets are segmented, the reductions in t *do not affect* exports to ROW. Similarly, for $\tau < \bar{\tau}$, reductions in external trade costs ($\tau \downarrow$) lead to an increase in the export volumes to ROW without impacting either x^N or y^N.

Under $(C1) - (C3)$, the representative firm's global profit for $t \leq \bar{t}$ and $\tau \leq \bar{\tau}$ is

$$\Pi^N = \frac{1}{9}(A+t)^2 + \frac{1}{9}(A-2t)^2 + \frac{1}{9\beta}(A-\tau)^2, \tag{2}$$

which is strictly convex in t and τ. Reciprocal reductions in t reduce a firm's profitability of serving its own market, but enhance the appeal of exporting to the other firm's market. This renders Π^N non-monotonic in t with $\arg\min_t \Pi^N = A/5$. Moreover, because a symmetric, homogeneous-good duopoly generates lower industry profits than a pure monopoly with the same cost structure, we have $\Pi^N(0,\tau,\beta) < \Pi^N(\bar{t},\tau,\beta)$. Turning to the role of τ and β, we find that $\Pi^N_\tau \equiv \partial\Pi^N/\partial\tau < 0$ and $\Pi^N_\beta < 0$, with $\Pi^N_{\tau\tau} > 0$ and $\Pi^N_{\beta\beta} > 0$ for $\tau < \bar{\tau}$. Thus, larger external trade costs and/or a lower market size for ROW imply lower global profit for the representative firm.

A cartel member's global profit under collusion is

$$\Pi^C = (A-x-y)(x+y) - ty + (A-\tau-2\beta z)z \quad \text{for} \quad x,y,z \geq 0, \tag{3}$$

which is concave in $q \equiv (x,y,z)$. The first two terms in (3) capture profits in the markets of cartel hosts. The third term captures the profit π_{ROW}, obtained in ROW. A special case of a collusive agreement arises when cartel members solve $\max_q \Pi^C$ in the absence of antitrust concerns and/or incentive compatibility constraints. The solution to this problem typically involves geographic separation of markets and can be identified as "monopoly", which we capture with superscript "M". Specifically, if internal trade costs are absent ($t = 0$), any combination of x and y that satisfies $x + y = \frac{A}{2}$ $(= Q^M)$ belongs to a profit-maximizing triple. However, if $t > 0$ the cartel can avoid trade costs by foreclosing on internal trade and by supplying the monopoly output locally (i.e., $y^M = 0$ and $x^M = Q^M$). Provided $\tau \leq \bar{\tau}$, exports to ROW are $z^M = \frac{A-\tau}{4\beta} = \arg\max_z \pi_{ROW}$. It now follows that a cartel member's unconstrained optimal global profit is

$$\Pi^M = \frac{1}{4}A^2 + \frac{1}{4\beta}(A-\tau)^2, \tag{4}$$

for $\tau \leq \bar{\tau}$. Clearly, Π^M is convex and decreasing in τ.

To prepare the ground for our upcoming analysis of the ICC, we should also examine a cartel member's optimal deviation strategy and associated global profit when its partner abides by a targeted agreement q. A firm's best-response to q is to deviate from q in all markets by supplying: $x^D(y) = \max\left(\frac{A-y}{2}, 0\right)$, $y^D(x;t) = \max\left(\frac{A-t-x}{2}, 0\right)$, and $z^D(z;\tau,\beta) = \max\left(\frac{A-\tau-\beta z}{2\beta}, 0\right)$. Substituting these quantities in (1) and simplifying gives

$$\Pi^D = \left(x^D\right)^2 + \left(y^D\right)^2 + \beta\left(z^D\right)^2. \tag{5}$$

Π^D is strictly convex and increasing in q when trade costs are below their corresponding prohibitive levels.[12] For any feasible q, reductions in internal or external trade costs enhance the deviating firm's profit by enabling it to expand its volume of exports (i.e., $y^D \uparrow$ and/or $z^D \uparrow$). Lastly, Π^D is decreasing and strictly convex in t, τ and β.

We use this detailed characterization of the optimal profits of the representative firm to examine the implications of multimarket collusion. Specifically, we focus on implicit collusion, sustained through a grim trigger strategy over the infinite time horizon, as we explain next.

2.2 Multimarket Collusion

We know from the theory of repeated games that regular and recurrent contact enables firms to sustain collusion through strategies that reward adherence to agreements with reciprocated "cooperation" and punish defections with "retaliation." Multimarket contact may facilitate "cooperation" by allowing firms to pool incentive constraints across markets (Bernheim and Whinston, 1990).

We focus on cartel agreements that allocate a triple $q = (x, y, z)$ to each firm. We assume that firms "enforce" collusion by utilizing a grim trigger strategy that prescribes adherence to the provision of q if all firms abide by the agreement and reversion to the Cournot-Nash equilibrium in all markets if a cartel member defects.[13] We aim to identify and characterize the most profitable, incentive-compatible cartel agreements. *First*, we describe the representative cartel member's ICC. *Second*, we study the stability of maximal collusion and its dependence on internal (t) and external

[12] As we will see shortly, the strict convexity of Π^D in q together with the concavity of Π^C in q imply the set of incentive-compatible agreements is convex.

[13] We choose reversion to the static Nash equilibrium as the punishment mechanism for two reasons: To know how the economies perform under collusion as compared to competition and to render our analysis comparable to numerous others in the literature that adopted the same approach. Later on we briefly discuss how the analysis may change when firms choose the more severe punishment that involves zero profits.

(τ) trade costs. (This also deepens our understanding of the circumstances under which the no "deviation constraint" is active or not.) *Third*, we develop a theory of endogenous cartel discipline.

2.2.1 Cartel Problem

Denote with δ firms' actual (and common) discount factor. A cartel member will supply q if

$$\Phi(q,t,\tau,\beta,\delta) \equiv \Pi^C(q,t,\tau,\beta) - (1-\delta)\Pi^D(q,t,\tau,\beta) - \delta\Pi^N(t,\tau,\beta) \geq 0, \qquad (ICC)$$

where Π^C, Π^D and Π^N respectively denote the global profit of the representative cartel member under a collusive agreement that targets q, under an optimal deviation from q, and in the Nash equilibrium. By virtue of the facts that Π^C is concave and Π^D is strictly convex in q, $\Phi(\cdot)$ is strictly concave in q. Therefore, the set of incentive-compatible cartel agreements $F(q,t,\tau,\beta,\delta) \equiv \{q \mid \Phi(\cdot) \geq 0 \text{ and } q \geq 0\}$ is convex in q. The cartel's optimization problem can thus be described as $\max_q \Pi^C(q,t,\tau,\beta)$, s.t. $q \in F(q,t,\tau,\beta,\delta)$. The solution to this problem is captured by the saddle point problem of the Lagrangian function

$$\max_q \min_{\lambda,\mu} \mathcal{L}(q,\lambda,t,\tau,\beta,\delta) = \Pi^C(q,t,\tau,\beta) + \lambda\Phi(q,t,\tau,\beta,\delta) + \mu y, \qquad (6)$$

where $\lambda \geq 0$ and $\mu \geq 0$ are the Lagrange multipliers associated with (ICC) and the non-negativity of internal trade constraint $y \geq 0$, respectively.[14] The necessary first-order conditions (FOCs) for an interior solution to (6) are

$$\Phi(q^*) \geq 0, \;\; \lambda^* \geq 0, \;\; \lambda^*\Phi(q^*) = 0, \;\; y^* \geq 0, \;\; \mu^* \geq 0, \;\; \mu^* y^* = 0, \qquad (7)$$
$$\nabla\mathcal{L}(q^*,\lambda^*,\mu^*) = \nabla\Pi^C(q^*) + \lambda^*\nabla\Phi(q^*) + \mu^* = 0,$$

where a star "$*$" identifies the solution. Define $\theta \equiv \frac{\lambda(1-\delta)}{1+\lambda}$. This function, which is increasing in λ, captures the tightness of the ICC and is a measure of the degree of competitiveness (or, alternatively, an inverse measure of cartel discipline). Importantly, $\theta \in [0,1)$ because $\lambda \geq 0$ and $\delta \in [0,1)$.[15]

[14] The non-negativity of trade constraint must be included in the Langrangian function because the volume of trade between the cartel hosts is eliminated at sufficiently high internal trade cost levels.

[15] Since $\theta_\lambda \equiv \partial\theta/\partial\lambda > 0$, we use θ and λ interchangeably. For deeper understanding consider the extreme cases where $\theta = 0$ and $\theta \to 1$. In the former case, the ICC is inactive, $q = q^M$. In the latter case, we will have $q \to q^N$.

2.2.2 Stability of Maximal Collusion

We now describe the minimum discount factor $\delta^M(t,\tau,\beta)$ that ensures $q^* = q^M$. Essentially this is the discount factor that solves $\Phi(q^M(\tau,\beta),t,\tau,\beta,\delta) = 0$ in (ICC) and thus satisfies

$$\delta^M \equiv \delta^M(t,\tau,\beta) = \frac{\Pi^D\left(q^M(\tau,\beta),t,\beta\right) - \Pi^M(\tau,\beta)}{\Pi^D\left(q^M(\tau,\beta),t,\beta\right) - \Pi^N(t,\tau,\beta)}. \tag{8}$$

To shed light on the manner in which the presence of third-country markets matters for collusive stability, we examine the dependence of $\delta^M(\cdot)$ on parameters. As noted earlier, this also unveils the conditions under which the ICC is active ($\lambda^* > 0$) and inactive ($\lambda^* = 0$), which facilitates our characterization of collusive optima.[16]

From Section 2.1, we know how trade costs and market size affect Π^M and Π^N. Thus, to complete the analysis of δ^M we need to characterize $\Pi^D\left(q^M(\tau,\beta),t,\beta\right)$. Suppose $t = 0$ initially. Then, any combination $x + y = Q^M$ implements the monopoly outcome in the host countries. Moreover, the strict convexity of Π^D in (x,y) implies that it is in the interest of cartel members to maintain a presence in each other's market through exports (see (5)). (One can verify that Π^D is lowest when $x = y = Q^M/2$). If t is close to but larger than 0, the cartel's optimal strategy is to foreclose on internal trade, so $y^M = 0$ and $x^M = Q^M$, as this reduces trade costs. Since this strategy increases Π^D, δ^M is discontinuous in t at $t = 0$. This discontinuity has important implications for the dependence of cartel discipline on internal trade costs.

Clearly, there are two possibilities with regards to external trade: $\tau \geq \bar{\tau}$ and $\tau < \bar{\tau}$. Since, in the former case, there is no external trade, the model collapses to the 2-country setting studied in Bond and Syropoulos (2008). As a benchmark, we summarize the salient features of $\delta^M(t,\tau,\beta)$ for $\tau \geq \bar{\tau}$ in Proposition $A1$ of Appendix A. In addition to the discontinuity of δ^M at $t = 0$, a key finding in that proposition is that δ^M is monotonically decreasing in t with $\lim_{t\to\bar{t}} \delta^M \to 0$, as indicated by the downward sloping dashed-line schedule in Fig. 1. Henceforth, we focus on $\tau < \bar{\tau}$ which allows for external trade. Define $\underline{\delta} \equiv \delta^M(0,\tau,\beta)$ and $\widehat{\delta} \equiv \lim_{t\to 0} \delta^M(t,\tau,\beta)$.[17] Proposition 1 describes the stability of maximal collusion in the presence of trade with ROW.

[16] Of course, we must also ensure we identify the conditions under which the non-negativity constraint $y^* \geq 0$ is active ($\mu^* > 0$) and inactive ($\mu^* = 0$).

[17] It is straightforward for one to show that $\underline{\delta} = 9/17$, which is independent of (τ,β). In contrast, $\widehat{\delta} = \frac{9(1+\eta)}{13+17\eta}$, where $\eta \equiv \frac{(\overline{\tau}-\tau)^2}{4\beta A^2}$. Thus, $\widehat{\delta} > \underline{\delta}$, $\partial\widehat{\delta}/\partial\tau < 0$, $\partial\widehat{\delta}/\partial\beta < 0$ and $\widehat{\delta} \to 9/13$ as $\tau \to \overline{\tau}$ or $\beta \to \infty$. See Fig. 1 for details.

Proposition 1 *(Stability of Maximal Collusion) The minimum discount factor that sustains the monopoly outcome, $\delta^M(t,\tau,\beta)$, has the following properties:*

a) Internal trade costs (t)

i) $\delta^M(0,\tau,\beta) = \delta^M(\bar{t},\tau,\beta) = \underline{\delta} < \widehat{\delta}$;

ii) $t \lesseqqgtr t_1 \Longrightarrow \delta^M \gtreqqless \underline{\delta}$, *where* $t_1 = \left[\delta^M\right]^{-1}(\underline{\delta},\cdot) = \frac{A}{14}$;

iii) $t \lesseqqgtr t_2 \Longrightarrow d\delta^M/dt \lesseqqgtr 0$, *where* $t_2 \equiv \arg\min_t \delta^M$.

b) External trade costs (τ)

$\circ$ $t \lesseqqgtr t_1 \Longrightarrow d\delta^M/d\tau \gtreqqless 0$.

c) Market size (β)

i) $t \lesseqqgtr t_1 \Longrightarrow d\delta^M/d\beta \gtreqqless 0$;

ii) $\lim_{\beta\to 0}\delta^M = \underline{\delta}$ *and* $\lim_{\beta\to\infty}\delta^M = \frac{18(\bar{t}-t)}{13A+22t}$.

Proposition 1, which can be visualized with the help of the thick, solid-line blue curve in Fig. 1, highlights the behavior of δ^M when export opportunities to *ROW* are present. Part (a) reveals that, while the discontinuity of δ^M at $t = 0$ is still present (compare $\underline{\delta}$ and $\widehat{\delta}$ in (i)), δ^M now is U-shaped in internal trade costs t. In particular, as t rises above 0, δ^M crosses $\underline{\delta}$ to reach a minimum at $\underline{\underline{\delta}} \equiv \min_t \delta^M(t,\tau,\beta) < \underline{\delta}$, and rises back to $\underline{\delta}$ where it remains thereafter. In sharp contrast to the 2-country case studied in Bond and Syropoulos (2008), the cartel's ability to access outside markets alters substantively the link between collusive stability and internal trade costs t.

The intuition behind the U-shaped relationship noted above is simple. Because Π^M is independent of t, the impact of changes in internal trade costs on δ^M is solely due to changes in the deviation and punishment payoffs Π^D and Π^N, respectively. For $t < \bar{t}$ an increase in t reduces Π^D because the per unit cost of internal trade rises. This fall in the deviation payoff reduces δ^M and facilitates collusion. The magnitude of this effect becomes of second order as $t \to \bar{t}$.[18] On the other hand, Π^N is non-monotonic in t. These effects of t on Π^D and Π^N imply $\lim_{t\to 0}\partial\delta^M/\partial t < 0$ and $\lim_{t\to\bar{t}}\partial\delta^M/\partial t > 0$. By continuity, δ^M is minimized at some internal trade cost t_2.[19]

The trade cost level t_1 noted in part ($a.ii$) is a pivot point that illustrates, among other things,

[18] In other words, while $\partial\Pi^D/\partial t < 0$ for $t < \bar{t}$, $\lim_{t\to\bar{t}}\partial\Pi^D/\partial t = 0$.

[19] Another way to visualize the just-described relationship is to note that δ^M is a weighted sum of $\underline{\delta}$ and $\delta^M(t,\bar{\tau},\beta)$, with the weight on the latter falling as t rises toward $\bar{t}$. Also, we derive the following properties of t_2: $\partial t_2/\partial\tau > 0$, $\partial t_2/\partial\beta > 0$ and $\lim_{\tau\to\bar{\tau}} t_2 = \lim_{\beta\to\infty} t_2 = \bar{t}$.

how the initial internal trade cost level t conditions the dependence of δ^M on external trade costs τ and relative size β. Parts (b) and (c) elaborate on this dependence.[20] These parts also clarify how the initial levels of τ and β shape the relationship between δ^M and t.

Proposition 1 indicates that (ICC) is inactive when $\delta > \underline{\delta}$ at $t = 0$ and when $\delta \geq \delta^M$ for $t > 0$. Conversely, (ICC) is active (i.e., $\theta > 0$) when $\delta < \underline{\delta}$ at $t = 0$ and when $\delta < \delta^M$ for $t \in (0, \bar{t})$. The non-monotonicity of δ^M in t implies that the ICC is inactive at intermediate levels of t for $\delta \in [\underline{\underline{\delta}}, \underline{\delta})$.

2.3 Cartel Discipline

Having examined how the presence of third-country markets affects the stability of maximal collusion, we now direct our attention to the solution of (6) when (ICC) binds. First note that, if internal trade costs t are sufficiently high (not necessarily $t \geq \bar{t}$), internal trade is eliminated (i.e., $y = 0$). On the other hand, if $\delta < \widehat{\delta}$ and t is sufficiently low, then $y > 0$. Thus, there exists a range of t values under which both the ICC and the non-negativity constraint on y are binding. We address this issue sequentially by separating the analysis into two distinct cases, identified with superscripts "1" and "2", respectively. In case 1, we focus on $y > 0$; in case 2, we deal with $y = 0$.[21]

We rewrite (ICC) in the cases noted above as $\Phi^1 \equiv \Phi^1(\theta, \delta, t, \tau, \beta) = 0$ and $\Phi^2 \equiv \Phi^2(\theta, \delta, t, \tau, \beta) \geq 0$, respectively. Because q^M is sustainable for all $\delta \geq \widehat{\delta}$, henceforth we pay attention to discount factor values that satisfy $\delta < \widehat{\delta}$. (The solution (x^*, y^*) is a correspondence for $\delta \in [\underline{\delta}, \widehat{\delta})$ and $t = 0$ because the ICC is inactive in this case.) To reduce the dimensionality of the problem and develop intuition we, first, use the FOCs to express the optimal output levels as functions of θ (our inverse measure of cartel discipline). We then substitute these values into $\Phi^1 = 0$ and $\Phi^2 = 0$ to obtain a unique θ^*. Even though there is no explicit solution to θ^*, it is possible to characterize it.

Starting with $y \geq 0$, we may rewrite the FOCs in (7) as

$$\mathcal{L}_j^1 = \Pi_j^C + \lambda \Phi_j^1 = 0 \quad \Rightarrow \quad \Pi_j^C = \theta \Pi_j^D < 0, \;\; j \in \{x, y, z\}, \tag{9}$$

where subscript j now denotes a partial derivative (e.g., $\mathcal{L}_x^1 = \partial \mathcal{L}^1 / \partial x$). The equality in the far right-hand side of (9) is obtained by utilizing the definition of θ ($\equiv \frac{\lambda(1-\delta)}{1+\lambda}$) and the fact that

[20] Fig. 1 clarifies the dependence of δ^M on τ by highlighting its shape for two extreme τ values: $\tau = 0$ and $\tau = \bar{\tau}$. At low (high) t values, increases in τ away from $\tau = 0$ pull point $(t_2, \delta^M(t_2, 0, \beta))$ in the direction of $\delta^M(t, \bar{\tau}, \beta)$ and toward $(\bar{t}, 0)$, thus causing δ^M to rotate clockwise around the pivot point F. This substantiates the idea that increases in external trade costs τ are anti-collusive for $t < t_1$ and pro-collusive for $t > t_1$, as noted in part (b).

[21] A third possibility is that $y = 0$ while (ICC) is not binding. We address this possibility by writing the no deviation constraint as a weak inequality and discuss it later.

$\Phi_j^1 = \Pi_j^C - (1-\delta)\,\Pi_j^D = (1-\delta-\theta)\,(-\Pi_j^D) > 0$. This inequality follows from the properties of Π^D. One can verify that the solution to (9) is

$$Q^1(\theta,t) = \frac{(2A-t)(2+\theta)}{8+\theta}, \tag{10a}$$

$$x^1(\theta,t) = \frac{1}{2}\left(Q^1 + \frac{2-\theta}{\theta}t\right), \tag{10b}$$

$$y^1(\theta,t) = \frac{1}{2}\left(Q^1 - \frac{2-\theta}{\theta}t\right), \tag{10c}$$

$$z^1(\theta,\tau,\beta) = \frac{(A-\tau)(2+\theta)}{\beta(8+\theta)}. \tag{10d}$$

The equations in (10) point out that the cartel's local deliveries and export supplies are functions of its discipline, trade costs, and market size. Indeed, Q^1, y^1 and z^1 are increasing and concave in θ.[22] Thus, the more disciplined the cartel ($\theta \downarrow$) the lower the volumes of internal output and of shipments to all markets. [23] Furthermore, Q^1 and y^1 (z^1) are linear and decreasing in internal (external) trade costs t (τ). We will discuss the properties of x^1 shortly.

Focusing on y^1, one can verify that there exists a positively-sloped schedule $t_o(\theta) \equiv \frac{A\theta(2+\theta)}{2(4-\theta)}$, such that $y^1(\theta, t_o(\theta)) = 0$ for $\theta \in [0,1]$. This schedule has the following properties: $t_o(0) = 0$ and $t_o(1) = \bar{t}$; $t_o'(\theta) > 0$ and $t_o''(\theta) > 0$. Henceforth, it is convenient to work with the inverse function $\theta_o(t) \equiv t_o^{-1}(t)$ for $t \in [0,\bar{t}]$. This function, which is increasing and concave in t as shown in Fig. 2, divides the space $[0,\bar{t}] \times [0,1]$ of (t,θ) pairs as follows: $y^1 \gtreqless 0$ if $\theta \gtreqless \theta_o(t)$. Naturally, (10) hold true only for $\theta \geq \theta_o(t)$ or, equivalently, for $t \leq t_o(\theta)$, which ensures that $y^1 \geq 0$. We recognize this restriction later when we study the complete solution.

Turning to the behavior of local production x^1, differentiation of (10b) gives $x_t^1 > 0$, with x^1 being strictly quasi-convex in θ and $x_\theta^1 \gtreqless 0$ for $t \lesseqgtr t_d$, where $t_d \equiv \frac{3A\theta^2}{2(16+4\theta+\theta^2)} < t_o(\theta)$. Thus, x^1 is non-monotonic in θ: it falls with improvements in cartel discipline when t is sufficiently small and rises with such improvements when t is sufficiently high. (In contrast, improved cartel discipline ($\theta \downarrow$) always induces cartel members to reduce output Q^1.)

We now take a closer look at the determination of cartel discipline θ^{1*}. Substituting q^1 from (10) in $\Phi^1 = 0$ readily defines $\theta^{1*} \equiv \theta^{1*}(\delta,t,\tau,\beta)$ implicitly. $\theta^{1*} = 1$ for $t \in [0,\bar{t}]$ is a generic

[22] See the proof of Lemma 1 below for a detailed description of the properties of these functions. Inspection of (10a) reveals that $Q^1 = Q^N$ if $\theta = 1$ and $Q^1 = Q^M$ if $\theta = 0$.

[23] In Section 3 we test empirically and find support for the link between cartel discipline and trade.

solution associated with $q^1 = q^N$. But, there exists another (more "collusive") solution $\theta^{1*} \in [0, 1)$.

Lemma 1 *(Cartel Discipline 1) Suppose $\delta < \widehat{\delta}$ and $\beta < \infty$. Then $\Phi^1(\theta, \cdot) = 0$ has a unique interior solution $\theta^{1*} \equiv \theta^{1*}(t, \cdot)$ with the following properties: If $t = 0$, then $\theta^{1*} = \max(\theta_g, 0)$, where $\theta_g \equiv \frac{17(\underline{\delta}-\delta)}{9+\delta}$. If $t \in (0, \bar{t})$, then $\theta^{1*} \in (0, 1-\delta)$ and*

a) $d\theta^{1*}/d\delta \leq 0$ *(with equality if $\delta \geq \delta^M$), $\lim_{\delta \to 0} \theta^{1*} = 1$ and $\lim_{\delta \to \delta^M} \theta^{1*} = 0$;*

b) $d\theta^{1*}/dt > 0$ *for $t > 0$:*

i) $\lim_{t \to 0} \left(d\theta^{1*}/dt\right) = 0$ *for $\delta \in [0, \underline{\delta}]$;*

ii) $\lim_{t \to 0} \left(d\theta^{1*}/dt\right) = \left[\frac{17}{32}\left(\frac{\delta-\underline{\delta}}{1-\delta}\right)\Pi^N|_{t=0}\right]^{-1/2}$ *for $\delta \in (\underline{\delta}, \widehat{\delta})$;*

c) $sign\left(d\theta^{1*}/d\tau\right) = sign\left(d\theta^{1*}/d\beta\right) \geq 0$*, with equality if $t = 0$;*

d) $sign\left(d^2\theta^{1*}/dtd\tau\right) = sign\left(d^2\theta^{1*}/dtd\beta\right) > 0$.

The key ideas behind Lemma 1 are contained in Fig. 2 which depicts several families of θ^{1*} associated with three discount factor δ values: high, intermediate and low. The curves within each family are differentiated by the level of external trade costs τ. Each of these curves describes how cartel discipline responds to changes in internal trade costs t.[24,25]

The intuition behind part (a) is simple. Since $\Pi^D - \Pi^N > 0$, a bigger weight on the value of future profits ($\delta \uparrow$) loosens the ICC, thus enabling firms to improve cartel discipline. This is shown in Fig. 2 by a downward shift of a family of curves.

Part (b) points out that internal trade cost reductions ($t \downarrow$) strengthen cartel discipline ($\theta^{1*} \downarrow$), as indicated by the upward sloping curves within each family in Fig. 2. By the implicit function theorem, $d\theta^{1*}/dt = -\Phi^1_t/\Phi^1_\theta$. Since $\Phi^1_\theta > 0$, cartel discipline improves with decreases in t only if $\Phi^1_t < 0$. But decreases in t reduce the marginal cost of cross hauling, causing global profits under a collusive agreement (Π^C) and under an optimal deviation (Π^D) to rise. The effect of t on Φ^1 through

[24] Note that $\theta^{1*} = 0$ for $t = 0$ and $\delta > \underline{\delta}$ because full collusion is sustainable in this case. Also keep in mind that the dashed-line portions of the contours in Fig. 2 will turn out to be irrelevant because they violate the non-negativity constraint on y. See Proposition 1 for details. As shown in in Lemma $A4$ of Appendix A, these contours intersect curve $\theta_o(t)$ (which captures the (t, θ) pairs that imply $y = 0$) at a unique level t_y.

[25] In Appendix A we establish the existence of θ^{1*} by showing that $\lim_{\theta \to 0} \Phi^1 < 0$ and $\lim_{\theta \to 1-\delta} \Phi^1 > 0$ and utilizing the fact that Φ^1 is continuous in $\theta \in (0, 1-\delta)$. We then prove that $\Phi^1_\theta \equiv d\Phi^1/d\theta|_{\Phi^1=0} > 0$ which confirms uniqueness. From (ICC) changes in θ affect Φ^1 solely through the impact on q^1; that is, $\Phi^1_\theta = \Phi^1_x x^1_\theta + \Phi^1_y y^1_\theta + \Phi^1_z z^1_\theta$. But, $\Phi^1_j = (1-\delta-\theta)(-\Pi^D_j) > 0$ for $j = x, y, z$ which, by (5), is proportional to a cartel member's best-reply in the relevant market (e.g., $-\Pi^D_x = y^D$). These effects together with the fact that increases in θ induce cartel members to expand their exports to all destinations—both absolutely and in comparison to local output (i.e., $y^1_\theta > 0$ and $y^1_\theta > x^1_\theta$)—explain why $\Phi^1_\theta > 0$. This is key to understanding the determination of cartel discipline for $y^1 > 0$.

Π^C relaxes the ICC, whereas the effect through Π^D tightens the ICC. But the direction of change in Nash profits also depends on the initial level of t (recall Π^N is U-shaped in t). Thus, a decrease in t on Φ^1 through Π^N tightens (relaxes) the ICC at low (high) t values. Finally, a reduction in t also affects Φ^1 through the changes in (x^1, y^1). In the proof, we show that the presence of internal trade ($y^1 > 0$), together with the fact that the volume of this trade expands when t falls, are dominant forces that loosen the ICC (i.e., $\Phi^1_t < 0$), thus explaining the strengthening of cartel discipline.[26]

Part (c) shows that, in the presence of internal trade, external trade cost reductions ($\tau \downarrow$) improve cartel discipline because $\Phi^1_\tau < 0$. In words, decreases in τ create slack in the no-deviation constraint and, to restore incentive compatibility, cartel discipline must improve ($\theta^{1*} \downarrow$). This effect is depicted in Fig. 2 by the downward shift of curves within a family.[27] In our empirical analysis in Section 3 we also examine the impact of external trade costs on cartel discipline in the data. The effect of a reduction in market size $\beta \downarrow$ is similar because $\Phi^1_\beta < 0$.

Part (d) reveals that the direct effect of an improvement of the export opportunities to ROW ($\beta \downarrow$ or $\tau \downarrow$) reduces the sensitivity of cartel discipline to internal trade cost changes, and conversely. This point is captured by the fact that the curves within each family become flatter as β and/or τ fall.

Note that, at higher discount factor values, the curves in Fig. 2 become steeper, so cartel discipline becomes more sensitive to internal trade cost changes. At the same time, the curves move further apart from each other which implies that the impact of external trade cost changes on cartel discipline becomes more pronounced, too.

Next, we consider the no deviation constraint $\Phi^2 \geq 0$ which (arbitrarily) rules out internal trade. Focusing on $(t, \theta) \in [0, \bar{t}] \times [0, 1]$, the relevant FOCs associated with $y = 0$ are:

$$\mathcal{L}^2_j = \Pi^C_j + \lambda \Phi^2_j = 0 \quad \Rightarrow \; \Pi^C_j = \theta \Pi^D_j < 0, \; j \in \{x, z\}. \tag{11}$$

[26] Parts (i) and (ii) of part (b) describe how cartel discipline responds to changes in internal trade costs in the neighborhood of internally free trade for alternative values in the discount factor. As we explain later, these parts play key roles in the determination of cartel shipments and welfare.

[27] The lowest contour within a family arises when external trade is free ($\tau = 0$) and the highest arises when there is no external trade ($\tau = \bar{\tau}$). The curve in the middle arises for some $\tau \in (0, \bar{\tau})$.

The above equations produce the following solution:

$$Q^2(\theta, t) = x^2(\theta, t) = \frac{A(2+\theta) - \theta t}{4+\theta}, \tag{12a}$$

$$z^2(\theta, \tau, \beta) = \frac{(A-\tau)(2+\theta)}{\beta(8+\theta)}. \tag{12b}$$

Inspection of (12) reveals that, in contrast to $y > 0$ considered earlier, increases in t (τ) reduce x^2 (z^2). The effect of cartel discipline on local output level x^2 ($= Q^2$) also differs. Since $x^2_\theta = \frac{4(\bar{t}-t)}{(4+\theta)^2} > 0$ for $t < \bar{t}$, improved cartel discipline ($\theta \downarrow$) now induces cartel members to reduce local deliveries.[28] (Earlier, we found that x^1 is non-monotonic in θ.) As before, the effect of cartel discipline on exports to *ROW* satisfies $z^2_\theta = \frac{6(\bar{\tau}-\tau)}{\beta(8+\theta)^2} \geq 0$.

To determine θ^{2*} we proceed as follows. First, we substitute (x^2, z^2) from (12) in $\Phi^2(\theta, t, \cdot)$ and study the shape of the resulting surface for all $(t, \theta) \in [0, \bar{t}] \times [0, 1]$. Second, to identify (t, θ) pairs that ensure the ICC is binding, we examine contours associated with $\Phi^2 = 0$. Then, to screen out irrelevant (negative) θ values, we limit our attention to (t, θ) pairs in $[t_y, \bar{t}] \times [0, 1]$. To avoid repetition and save on space, the detailed analysis and discussion of this case is provided in Lemma 2 of Appendix A.[29] Nonetheless, the following points related to Lemma 2 deserve mention here. *First*, depending on the values of the discount factor, external trade costs and market size, cartel discipline θ^{2*} may be non-monotonic or insensitive to changes in internal trade costs t. Clearly, this finding contrasts sharply to the one in Lemma 1 where $d\theta^1/dt > 0$. The reason why θ^{2*} may depend on t is because it affects deviation and punishments payoffs. *Second*, for $t > t_y$, there always exists a range of t values adjacent to t_y such that $d\theta^{2*}/dt < 0$. Going to the other extreme, there may exist a range of t values adjacent to $\bar{t}$ such that $d\theta^{2*}/dt > 0$. The possibility of $d\theta^{2*}/dt = 0$ arises only for intermediate values of t between these extremes. *Third*, there exist several "pivot" points in (t, θ) that ensure θ^2 is insensitive to changes in external trade costs and market size. Fig. $A.1$ in Appendix A helps shed further light on these points.

Having examined cartel discipline both in the presence and in the absence of cross hauling, we now combine Lemma 1 and Lemma 2 to describe the salient traits of cartel discipline.

[28] Still, the dependence of Q^2 on θ is similar to the dependence of Q^1 on θ. In particular, Q^2 is increasing and concave in θ. Moreover, $Q^2 = Q^M$ for $\theta = 0$.

[29] Lemma 2 is obtained after a series of lemmas (specifically, Lemmas $A1 - A3$). Fig. 3 and Fig. $A.1$ in Appendix A contain a graphical depiction of the definitions of several threshold values of t (e.g., $\underline{t}_m$, $\bar{t}_m$, t'_m, and t_g) that appear in Lemma 2 as well as in Propositions $2 - 4$.

Proposition 2 *(Equilibrium Cartel Discipline) For $\delta < \widehat{\delta}$, $\beta < \infty$, and $t \in [0, \bar{t}]$, equilibrium cartel discipline is defined as*

$$\theta^* \equiv \begin{cases} \theta^{1*}(t, \cdot) & \text{if} \quad t \in [0, t_y) \\ \theta^{2*}(t, \cdot) & \text{if} \quad t \in [t_y, \bar{t}] \end{cases} .$$

a) Cartel discipline is increasing in firms' valuation of future profits (i.e., $\partial\theta^*/\partial\delta < 0$).

Moreover, cartel discipline is

i) weakest at $t = t_y$;

ii) strongest if:

- $t_{\min} \in (t_y, \bar{t})$ *for* $\delta < \underline{\underline{\delta}}$, *where* $\underline{\underline{\delta}} \equiv \min_t \delta^M(t, \cdot)$,
- $t \in [\underline{t}_m, \bar{t}_m]$ *for* $\delta \in (\underline{\underline{\delta}}, \underline{\delta}]$, *where* $\underline{t}_m = \min\{\left[\delta^M\right]^{-1}(\cdot)\}$ *and* $\bar{t}_m = \{\max\left[\delta^M\right]^{-1}(\cdot)\}$,
- $t = 0$ *and* $t \geq t'_m$ *for* $\delta \in (\underline{\delta}, \widehat{\delta}]$, *where* $t'_m = \left[\delta^M\right]^{-1}(\delta, \cdot)$.

b) Internal trade cost reductions ($t \downarrow$)

i) strengthen cartel discipline if cross hauling is present ($t < t_y$), and possibly if t is sufficiently large;

ii) weaken cartel discipline if cross hauling is absent and t is sufficiently close to t_y.

c) Expansion of trade opportunities in ROW ($\tau \downarrow$ or $\beta \downarrow$)

i) strengthen cartel discipline for $t < t_g^{'}$, where $t_g^{'} \in (t_y, \bar{t})$, but

ii) weaken or do not affect cartel discipline for $t \geq t_g^{'}$.

Proposition 2 can be illustrated with the help of Fig. 3. The blue, solid-line curve in panel (b) unveils the dependence of equilibrium cartel discipline on internal trade costs, under the assumption that $\delta < \underline{\underline{\delta}}$ initially. Larger values in the discount factor force this curve to shift down (not shown) because they create slack in the ICC, thereby boosting discipline. (See also Fig. $(A.1a)$ in Appendix A for details.) The peak of this curve is attained at $t = t_y$ (i.e., at the lowest internal trade cost level that eliminates cross hauling that is consistent with a binding ICC), thus affirming the point in part $(a.i)$ that cartel discipline is weakest at t_y. Cartel discipline is strongest at the global minimum which in the context of this curve is attained at $t_{\min}$, as noted in part $(a.ii)$. These findings, and the other parts of (a), are natural consequences of Lemmas $1 - 2$.

Fig. 3 also depicts the response of cartel discipline to changes in internal trade costs t considered in part (b). For t sufficiently close to $\bar{t}$, reductions in t do not affect Π^C because there is no cross hauling. In this case, these reductions boost cartel discipline as they intensify the severity of punishments ($\Pi^N \downarrow$) more than they raise deviation profits ($\Pi^D \uparrow$) in the ICC.[30] However, when internal costs fall below $t_{\min}$, further reductions in t weaken cartel discipline because the intensity of their impact on Π^N and Π^D gets reversed. Once t falls below t_y, so that cross hauling is viable, additional decreases in t always strengthen cartel discipline as the favorable impact on Π^C in the ICC dominates.

Part (c) explains how the presence of third-country markets and the possible expansion and/or promotion of trade opportunities there affect cartel discipline. A noteworthy insight of this part is that such opportunities strengthen cartel discipline if internal trade costs are sufficiently low but may weaken it if these costs are large enough. This point can be visualized with the help of Fig. 3 (b), where the dotted-line curve is associated with $\tau > 0$ while the thick, solid-line curve arises when $\tau = 0$. Clearly, the reduction in τ rotates the curve in a clockwise fashion around the pivot point at G.[31] We hasten to add that changes in export opportunities to ROW do not affect cartel discipline at the "pivot" points A, G and E. (See Lemma $A2$ for details.) Importantly, all types of trade cost reductions promote cartel discipline if regional trade liberalization has already advanced significantly (i.e., t is sufficiently low). In light of the fact that many countries have favored preferential trading over the last three decades, this raises uncomfortable questions about the welfare consequences of deepening integration at any front. At the same time, one wonders how competition policy may matter in this context.

Proposition 2 places at a center stage a novel channel through which trade cost reductions affect equilibrium outcomes: cartel discipline. By paying close attention to the ICC, the proposition describes the determination of this discipline and explains how market characteristics and/or trade policies influence the behavior of firms. We now use these insights to study the implications for cartel output, shipments, and welfare.

[30] Would the analysis change if firms adopt more severe punishments? A natural case to consider is when cartel punishments eliminate global profits. In this case the most collusive outcome is sustainable for a larger range of discount factors. Perhaps more interestingly, one can show that all parts of Proposition 2 remain intact except this: θ^* no longer rises with increases in internal trade costs t when these costs are close to the prohibitive level $\bar{t}$.

[31] For additional details, see also Fig. $(A.1b)$ in Appendix A and the discussion in Lemmas $A1 - A3$. With the help of Lemma 2 one can show that $t'_g = t_g$ if $\delta < \underline{\delta}$ while $t'_g = \min\{t \mid \theta^{2*} = 0\}$ if $\delta \in [\underline{\delta}, \widehat{\delta}]$.

2.4 Cartel Output and Shipments

In this section we study the dependence of cartel shipments to all markets on trade costs, time preferences and export opportunities to ROW. Among other things, this also prepares the ground for our analysis of welfare.

Prior to the determination of cartel discipline, we showed that Q^i $(i = 1, 2)$ is decreasing in internal trade costs t but increasing and concave in θ. Thus, Q^i is maximized at $(t, \theta) = (0, 1)$ (which coincides with the Cournot-Nash output Q^N under internally free trade) and minimized at $\theta = 0$ (which coincides with output Q^M under maximal collusion). But when cartel discipline is endogenous, the discovery of the traits of Q^* requires a deeper investigation. Proposition 2 helps address this issue. In this proposition we argued that θ^* is increasing in internal trade costs t when these costs permit cross hauling (i.e., $y^* > 0$) and possibly when t is very large (close to $\bar{t}$). This suggests that the initial level of internal trade barriers affects the dependence of Q^* on t. We clarify this relationship in Proposition 3 that follows. In this proposition, we also discuss the role of time preferences and export opportunities to ROW. At the same time, we unveil several noteworthy traits of internal and external trade volumes: y^* and z^*, respectively.

Proposition 3 *(Output and Shipments) For given $\delta < \widehat{\delta}$, $t < \bar{t}$, and $\beta < \infty$, output Q^* and shipments y^* and z^* depend on time preferences, trade costs, and market size as follows:*

a) ***Output*** **(Q^*)**

i) $\lim_{t \to 0} dQ^*/dt \gtreqless 0$ *if* $\delta \gtreqless \underline{\delta}$ *for* $\delta \in (0, \widehat{\delta})$*;* $dQ^*/dt < 0$ *for* $t > t_y$ *but close to* t_y*.*

ii) If $\delta \in [\underline{\delta}, \widehat{\delta})$*, then* Q^* *attains*

- *a unique maximum* $Q^*_{\max} > Q^M$ *at some* $t_Q \in (0, t_y]$*;* $t_Q = t_y$ *for* δ *close to* $\widehat{\delta}$*;*
- *the monopoly output* Q^M *at* $t = 0$ *and at any* $t \geq \underline{t}'_m$*, where* $\underline{t}'_m > t_y$*.*

iii) If $\delta \in (0, \underline{\delta})$*, then* Q^*

- *may have multiple peaks, including one at* $t = 0$*, another peak in* $(0, t_y]$*, and possibly a third one at some* t *close to* $\bar{t}$*;* $t_Q = 0$ *if export opportunities to ROW are extensive;*
- *equals* Q^M *for* $t \in [\underline{t}_m, \bar{t}_m]$ *if* $\delta \in [\underline{\underline{\delta}}, \underline{\delta})$*.*

iv) Time preferences and export opportunities to ROW affect Q^* *solely through cartel discipline; thus* $sign\,(dQ^*/d\xi) = sign\,(\partial\theta^*/\partial\xi)$ *for* $\xi \in \{\delta, \beta, \tau\}$*.*

b) ***Internal Trade*** $(\boldsymbol{y^*})$*: For* $t \in (0, t_y)$*, the volume of internal trade* y^* *rises with*

i) decreases in internal trade costs $(t \downarrow)$ *and/or the discount factor* $(\delta \downarrow)$ *;*

ii) improvements in export opportunities to ROW $(\beta \downarrow$ *or* $\tau \downarrow)$ *iff these improvements weaken cartel discipline.*

c) ***External Trade*** $(\boldsymbol{z^*})$*: The volume of trade with ROW* z^* *rises with*

i) decreases in the discount factor $(\delta \downarrow)$*;*

ii) improvements in export opportunities to ROW $(\beta \downarrow$ *or* $\tau \downarrow)$*;*

iii) decreases in internal trade costs $(t \downarrow)$ *iff these reductions weaken cartel discipline.*

Part $(a.i)$ highlights several general traits of the dependence of Q^* on internal trade costs t. Provided the initial level of t is sufficiently low, output Q^* falls with reductions in t for $\delta \in [\underline{\delta}, \widehat{\delta})$ but rises with such reductions if $\delta \in (0, \underline{\delta})$. In the former case, this is so because the contractionary effect of the incipient strengthening in cartel discipline $(\theta^* \downarrow)$ due to trade cost reductions $(t \downarrow)$ dominates its direct and expansionary effect of t on Q^*. Exactly the opposite is true in the latter case. In part $(a.i)$ we also point out that if internal trade costs are high enough to eliminate cross hauling, then $dQ^*/dt < 0$ for t sufficiently close to the prohibitive trade cost level t_y. The logic behind this finding is based on Proposition 2 $(b.ii)$, which explains that the disciplinary and direct effects of t on Q^* move in the same direction.

Parts $(a.ii)$ and $(a.iii)$ of Proposition 3 elaborate further on the nature of the dependence of Q^* on t. Suppose $\delta \in [\underline{\delta}, \widehat{\delta})$ and $t < t_y$, so that cross-hauling is economically meaningful. Part $(a.ii)$ shows that, if δ is close to $\widehat{\delta}$ (which materializes if δ rises or export opportunities to ROW expand sufficiently), then $t_Q = t_y$, so Q^* is decreasing in t for $t < t_y$. Panel (a) of Fig. 4 depicts this possibility. In contrast, part $(a.iii)$ suggests that if the discount factor is sufficiently low then $dQ^*/dt < 0$ for $t < t_y$ and $t_Q = 0$, as shown in Fig. 4 (c). Panel (b) of Fig. 4 illustrates that Q^* may have multiple peaks in t when the discount factor assumes other intermediate values.

Part $(a.iv)$ argues that parameters (δ, β, τ) influence Q^* solely through their impact on cartel discipline θ^*, an effect that is simply absent in static analyses. To see this, consider the consequences of a reduction in external trade costs $(\tau \downarrow)$ when t is sufficiently low. Because such reductions strengthen cartel discipline ($\theta^* \downarrow$ by Proposition 2 (d)), local output Q^* necessarily falls. (As noted,

this possibility also arises even when cross hauling is absent.) By the same logic, $dQ^*/d\delta \leq 0$ because increases in δ do not weaken cartel discipline.

Part (b) sheds light on the behavior of internal trade y^*. Reductions in internal trade costs t expand y^* because their favorable (and direct) effect outweighs the negative (and indirect) effect due to improved cartel discipline. The dependence of y^* on all other parameters hinges solely on their effect on cartel discipline. For instance, because $\partial y^*/\partial\theta > 0$ and $d\theta^*/d\delta < 0$, larger discount factor values reduce internal trade. In contrast, y^* shrinks in response to external trade cost reductions ($\tau \downarrow$) and/or to increases in ROW's market ($\beta \downarrow$) as both strengthen cartel discipline (for $t < t_y$).

Part (c) focuses on the volume of external trade z^*. The logic to the findings in this part is similar to that in part (b), so we only discuss the significance of internal trade cost reductions ($t \downarrow$). Once again, this effect is transmitted exclusively through cartel discipline and is at work regardless of whether cross hauling is present or not. Interestingly, if cross hauling is present, then reductions in t divert external trade because they improve cartel discipline. In contrast, if cross hauling is absent and t is close to t_y, reductions in t promote external trade. These insights and the ones in parts (a) and (b) place at a center stage the strategic linkages among markets via cartel discipline through the ICC. In the next section, we explore the importance of these insights for welfare.

2.5 Welfare

The adjustments in cartel shipments due to changes in trade costs are of interest in their own right. In this section we demonstrate that, when cartel discipline is endogenous, the dependence of welfare on trade costs is richer and more nuanced than static analyses suggest.

Suppose t and τ in $(C1) - (C3)$ are interpreted as transportation costs. One can show that in this case the welfare level of a cartel host is the sum of consumer surplus and cartel profits in ROW, minus the waste in shipping goods internally; that is, $V = u(Q) + \pi_{ROW}(z; \beta, \tau) - ty$.[32] Similarly, welfare in ROW is $V_{ROW} = CS_{ROW}(z; \beta) = 2\beta z^2$.[33]

Now suppose t represents a (reciprocal) tariff on intra-industry trade. In this case, the relevant welfare levels become

[32] This is so because $V = CS + \Pi^C$, where $CS = u(Q) - pQ$ and $\Pi^C = pQ - ty + \pi_{ROW}$ for $Q \equiv x + y$.

[33] Welfare in ROW coincides with consumer surplus as there is no local production. CS_{ROW} is increasing and convex in z.

$$W = V + ty = u(\cdot) + \pi_{ROW}(\cdot), \tag{13a}$$

$$W_{ROW} = V_{ROW} = CS_{ROW}(\cdot). \tag{13b}$$

Clearly, $W \geq V$ for $y \geq 0$ due to tariff revenues. In the remainder of this section, we interpret t as a tariff for the following reasons. *First*, because this simplifies the welfare analysis as changes in t and δ are transmitted solely through their effects on Q and z. Further, because tariffs generate an upper bound on the welfare levels of cartel hosts (due to tariff revenues), their analysis also sheds light on the welfare implications of transportation costs. *Second*, reductions in t contain valuable information on the welfare effects of tariff cuts in preferential trade agreements. *Third*, the analysis of tariffs illustrates how constrained collusive outcomes compare, in terms of welfare, to outcomes typically studied in Cournot-Nash competition and pure monopoly.[34]

Differentiation of (13) with respect to Q and z gives

$$dW = pdQ + (\partial\pi_{ROW}/\partial z)\, dz, \tag{14a}$$

$$dW_{ROW} = (4\beta z)\, dz \tag{14b}$$

where $W_Q = p > 0$, $W_z = \partial\pi_{ROW}/\partial z < 0$ for $z > z^M$, and $\partial\pi_{ROW}/\partial\xi < 0$ for $\xi \in \{\beta, \tau\}$. It it thus clear from (14a) that increases (decreases) in Q (z) improve a cartel host's welfare W by expanding $u(Q)$ ($\pi_{ROW}(z)$). In contrast, (14b) affirms that increases in z improve welfare in ROW.[35]

When the ICC binds, the direction of change in W^* is a mix of the changes in Q^* and z^* described in Proposition 3. As a benchmark, let us temporarily assume the absence of ROW (i.e., $\beta \to \infty$ or $\tau \geq \bar{\tau}$), so that only the effect on consumer surplus matters for cartel hosts. How would a reduction in t affect W^* in this case? Since the behavior of W^* is determined solely by the behavior of Q^*, the answer follows from Proposition 3 (a) and can be illustrated with the blue curves in the three panels of Fig. 4 which depict the effect of t on Q^*. Fig. 5 (a) combines these

[34] See Lemma $A5$ in Appendix A for an analysis of W^N. Since, as noted in Section 2.1, reductions in t always cause domestic output Q^N to rise, reciprocal tariff cuts always enhance welfare in the standard, segmented markets model. However, when t is identified with transportation costs, welfare V^N is non-monotonic in t (Brander and Krugman, 1983). In contrast, W^N_{ROW} is invariant to changes in t because z^N is independent of t. In the case of pure monopoly, the nature of t is inconsequential because $y^M = 0$ for any $t > 0$. As a consequence, $V^M = W^M$ and $V^M_{ROW} = W^M_{ROW}$.

From the definitions of z^N and z^M, one can see that, if $\tau \geq \bar{\tau}$, then $W^N \geq W^M$ while $W^N_{ROW} = W^M_{ROW}$ for all $t \leq \bar{t}$. Thus, *in the case of tariffs*, competition weakly dominates monopoly under isolation from ROW. However, as detailed in Lemma $A6$, $\pi^M_{ROW} > \pi^N_{ROW}$ for $\tau < \bar{\tau}$. Depending on the relative size of these profits, cartel hosts may find monopoly more appealing than competition. There exists a threshold $\breve{\beta}(t, \tau)$ such that $W^M \gtreqless W^N$ for $\beta \lesseqgtr \breve{\beta}$.

[35] Since $u = AQ - \frac{1}{2}Q^2$ and $\pi_{ROW} = (A - \tau - 2\beta z)\, z$, u and π_{ROW} are concave in Q and z. W_{ROW} is convex in z.

ideas to offer a more comprehensive view of the dependence of W^* on t for several values of δ.

Let us now consider the importance of exporting to ROW (i.e., $\beta < \infty$ and $\tau < \bar{\tau}$). Suppose cross hauling is present ($t < t_y$). Because in this case reductions in t strengthen cartel discipline — causing z^* to fall — the presence of ROW enhances the welfare appeal of internal trade liberalization to cartel hosts through its positive effect on π^*_{ROW}. But, as noted in Lemma 1 (d), export opportunities to ROW also reduce the sensitivity of cartel discipline to internal trade liberalization which, in turn, affects output Q^*. Exactly how Q^* responds to reciprocal tariff cuts depends on time preferences and the relative size of ROW.[36] Increases in ROW's market ($\beta \downarrow$) and/or reductions in external trade costs ($\tau \downarrow$) also exert a direct and positive effect on π_{ROW} and thus on W^*.

Does the presence of ROW eliminate the potentially harmful effects of internal trade liberalization of welfare of cartel hosts? As noted in Proposition 4, the short answer is NO. If $\delta \in (\underline{\delta}, \widehat{\delta})$ and the level of t is sufficiently "low" (due to past successes in liberalizing trade preferentially), then W^* necessarily falls! Why? Because the impact of t on W^* through π_{ROW} is negligible (as $\theta^* \to 0$ and $z \to z^M$) and the effect on W^* through Q^* is negative (Proposition 3 $(a.i)$). Fig. 5(b) helps visualize this point.[37] This figure also illustrates that, unlike the case of no exporting to ROW, it is now possible for W^* to rise with increases in δ.[38] Lastly, Fig. 5 (b) sheds light on the dependence of W^* on t when cross hauling is absent ($t \geq t_y$). Clearly, this is a complex relationship. The driving force behind it is the non-monotonic dependence of cartel discipline θ^* and internal costs t.

What about welfare in ROW? From (14b), the effect of t on W^*_{ROW} is determined by the dependence of z^* on t. But, as we have already seen (Proposition 3(c)), the direction of change in z^* coincides with the direction of change in cartel discipline θ^*. For clarity, we summarize and extend the above ideas as follows:

Proposition 4 *(Welfare) Under endogenous cartel discipline, ROW welfare, W^*_{ROW}, and welfare of the representative cartel host, W^*, have the following traits:*

a) Regional trade liberalization ($t \downarrow$) reduces ROW welfare ($W^*_{ROW} \downarrow$) if cross hauling is present

[36] For clarity, we highlight this issue in the various panels in Fig. 4 which depict how the dependence of Q^* on t.

[37] Interestingly, and in contrast to the case of no trade with ROW, the possibility that W^* may fall with reductions in t also arises even in the absence of cross hauling.

[38] The various panels in Fig. 6 provide a detailed account of how a cartel host's welfare W^* depends on the discount factor δ and ROW size β at the following tariff levels: $t = 0$, $t = t_y$, $t = t_g$, and $t = \bar{t}$. (Recall that Fig. 3 provides a graphical explanation of these trade costs and their relevance for cartel discipline.) Again, as a benchmark, panel (a) abstracts from the presence of ROW, whereas panels (b) and (c) consider the presence of trade with ROW. The difference between the last two panels is that ROW's market is relatively larger in the last panel.

and possibly if t is sufficiently large.

b) If regional trade liberalization has already advanced substantially (i.e., t is "low"), then the deepening of regional integration ($t \downarrow$):

i) necessarily reduces welfare of cartel hosts ($W^* \downarrow$) if $\delta \in (\underline{\delta}, \widehat{\delta})$;

ii) improves welfare of cartel hosts ($W^* \uparrow$) if $\delta \in (0, \underline{\delta})$.

c) Welfare of a cartel host W^* is non-monotonic in δ if export opportunities to ROW are large.

d) If the market of ROW is sufficiently large, then constrained collusion may improve welfare of cartel hosts beyond the levels associated with Cournot-Nash competition and pure monopoly; that is, $W^* > \max\left[W^N, W^M\right]$.

Among other things, part (a) emphasizes the idea that preferential trade liberalization unambiguously hurts ROW when cross hauling is present ($y^* > 0$). The driving force behind this finding is the impact of t on consumer surplus in ROW through its effect on cartel discipline. This novel insight — which the canonical theory oversees — underscores the importance of strategic market linkages due to the ICC. The lesson is clear: PTAs threaten ROW's interests. Corrective antitrust policy in ROW could rectify the problem.

Part (b) takes a closer look on how the deepening of regional integration affects welfare of cartel hosts when t has already been reduced substantially. This type of trade liberalization hurts cartel hosts if δ is sufficiently large (but not large enough to support maximal collusion). There is a certain irony to this. Even though the size of cartel rents in ROW is large at such δ values, the adverse welfare effect of reductions in t on output Q^* plays a dominant role! But, as noted in part (a), the exploitation of the cartel's market power in ROW also harms ROW. We thus arrive at

Corollary 1 *If $\delta \in (\underline{\delta}, \widehat{\delta})$, then the deepening of integration in preferential trade agreements that have already reduced internal trade costs substantially is welfare-reducing in the Pareto sense.*

The above corollary is a novel contribution to the literature on preferential trade agreements. Turned on its head, the corollary reveals that the absence or outright prohibition of trade between cartel hosts is Pareto superior to regional trade agreements that aim to dismantle *virtually all* barriers to internal trade. But Customs Unions and Free Trade Areas do in fact aim to remove all such barriers. Moreover, Article 24 of the World Trade Organization (WTO) codifies this as a

key objective of preferential trade agreements. Strikingly, then, in the absence of joint competition policy to address this issue, regional trade liberalization may reduce world efficiency.

Nevertheless, part (b) of Proposition 4 suggests that the deepening of regional integration enhances welfare of cartel hosts if δ is sufficiently small. In this case reductions in t raise domestic welfare through Q^* and expand cartel profits in ROW through z^*. This is clearly a case, then, where the welfare interests of cartel hosts collide with the interests of ROW. This could also help explain the potential difficulties policymakers face in coordinating antitrust policy at the multilateral level.

Part (c) reveals that, in sharp contrast to the case where ROW is absent, a cartel host's welfare may rise with increases in δ. Focusing on the more interesting case of low t, a sufficient (though hardly necessary) condition for this eventuality is that output Q^* rises with increases in δ.[39] But, as we have already seen, this is exactly what happens when δ is sufficiently low. However, because $dQ^*/d\delta < 0$ for δ sufficiently close to $\widehat{\delta}$ and, moreover, the impact of δ on π_{ROW} is negligible when t is sufficiently low, $dW^*/d\delta < 0$ in this case. As noted earlier, the various panels in Fig. 6 provide a more precise view of this idea for the case of no barriers to cross hauling ($t = 0$). These panels also clarify how the size of ROW's market matters in this context.

Part (d) emphasizes the idea that the presence of the cartel could enhance welfare of its hosts. One novel aspect of this part is that it clarifies how export opportunities to ROW (viz. β) matter. More interestingly, this part asserts that cartels may raise W^* not only beyond W^N (Auqier and Caves, 1979; Brander and Spencer, 1984), but also beyond W^M.[40] The non-monotonic curves in panels (b) and (c) of Fig. 6 illustrate that $W^* > \max\left[W^N, W^M\right]$ for certain ranges in δ.[41] Among other things, these panels also point out that fixing t at the prohibitive level t_y dominates the case of internally free trade for cartel hosts if δ is sufficiently large but below $\widehat{\delta}$. Again, we hasten to add that static analyses fail to capture these points because they abstract from incentive constraints.

[39] In this case, $dW^*/d\delta > 0$ because $dQ^*/d\delta > 0$ and $dz^*/d\delta \leq 0$ cause $u(Q)$ and $\pi_{ROW}(z)$ to rise, respectively.

[40] Once can also show that under some circumstances, constrained collusion may advance the welfare interests of all sides as compared to pure monopoly.

[41] Panels (b) and (c) also reveal that $W^N > \max\left[W^M, W^*\right]$ when the size of ROW's market is relatively small, whereas $W^M > \max\left[W^N, W^*\right]$ (for certain discount factor values) when ROW's size is sufficiently large.

3 Empirical Analysis

In this section we first translate some of the predictions of our theory into testable hypotheses. Then, we describe the econometric approach that we adopt and the dataset that we employ. We also present the main empirical results along with a series of robustness experiments.

3.1 From Theory to An Econometric Model

Our theory offers a rich set of predictions about the interactions between trade costs, trade liberalization, and multimarket collusion in the determination of internal and external trade. In addition to the standard effects of trade costs on trade, we uncover new channels through which trade costs have an indirect impact on trade, through cartel discipline. *Lemma 1* characterizes the relations between discipline and trade costs and translates them into the following testable hypotheses:[42]

- **H1:** Larger internal cartel trade costs ($t \uparrow$) should weaken cartel discipline ($\theta \uparrow$).
- **H2:** Larger external cartel trade costs ($\tau \uparrow$) should weaken cartel discipline ($\theta \uparrow$).

The relations between trade and cartel discipline are characterized by the optimal output allocations to the constrained cartel problem in equations (10c)-(10d), which imply:

- **H3:** Stronger cartel discipline ($\theta \downarrow$) should lead to less internal cartel shipments ($y \downarrow$).
- **H4:** Stronger cartel discipline ($\theta \downarrow$) should lead to less external cartel shipments ($z \downarrow$).

The key predictions of our theory, as summarized in hypotheses H1-H4, translate naturally into a two-stage econometric model. The first stage of the model captures the relations between cartel discipline and trade costs (hypotheses H1-H2). The second stage captures the impact of cartels and cartel discipline on internal and external cartel trade (hypotheses H3-H4).

3.1.1 Stage 1: Cartel Discipline and Trade Costs

Our theoretical analysis demonstrates that cartel discipline is an important determinant of cartel shipments and that it is in fact influenced by both internal and external trade costs. To the best of our knowledge, no direct measure of cartel discipline exists. Therefore, we construct several proxies for cartel discipline. The first proxy that we employ is cartel duration, and it is taken directly from

[42] In the econometric analysis, we limit our analysis to the empirically relevant case of positive internal trade.

the data. To construct the second proxy for cartel discipline, we rely on the intuitive assumption that weaker cartel discipline increases the probability of cartel dissolution. Accordingly, we expect that, among other factors, the effects of the key determinants of cartel discipline from our theory (e.g., internal and external trade costs) should also be important determinants of the probability of cartel 'death.' Thus, we evaluate their impact within an empirical cartel-duration specification, which we then use to construct several proxies for cartel discipline. An additional advantage of the two-step estimation approach is that it also enables us to address any potential endogeneity concerns related to cartel discipline if measured directly by cartel age. Specifically, cartel discipline is generated in the first-stage analysis in the presence of exclusion restrictions that are not likely to affect trade, and, consequently, used as a covariate in the second-stage estimations that link discipline to trade.

By introducing the link between trade costs and cartel duration our work contributes to a relatively young but exciting literature that studies the determinants of cartel 'success.'[43] Following this literature, we adopt the Cox Proportional Hazard model as our preferred first-stage estimator.[44] Applied to our setting, the hazard at time T, which denotes the elapsed time since the start date of the collusive period for cartel k in sector g, is:

$$h_k^g(T|\mathbf{COSTS_k^g}, \mathbf{DSPLN_k}, \mathbf{X_g}) = \mathbf{h_0(T)} \times \mathbf{exp}[\mathbf{COSTS_k^g}\alpha + \mathbf{DSPLN_k}\beta + \mathbf{X_g}\gamma]. \tag{15}$$

Here, $h_0(T)$ denotes the baseline hazard function that is common to all units in the population, and the exponential term captures the relative risk, a proportionate increase/decrease in risk, associated with the set of characteristics $\mathbf{COSTS_k^g}$, $\mathbf{DSPLN_k}$, and $\mathbf{X_g}$.

$\mathbf{COSTS_k^g}$ indicates the vector of internal and external trade costs, which are intended to reflect the key predictions of our theory. In accordance with hypotheses H1 and H2, we expect that larger trade costs (both internal and external) should weaken cartel discipline and, therefore, are likely to contribute (positively) to cartel dissolution. Thus, we expect to obtain positive coefficient estimates, $\hat{\alpha}$, of the effects of the covariates in vector $\mathbf{COSTS_k^g}$. Our most preferred trade cost proxy is distance and we distinguish between internal ($DIST_INTRL$) and external ($DIST_EXTRL$)

[43] Representative studies from this strand of the literature include Connor et al. (2013), Zhou (2012), Levenstein and Suslow (2010), and Dick (1996). We discuss these studies in the literature review.

[44] Cox's (1972) Proportional Hazard model is appealing as it allows the effects of the predictor variables to be estimated quite generally without making any distributional assumptions about the hazard function. The Cox model is the most widely used estimator in the cartel duration literature (Zhou, 2012, Levenstein et al., 2010, Dick, 1996).

cartel distance.[45] In addition, in the empirical analysis we also experiment with appropriately aggregated internal tariffs ($TRFF_INTRL$), external tariffs ($TRFF_EXTRL$), internal and external tariff percentage changes ($\Delta\%TRFF_INTRL$ and $\Delta\%TRFF_EXTRL$) as proxies for trade costs and trade liberalization. A list of all trade cost covariates appears in the first column of Table 1. Details on the construction of the trade cost aggregates can be found in Appendix B.

$\mathbf{DSPLN_k}$ denotes a vector of cartel characteristics and collusive practices, which we believe may impact cartel discipline in addition to trade costs. A list of these variables appears in the first column of Table 1, and many of them have been used in the cartel duration literature. A detailed description of each of these variables, their use in the literature, and construction, can be found in the Data Appendix. $\mathbf{X_g}$ denotes a vector of industry fixed effects, which control for any observable and unobservable determinants of cater duration that might be omitted from our specification.

We employ the estimates of $\{\alpha, \beta, \gamma\}$ along with data on the corresponding covariates to construct several measures of cartel discipline, which are used to test hypotheses H3 and H4 in the second-stage analysis. Our most preferred measure of cartel discipline is constructed from the covariates that are directly related to discipline. Moreover, since the predicted hazard indexes in our model reflect the probability of cartel dissolution, we take the inverse of the hazard predictions to construct the following proxy for discipline:

$$DISCIPLINE_k^g = 1/exp[\mathbf{COSTS_k^g}\hat{\alpha} + \mathbf{DSPLN_k}\hat{\beta}] \tag{16}$$

We use this measure of discipline to obtain our main results. We also experiment with several other proxies for discipline. The first proxy for discipline is a 'conservative' measure, which omits $\mathbf{DSPLN_k^g}\hat{\beta}$ from specification (16), and is constructed exclusively based on our theoretical predictions. The second proxy for discipline takes into consideration only the significant regressors from equation (15). We dub the third measure 'liberal', as it is constructed from all covariates in equation (15). Finally, as discussed earlier, we also employ directly the measure of cartel duration from our raw data as an additional proxy for cartel discipline. Armed with these cartel discipline proxies, we proceed to examine the impact of cartel discipline on (internal and external) trade.

[45] Besides being the most robust and the most widely used determinant of trade costs (Anderson and van Wincoop, 2004, and Head and Mayer, 2014), the distance covariate has the advantage of being exogenous, by definition. In the current context because, as discussed in Zhou (2012), many of the covariates in the cartel duration literature are subject to endogeneity concerns. Finally, distance data are widely available and there are well-established methods to construct consistent distance measures within and across regions (Mayer and Zignago, 2011). These methods are particularly useful for our study as we need to construct measures for internal and for external cartel distance.

3.1.2 Stage 2: Trade Flows, Cartels, and Cartel Discipline

To study the effects of cartel discipline on trade flows, we employ a reduced-form gravity-type empirical specification, which we amend to capture the predictions of our theory:[46]

$$\ln X_{ij,t}^{k,g} = \mathbf{CARTEL_{ij,t}^{k,g}}\tilde{\alpha} + \mathbf{CARTEL_DISCIPLINE^{k,g}}\tilde{\beta} + \mathbf{GRAV_{ij,t}^{k,g}}\tilde{\gamma} + \mathbf{FES_{ij,t}^{g}} + \tilde{\epsilon}_{\mathbf{ij,t}}^{\mathbf{k,g}}. \quad (17)$$

Here, $X_{ij}^{k,g}$ denotes bilateral trade flows between exporter i and importer j in year t for cartel k in product category g. $CARTEL_{ij,t}^{k,g}$ is a vector of indicator variables that capture the presence of cartels. While our theory does not model cartel formation and does not generate predictions about the effects of cartels on trade flows, cartels exist and, therefore, we control for their existence in our estimations. We use several cartel variables, including: $CRTL_INTRNL_{ij,t}^{k,g}$, which is an indicator variable that takes the value of one if country i and country j both participate in cartel k in sector g at time t; $CRTL_EXTRNL_{i-j,t}^{k,g}$ is an indicator equal to one for exports from cartel member i to a third market $-j$ in sector g at time t; and $CRTL_{ij,t}^{k,g}$, which is defined as the sum of $CRTL_INTRNL_{ij,t}^{k,g}$ and $CRTL_EXTRNL_{i-j,t}^{k,g}$.

$CARTEL_DISCIPLINE^{k,g}$ is a vector of covariates that capture the effects of cartel discipline on trade. We distinguish between three alternative measures of cartel discipline, including: $CRTL_DSCPLN_INTRNL_{ij,t}^{k,g}$, defined as the product of our measure of discipline, $DISCIPLINE_k$, and $CRTL_INTRNL_{ij,t}^{k,g}$; $CRTL_DSCPLN_EXTRNL_{i-j,t}^{k,g}$, defined as the product of our measure of discipline, $DISCIPLINE_k$, and $CRTL_EXTRNL_{i-j,t}^{k,g}$; and $CRTL_DSCPLN_{ij,t}^{k,g}$, defined as the sum of $CRTL_DSCPLN_INTRNL_{ij,t}^{k,g}$ and $CRTL_DSCPLN_EXTRNL_{i-j,t}^{k,g}$. Our theory predicts that the estimates of the effects of each of the discipline covariates should be negative, reflecting the inverse relation between cartel discipline and cartel trade.

$GRAV_{ij,t}^{k,g}$ captures a series of covariates used routinely as determinants of bilateral trade flows in the gravity literature (Anderson and van Wincoop, 2004, Head and Mayer, 2014). Specifically, these include: the logarithm of bilateral distance, $DIST_{ij}$; a binary variable that takes the value of one if i and j share a contiguous border, $CNTG_{ij}$; a binary variable, which takes the value of one if i and j share colonial ties, $CLNY_{ij}$; a binary variable, which takes the value of one if i and j share a common language, $LANG_{ij}$; a binary variable, which takes the value of one if i and j have a regional

[46] The empirical gravity model of trade is viewed as the workhorse and most successful empirical model in international economics and it naturally lends itself to accommodating the impact of international cartels.

trade agreement at time t, $RTA_{ij,t}$; and a measure of bilateral tariffs $TARIFFS_{ij,t}^{k,g} = \ln(1 + \tau_{ij,t}^{k,g})$, where $\tau_{ij,t}^{k,g}$ is the ad-valorem tariff on imports in class g in country j from country i at time t. Finally, $FES_{ij,t}^{g}$ is the vector of fixed effects that will be employed in our estimations.

3.2 Data

To perform the empirical analysis, we compile a novel dataset that covers the period 1988-2012 for the 34 members of the Organization for Economic Co-operation and Development (OECD) at the 6-digit Harmonized System (HS) level. The 6-digit HS product level is the most disaggregated level for which there exist internationally consistent data on bilateral trade flows.[47] Availability of trade flows data limits the period of investigation to 1988-2012. We focus on the OECD countries for the following reasons. First, bilateral trade data at the 6-digit HS level of aggregation are more reliable for OECD nations. Second, 165 of the 173 cartels in the original dataset include participants exclusively from OECD countries. Third, trade between OECD countries accounts for about two-thirds of world trade. Finally, non-cartel OECD countries represent the most appropriate reference group for our analysis. Our sample combines data on International Cartels, including Cartel Characteristics, Collusive Practices, Causes of Cartel Death, Other Cartel-Related Variables, as well as data on Bilateral Trade Flows and Bilateral Trade Costs. For brevity, we delegate the summary statistics, the detailed description of the data sources, and the construction of the variables that we employ in our analysis to the supplementary Data Appendix B.

3.3 Estimation Results

Following the structure of our two-stage econometric model, we present our empirical findings in two steps. First, we study the relation between (internal and external) trade costs and cartel discipline. Then, we focus on the effects of cartel discipline on (internal and external) trade.

3.3.1 On the Effects of Trade Costs on Cartel Discipline

A natural starting point for the first-stage analysis is to construct Kaplan-Meier curves, which depict the shape of the survival functions and their relation to each other as influenced by predictors from our theory. Since all of our trade cost measures are continuous, we transform each of them into indicator variables that take the value of one for values above the mean and are zero otherwise. For

[47] It is encouraging to note that, on average, cartels in our sample controlled about 82% of the relevant market.

brevity, we delegate the Kaplan-Meier figures to the supplementary appendix (see Fig. 8), but we note here that the curves for internal and external distance are rather parallel, except in the very beginning and toward the end of the period. The visual results from Fig. 8 are reinforced by the p-values from log-rank tests of equality across strata: 0.0227 for internal distance and 0.0003 for external distance. The graphs for tariffs are not as parallel and overlap at some points, however, the log-rank test p-values (0.0544 and 0.0492 for internal and external tariffs, respectively) reject equality across strata. In sum, the preliminary analysis offers encouraging evidence that trade costs are important predictors of cartel discipline and should be included in our econometric model.

Estimates from a series of Cox proportional hazard regressions that gradually introduce our main regressors and covariates are presented in Table 1. In the first four columns of the table, we experiment by sequentially introducing our proxies for trade costs. In column (1), we use the logarithm of internal distance, $DIST_INTRL$, as the only covariate. The positive and significant estimate $DIST_INTRL = 0.141$ (std.err. 0.044) suggests that larger internal trade costs contribute to the dissolution of cartels. This result is exactly in accordance with our theory, which predicts that larger internal trade costs should be associated with weaker cartel discipline. Similar results are obtained in column (2) of Table 1, where we also add internal tariffs, $TRFF_INTRL$. Larger tariffs on trade between cartel members weaken cartel discipline. The estimates of the effects of external trade costs, as measured by external distance, in column (3), and by external distance and external tariffs, in column (4), are also consistent with our theory. Specifically, the positive and significant estimates on $DIST_EXTRL$ and $TRFF_EXTRL$ suggest that higher external trade costs lead to weaker cartel discipline and, therefore, increase the probability of cartel dissolution.

We combine all trade cost measures in a single specification in column (5) of Table 1. Three of the four trade costs estimates are positive and statistically significant as predicted by theory. The only estimate that loses significance is on external tariffs. A possible explanation for this result is that tariffs are no longer such a prominent determinant of trade costs as they were in the past, especially among the OECD countries in our sample. Nevertheless, we still obtain a positive and significant effect of internal tariffs on cartel discipline. This motivated us to push the analysis further by including two additional covariates, $\Delta\%TRFF_INTRL$ and $\Delta\%TRFF_EXTRL$, which are constructed as percentage changes in internal and external tariffs, respectively. The estimates

in column (6) reveal that the changes in tariffs are not significant determinants of cartel discipline.

Motivated by the existing literature on cartel duration, in column (7) of Table 1 we introduce a series of additional covariates that may be important determinants of cartel discipline. We find evidence that some of the additional regressors are indeed significant. For example, our estimates suggest that using price-fixing collusive strategies has a positive and significant effect on the risk of cartel death. This is consistent with Dick (1996). We also find that the more pronounced the cultural diversity of a cartel, the higher the hazard of dissolution. This is in line with the results from Connor et al. (2013). On the other hand, setting up sales quotas or allocating markets are both negatively related to the risk of cartel break-up, which confirms the findings from Levenstein and Suslow (2010). In accordance with the existing literature, e.g., Connor et al. (2013), we find that cartel discovery varies by region.[48] Finally, our results suggest that bid-rigging as a collusive practice exerts a positive and significant impact on the hazard of dissolution, contrary to the estimates of Connor et al. (2013). The remainder of the cartel controls from our specification do not have a statistically significant effect on cartel discipline.[49] Most importantly for our purposes, the effects of trade costs on cartel discipline remain positive and statistically significant even in the presence of a large number of relevant control variables.

We finish this section with a series of sensitivity checks. For brevity, here we only list the experiments, and we refer the reader to Appendix C for further details. First, we use different proxies for trade costs as the key covariates in our analysis: 1) GDP-weighted distances; 2) population-weighted distances, constructed using bilateral distance, instead of the inverse of bilateral distance; and 3) only internal and external distances without including the tariff measures. Second, we vary our definition of cartel outsider from liberal to conservative by defining an external market to be one where: 1) at least one of the cartel members exports to; 2) three or more cartel members meet; and 3) all cartel members simultaneously export to. Third, we employ the initial effectively applied tariffs and also experiment with most favored nation tariffs, instead of the effectively applied tariffs. Fourth, we add sector fixed effects to our main specification. Our main results remain qualitatively

[48] Connor et al. (2013) include only three dummy variables to control for the region of discovery – U.S., E.U., and other in their case – and find them all to decrease the risk of cartel dissolution.

[49] This is not surprising as it is often the case in the cartel duration literature that different studies find opposing effects for the same covariate. For example, Connor et al. (2013) and Levenstein and Suslow (2010) find the number of cartel members to exert a positive, but mostly insignificant, impact on the hazard rate. On the other hand, Dick (1996) and in Zhou (2012), find that the number of cartel members has a negative and statistically significant impact on the hazard of dissolution.

unchanged and quantitatively very similar in all of the above experiments. Thus, we conclude that the analysis from this section offers robust empirical evidence that both internal and external trade costs are positively related to the hazard of cartel dissolution and, therefore, lends strong support for our theoretical predictions about the relation between trade costs and cartel discipline. Encouraged by these findings, we construct the measures of cartel discipline that we describe in Section 3.1.1, and we use them to study the impact of cartel discipline on trade.

3.3.2 On the Effects of Cartel Discipline on International Trade

Column (1) of Table 2 reports the results from a standard gravity specification that does not include our new covariates. The estimates are obtained with the OLS estimator and exporter, importer, sector, and time fixed effects.[50] Standard errors are clustered by country pair. Without going into details, we note that the results from column (1) are as expected. We obtain a negative and significant estimate of the effect of bilateral distance ($DIST$), and positive and significant estimates of the effects of contiguity ($CNTG$), sharing a colonial relation ($CLNY$), and participation in a regional trade agreement (RTA). The only insignificant estimate in column (1) is of the effect of common language. In terms of magnitude, our estimates are comparable to the summary meta-analysis indexes from Head and Mayer, 2014. Finally, with an $R^2 = 0.78$, the trade model delivers a strong fit. Overall, the estimates from column (1) are very similar to their counterparts from the literature, and we interpret this as evidence of the representativeness of our sample.

We introduce two additional covariates in column (2) Table 2. As defined in Section 3.1, $CRTL$ is an indicator variable that takes a value of one for exports by cartel members. This specification imposes a common effect of cartels on internal and external trade. $CRTL_DSCPLN$ is the interaction between $CRTL$ and our most preferred measure of cartel discipline, which is constructed from the trade cost covariates and from the other determinants of cartel discipline using the first-stage estimates from column (7) of Table 1 and actual data. Since $CRTL_DSCPLN$ is a generated regressor, the standard errors in column (2), as well as the standard errors in all remaining columns of Table 2, are bootstrapped. Two results stand out from column (2). First, we obtain a large, positive, and highly statistically significant estimate on $CRTL$. This result

[50] Later in this section and in the robustness analysis we experiment with alternative sets of fixed effects and with an alternative estimator, the Poisson Pseudo Maximum Likelihood (PPML) estimator.

suggests that international cartels promote trade. Even though cartels are exogenous in our theory, which does not generate predictions about the effects of cartel existence on trade, we find this result quite intriguing as it reveals a potential channel through which international cartels may in fact improve welfare by stimulating trade. Second, we obtain a negative and also very precisely estimated effect of cartel discipline on trade. This result supports the predictions of our theory. Finally, the estimates of all standard trade cost covariates (e.g. distance, colony, etc.) are robust to the introduction of the new cartel variables.

We investigate separately the effects of cartels and cartel discipline on internal and external trade in column (3) of Table 2. All four cartel variables are statistically significant at any conventional level. The positive estimates on $CRTL_INTRNL$ and $CRTL_EXTRNL$ suggest that the presence of international cartels promotes internal as well as external trade. In accordance with our theory, we obtain negative estimates of the effects of cartel discipline on internal trade, as evident from the estimate on $CRTL_DSCPLN_INTRNL$, and on external trade, as supported by the estimate on $CRTL_DSCPLN_EXTRNL$. Finally, our estimates reveal that the effects of cartels and cartel discipline are much stronger on internal trade than on external trade.

We view the estimates from column (4) of Table 2 as our main results because these indexes are obtained with a rich set of importer-time, exporter-time, and sector-time fixed effects that control for any observable and unobservable characteristics at these particular dimensions.[51] The key cartel estimates from column (4) are slightly smaller as compared to the corresponding numbers from column (2). However, the two sets of estimates are not statistically different from each other, and we note that the fit of the model improves only marginally. More importantly, all four cartel covariates retain their signs and magnitude, and remain statistically significant.

Finally, in column (5) of Table 2, we introduce 6-digit HS tariffs as an additional trade policy covariate. The reason for not including tariffs in the previous specifications is that data on tariffs are patchy and limited. This is confirmed in column (5), which reveals that the introduction of tariffs results in a loss of more than 20 percent of the observations in our main sample. Despite the smaller sample size, we find that the effects of tariffs on trade are negative and statistically significant as expected. In addition, and more important for our purposes, we see that the estimates

[51] In the robustness analysis, we also experiment by adding symmetric and asymmetric pair-fixed effects as well as exporter-product-time and importer-product-time fixed effects.

of all cartel covariates remain unchanged. In fact, the effects of each of the cartel variables are more precisely estimated in column (5) as compared to the main estimates from column (4).

We finish this section with a battery of sensitivity checks. First, we reproduce the results from columns (2)-(5) of Table 2 with cartel duration measured directly from our data, as a proxy for cartel discipline. The estimates from columns (6)-(9) are qualitatively identical to the corresponding numbers from columns (2)-(5). The effects of cartel discipline, as measured by cartel duration are about twice stronger. A possible explanation for the differing magnitudes could be the fact that, as discussed earlier, our two-step econometric model enables us to also account for possible endogeneity concerns with cartel discipline. It is encouraging, however, to find that the estimates on all the alternative proxies for cartel discipline have the same signs and are statistically significant.

For brevity, we only list the rest of the experiments. Our estimates along with an accompanying discussion are presented in Appendix C. First, we employ alternative proxies for cartel discipline, constructed using: 1) only the first-stage estimates of and actual data on our proxies for trade costs and trade liberalization (distance and effectively applied tariffs); 2) only the estimates of and data on the statistically significant controls for cartel discipline; and 3) all estimates of the determinants of cartel duration from the first stage. Second, we experiment with the definition of a cartel outsider by allowing an external market to be an importer that trades with: 1) at least one of the cartel members; 2) three or more cartel members; 3) all cartel members simultaneously. Third, we employ the Poisson Pseudo Maximum Likelihood (PPML) technique, which, as advocated by Santos-Silva and Tenreyro (2006), simultaneously accounts for the heteroskedasticity of trade data and the information contained in the zero trade flows. Fourth, we experiment with a rich set of fixed effects, including: 1) (symmetric) bilateral fixed effects, which not only control for all time-invariant impediments to trade, but also mitigate potential endogeneity concerns of our cartel variables; 2) asymmetric bilateral fixed effects; 3) exporter-product-time and importer-product-time fixed effects. Next, in addition to using exporter-product-time and importer-product-time fixed effects, we allow all bilateral trade costs to vary at the 6-digit HS level. We also experiment by eliminating duplicate observations from our sample, where several cartels exist simultaneously in a given sector. Lastly, we experiment with the sample size by: 1) including all cartels; and 2) employing 2-year, 3-year, and 5-year intervals. Our second-stage estimates remain robust to all

sensitivity tests and offer strong support that cartel discipline exerts a negative effect on trade.

4 Concluding Remarks

We consider a duopoly model in which firms collude implicitly due to repeated interactions and multimarket contact in their own as well as in third-country markets. As a consequence, collusion induces cartel members to treat their output decisions in all markets as interdepedent. In this setting, a primary objective of our work has been to identify, operationalize and substantiate the empirical relevance of this interdependence. We first identify the conditions on trade costs, the relative size of markets, and the salience of the future that ensure the sustainability of maximal collusion. Then, with the help of a simple index—related to the shadow price of the cartel's ICC—capturing cartel discipline, we elucidated the dependence of that discipline on fundamentals. This enabled us to pursue a second objective: to characterize, not just the direct effects of trade costs on shipments and welfare, but also their indirect effects through cartel discipline.

Among other things, our analysis reveals that reductions in internal trade costs (perhaps due to the implementation of preferential trade agreements) boost cartel discipline when cross hauling between cartel hosts is present. In turn, the strengthening of cartel discipline brings about external trade diversion which, inevitably, hurts ROW. But the diversion of external trade is not necessarily accompanied by expansion of local output in cartel hosts. In fact, depending on time preferences and the relative size of national markets, this output may also fall. Further, the reduction in consumers' well-being may overwhelm the expansion of profits in ROW to thereby reduce welfare of cartel hosts. In other words, regional trade liberalization may be welfare-reducing in the Pareto sense. Of course, this need not always be so if export opportunities to ROW are highly profitable. Our analysis also sheds light on how external trade costs affect cartel discipline and, through it, trade volumes and welfare. Last but not least, we show that constrained collusion itself may promote the welfare interests of cartel hosts more than (Cournot-Nash) competition and/or pure monopoly, the cases typically considered in canonical analyses.

Capitalizing on extensive data on international cartels and international trade, we test our hypotheses about the impact of trade costs on cartel discipline and the effect of cartel discipline on trade flows. In accordance with the theory, we find that both internal and external trade costs

are positively related to the hazard of cartel dissolution. We also demonstrate empirically that stronger cartel discipline impedes both internal and external trade, again in line with our theory. Finally, we establish a positive relation between the presence of cartels and trade, which uncovers a channel through which international cartels may actually be welfare-enhancing. We view this result worthy of further investigation.

The analysis can be extended in several other directions. First, one could study more severe punishments than the permanent reversion to the Nash equilibrium. The gist of our conclusions is preserved if one considers strategies that stipulate zero profits upon defection from the cartel agreement. Second, it is of interest to extend the analysis to study the presence of asymmetric trade costs. This is a challenging problem that requires modeling the disposition of profits among cartel members.[52] Third, we could allow for more than one firm per country to investigate how cartel discipline depends on economic integration. Fourth, our work currently abstracts from the implications of antitrust policy for cartel discipline and, in turn, for cartel shipments and national welfare. This is another avenue we plan to pursue in future projects.

References

[1] Akinbosoye, O., Bond, E.W. and C. Syropoulos. 2012. "On the Stability of Multimarket Collusion in Price-Setting Supergames," *International Journal of Industrial Organization*, vol. 30(2), pp. 253-264.

[2] Anderson, J. E., and E. van Wincoop. 2004. "Trade Costs," *Journal of Economic Literature*, vol. 42(3), pp. 691-751.

[3] Ashournia, D., Hansen, P.S., and J.W. Hansen. 2013. "Trade Liberalization and the Degree of Competition in International Duopoly," *Review of International Economics*, vol. 21(5).

[4] Auqier, A.A. and R.E. Caves. 1979. "Monopolistic Export Industries, Trade Taxes, and Optimal Competition Policy," *The Economic Journal*, vol. 89(355), pp. 559-581.

[5] Bejger, S. 2011. "Polish Cement Industry Cartel - Preliminary Examination of Collusion Existence," *BEH - Business and Economic Horizons*, vol. 4(1), pp. 88-107.

[52] See Vasconcelos (2005) and Bos and Harrington (2010) for important contributions in this direction.

[6] Bejger, S. 2012. "Cartel in the Indian Cement Industry: An Attempt to Identify It," *Economics Discussion Papers*, No. 2012-18, Kiel Institute for the World Economy.

[7] Bernheim, D.B. and M.D. Whinston. 1990. "Multimarket Contact and Collusive Behavior," *RAND Journal of Economics*, vol. 21(1), pp. 1-26.

[8] Bolotova, Y., J. M. Connor and D.J. Miller. 2008. "The Impact of Collusion on Price Behavior: Empirical Results from Two Recent Cases," *International Journal of Industrial Organization*, vol. 26, pp. 1290 - 1307.

[9] Bond, E.W. and C. Syropoulos. 2008. "Trade Costs and Multimarket Collusion," *RAND Journal of Economics*, vol. 39(4), pp. 1080-1104.

[10] Bos, I. and J.E. Harrington, Jr. 2010. "Endogenous Cartel Formation with Heterogeneous Firms," *RAND Journal of Economics*, vol. 41(1), pp. 92–117.

[11] Brander, J.A. and P. Krugman. 1983. "A Model of Reciprocal Dumping," *Journal of International Economics*, vol. 5, pp. 313-323.

[12] Brander, J.A. and J.B. Spencer. 1984. "Trade Warfare: Tariffs and Cartels," *Journal of International Economics*, vol. 16, pp. 227-242.

[13] Brenner, S. 2005. "An Empirical Study of the European Corporate Leniency Program," *International Journal of Industrial Organization*, vol. 27(6), pp. 639-645.

[14] Connor, J. M. 2001. "Our Customers are Our Enemies: The Lysine Cartel of 1992-1995," *Review of Industrial Organization*, vol. 18(1), pp. 5-21.

[15] Connor, J. M. 2003. "Private International Cartels: Effectiveness, Welfare, and Anticartel Enforcement," Working Paper 03-12, Purdue University, College of Agriculture.

[16] Connor, J. M. and J. Zimmerman. 2005. "Determinants of Cartel Duration: A Cross-Sectional Study of Modern Private International Cartels." Manuscript.

[17] Connor, J.M., R. M. Abrantes-Metz and A. D. Metz. 2013. "The Determinants of Cartel Duration." $http://papers.ssrn.com/sol3/papers.cfm?abstract_id = 2263782$.

[18] Cox, D. R. 1972. "Regression Models and Life-Tables (with Discussions)," *Journal of Royal Statistical Society*, Series B, 34, pp. 187-220.

[19] Davidson, C. 1984. "Cartel Stability and Tariff Policy," *Journal of International Economics*, vol. 17, pp. 219-237.

[20] Deltas, G., Salvo, A. and H. Vasconcelos. 2012. "Consumer-Surplus-Enhancing Collusion and Trade," *RAND Journal of Economics*, vol. 43(2), pp. 315-328.

[21] Dick, Andrew R. 1996. "When Are Cartels Stable Contracts?," *The Journal of Law & Economics*, vol. 39(1), pp. 241-283.

[22] Fung, K.C. 1992. "Economic Integration as Competitive Discipline," *International Economic Review*, vol. 33, pp. 837-847.

[23] Harrington, J. E. 2006. "How Do Cartels Operate?," *Foundations and Trends in Microeconomics*, $http://assets.wharton.upenn.edu/\ harrij/pdf/fnt06.pdf$.

[24] Harrington, J. E., K. Huschelrath, U. Laitenberger and F. Smuda. 2015. "The Discontent Cartel Member and Cartel Collapse: The Case of the German Cement Cartelotedblleft," *International Journal of Industrial Organization*, vol. 42, pp.196-119.

[25] Head, K., and T. Mayer. 2014. "Gravity Equations: Workhorse,Toolkit, and Cookbook," *The Handbook of International Economics*, vol. 4, pp. 131-195.

[26] Levenstein, M. C. and V. Y. Suslow. 2006. "What Determines Cartel Success?," *Journal of Economic Literature*, vol. XLIV, pp. 43-95.

[27] Levenstein, M. C. and V. Y. Suslow. 2008. "International Cartels," *TWO ISSUES IN COMPETITION LAW AND POLICY*, 1107.

[28] Levenstein, M. C. and V. Y. Suslow. 2011. "Breaking Up Is Hard to Do: Determinants of Cartel Duration," *Journal of Law and Economics*, vol. 54(2), pp. 455-492.

[29] Levenstein, M. C., J. Sivadasan and V. Y. Suslow. 2015. "The Effect of Competition on Trade: Evidence from the Collapse of International Cartels," *International Journal of Industrial Organization*, vol. 39, pp. 56-70.

[30] Lommerud, K.E. and L. Sørgard. 2001. "Trade Liberalization and Cartel Stability," *Review of International Economics*, vol. 9, pp. 343-355.

[31] Matschke, X. 1999. "On the Impact of Import Quotas on a Quantity-Fixing Cartel in a Two-Country Setting," *Jahrbucher fur Nationalokonomie und Statistik*, vol. 219, pp. 438-457.

[32] Mayer, T. and S. Zignago. 2011. "Notes on CEPIIs Distances Measures: The GeoDist Database," *Working Papers*.

[33] Pinto, B. 1986."Repeated Games and the 'Reciprocal Dumping' Model of Trade," *Journal of International Economics*, vol. 20, pp. 357-366.

[34] Röller, L. and F. Steen. 2006. "On the Workings of a Cartel: Evidence from the Norwegian Cement Industry," *American Economic Review*, vol. 96(1), pp. 321-338.

[35] Rotemberg, J. J. and G. Saloner. 1989. "Tariffs vs Quotas with Implicit Collusion," *The Canadian Journal of Economics*, vol. 22(2), pp. 237-244.

[36] Syropoulos, C. 1992. "Quantitative Restrictions and Tariffs with Endogenous Firm Behavior," *European Economic Review*, vol. 36(8), pp. 1627-1646.

[37] Vasconcelos, H. (2005). "Tacit Collusion, Cost Asymmetries, and Mergers," *RAND Journal of Economics*, vol. 36(1), pp. 39-62.

[38] Zhou, J. 2012. "Cartel Duration and Endogenous Private Monitoring and Communication: An Instrumental Variables Approach." $http://www.sfbtr15.de/uploads/media/369.pdf$

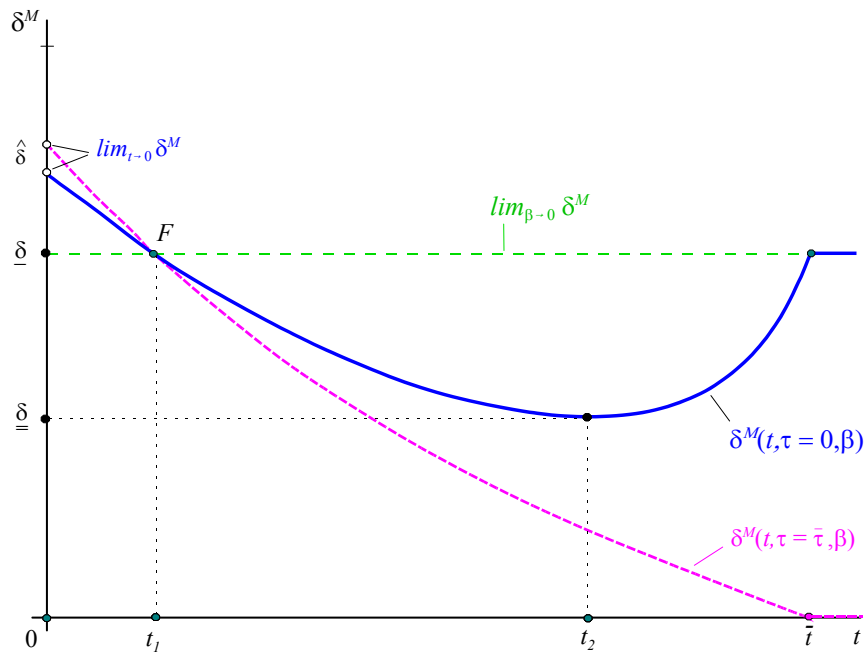


Figure 1: Minimum Discount Factors and Trade Costs

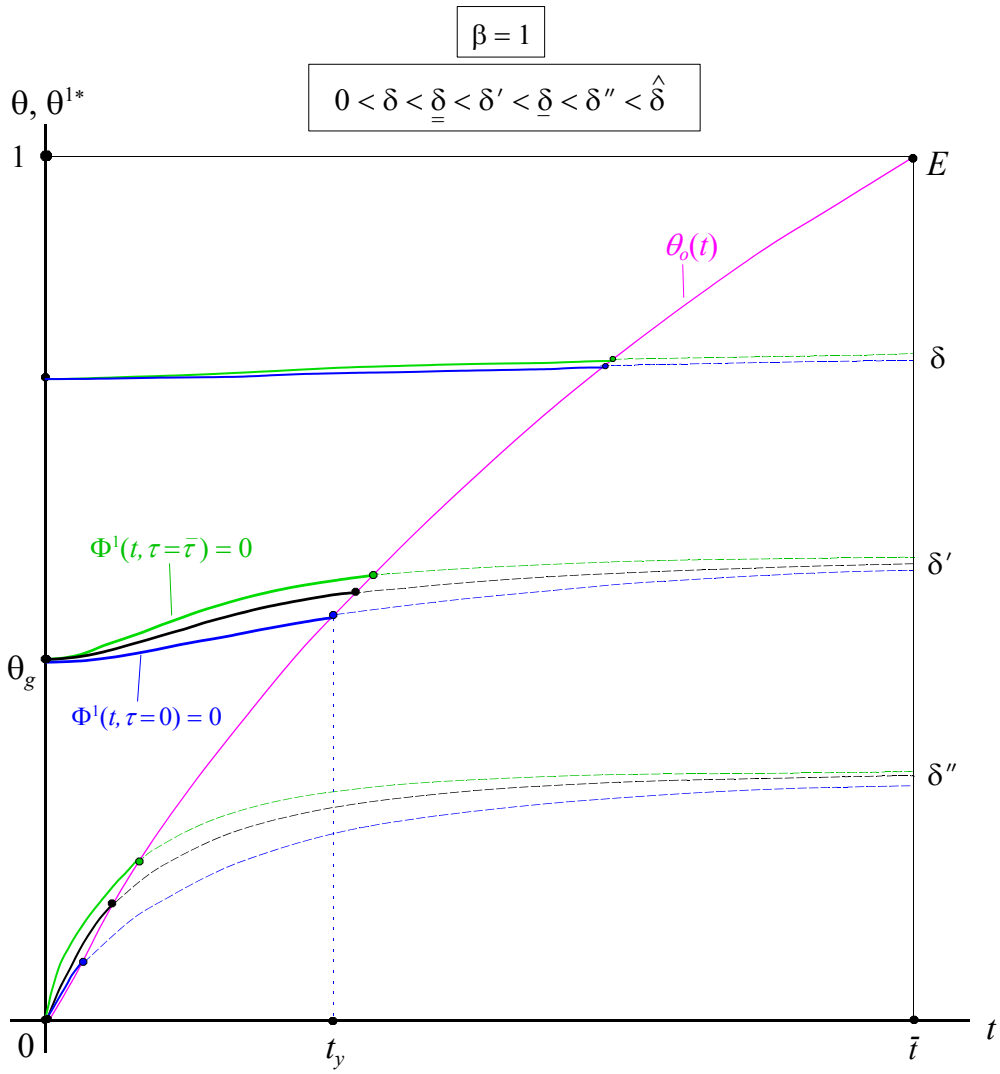


Figure 2: Cartel Discipline in the Presence of Cross Hauling ($\Phi^1 = 0$) under Various Trade Costs (t,τ) and Discount Factors (δ)

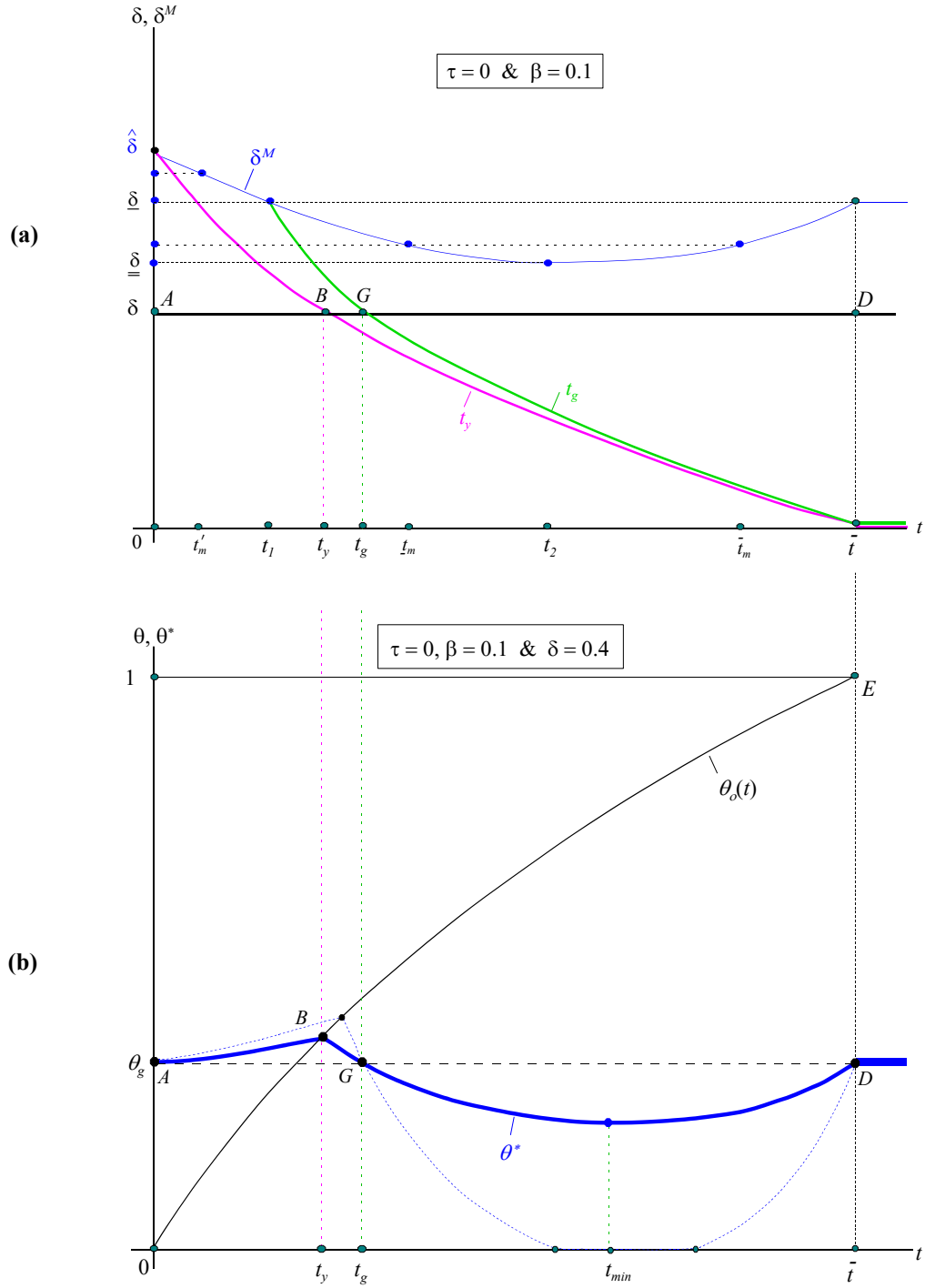


Figure 3: Equilibrium Cartel Discipline (θ^*) and Its Dependence on Internal Trade Costs (t)

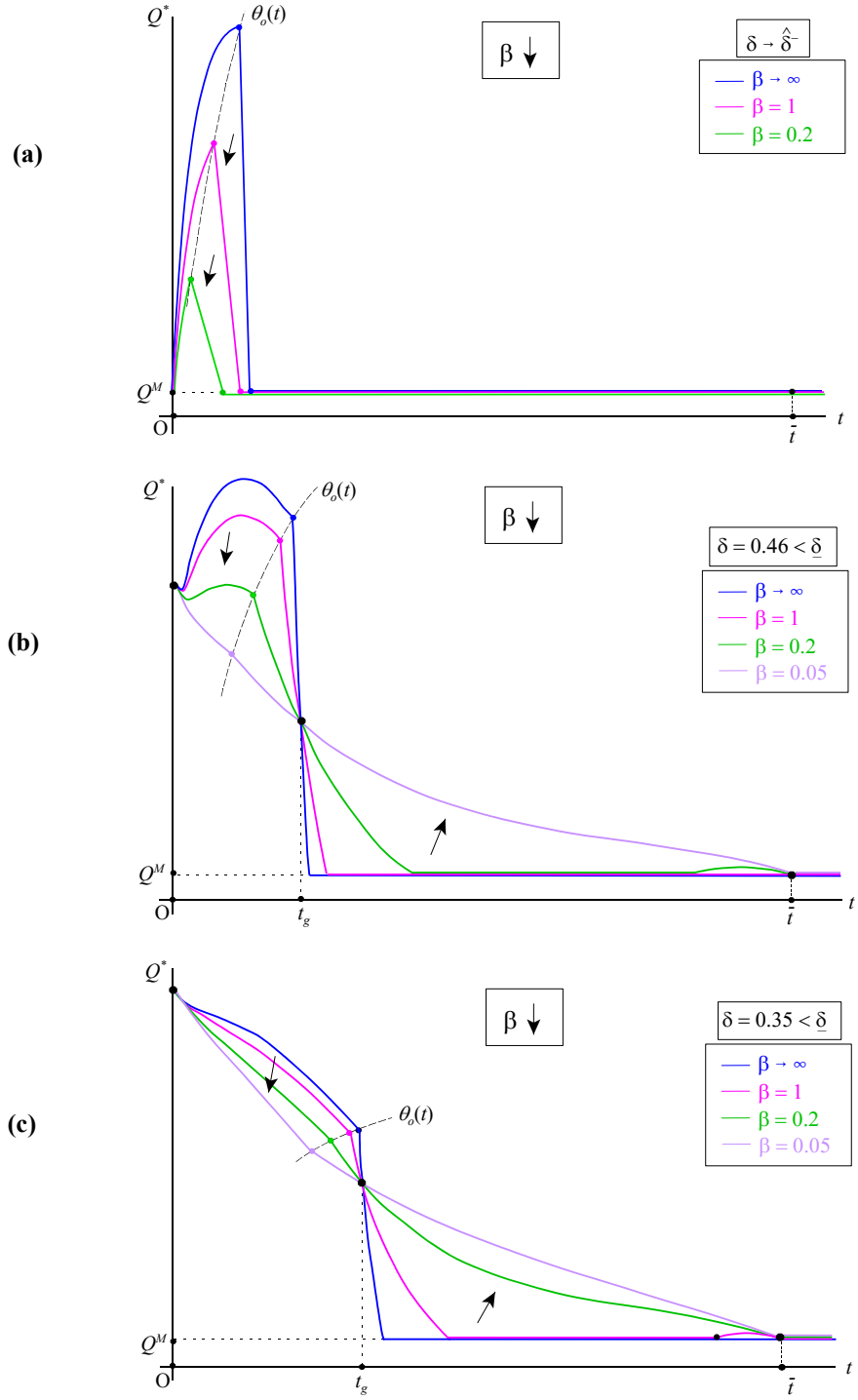


Figure 4: Output in Cartel Hosts and Its Dependence on the Discount Factor (δ), Internal Trade Costs (t) and Market Size (β)

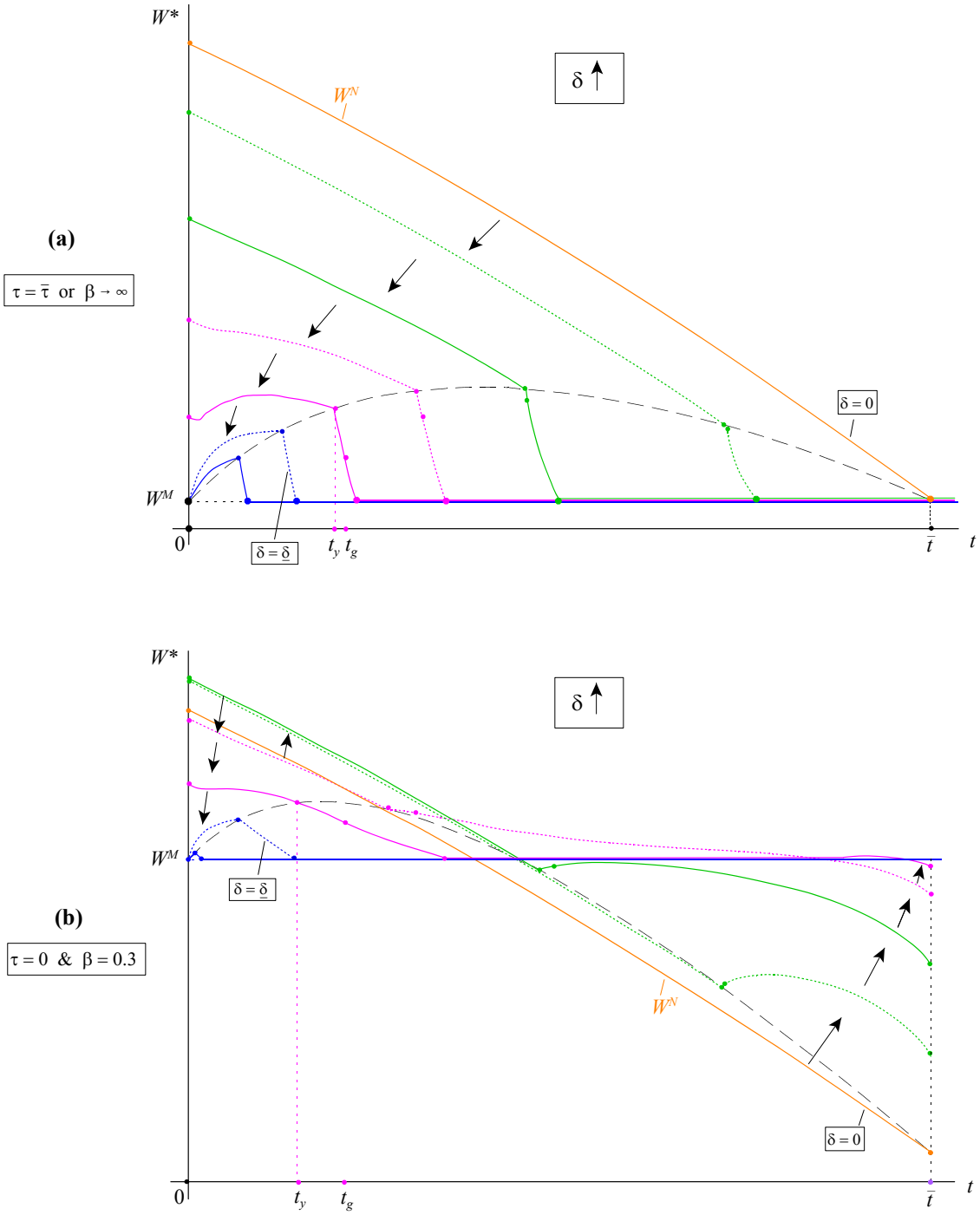


Figure 5: The Dependence of Welfare on Internal Trade Costs (t) and Various Discount Factor Values (δ) and Market Size (β)

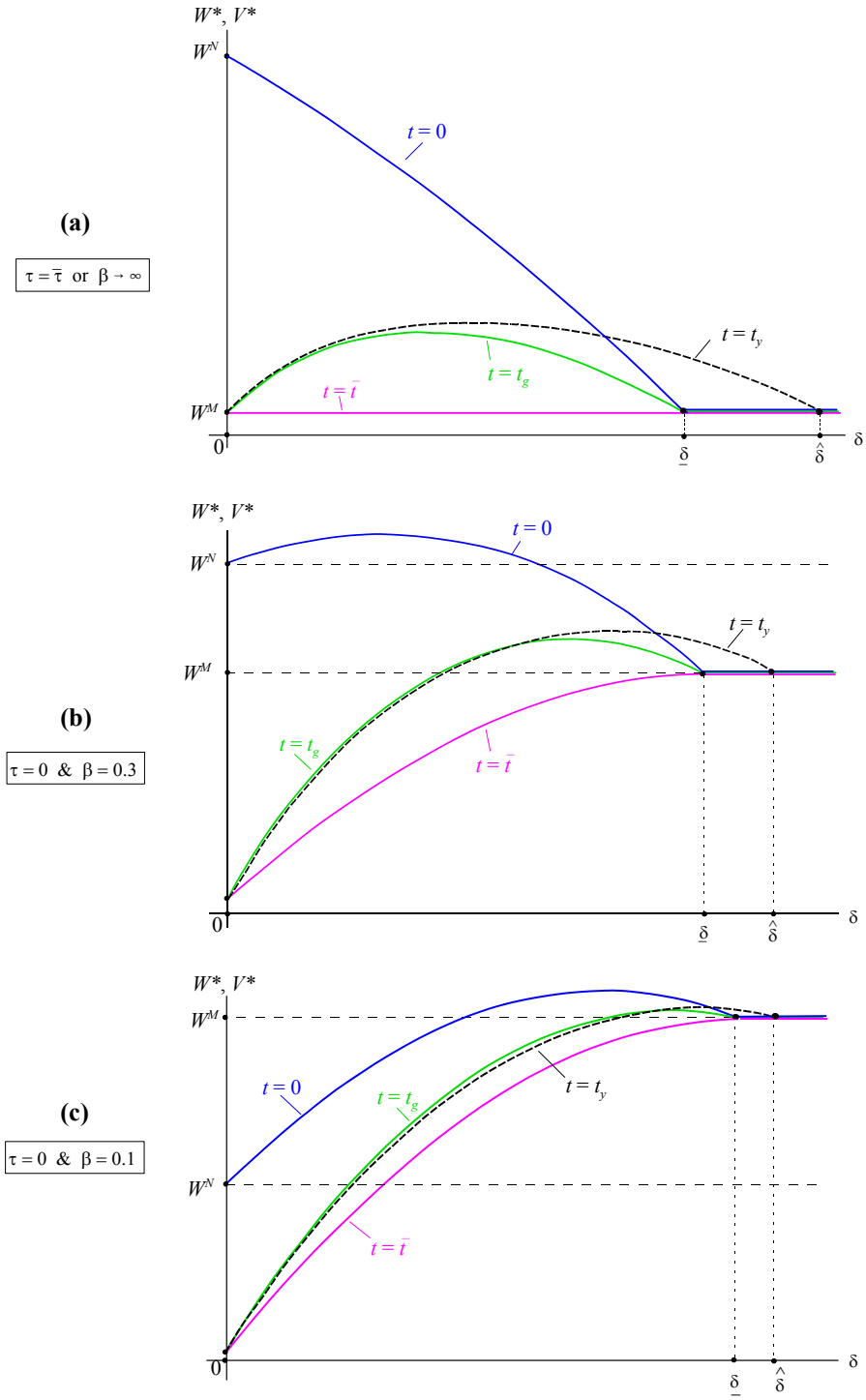


Figure 6: The Dependence of Welfare on the Discount Factor (δ) under Alternative Configurations of Internal Trade Costs (*t*) and Market Size (β)

Table 1: Cartel Discipline and International Trade Costs

VARIABLE NAMES	(1) INTRNL COSTS I	(2) INTRNL COSTS II	(3) EXTRNL COSTS I	(4) EXTRNL COSTS II	(5) ALL COSTS	(6) TRADE LBRLZN	(7) DISCPLN CNTRLS
TRADE COSTS							
DIST_INTRA	0.141	0.470			0.369	0.416	0.525
	(0.044)**	(0.083)**			(0.095)**	(0.109)**	(0.157)**
TRFF_INTRA		0.263			0.472	0.524	0.642
		(0.103)*			(0.236)*	(0.286)+	(0.367)+
DIST_EXTRL			0.242	0.471	0.308	0.299	0.546
			(0.063)**	(0.086)**	(0.107)**	(0.140)*	(0.175)**
TRFF_EXTRL				0.271	-0.131	-0.098	-0.185
				(0.107)*	(0.240)	(0.307)	(0.396)
Δ% TRFF_INTRA						-0.172	-0.203
						(0.160)	(0.203)
Δ% TRFF_EXTRL						0.223	0.268
						(0.158)	(0.199)
DISCPLN CNTRLS							
FIRMS							-0.017
							(0.056)
MKTSHR							0.088
							(0.366)
ALLCTN							-0.341
							(0.263)
DOMFIRM							0.241
							(0.313)
PRCFIX							1.396
							(0.605)*
INFRMN							0.557
							(0.347)
QUOTA							-1.569
							(0.449)**
BIDRGG							0.689
							(0.414)+
RCDVST							-0.016
							(0.340)
BUYBCK							-0.141
							(0.421)
CLTRDV							1.120
							(0.541)*
DSCVR_US							1.451
							(0.716)*
DSCVR_CA							-5.176
							(1.787)**
DSCVR_EU							1.031
							(0.690)
DSCVR_OTHR							3.192
							(1.232)**
Observations	153	119	153	123	118	110	110

Notes: This table reports estimates of the relationship between cartel discipline and trade costs. The dependent variable is always cartel duration measured in months. The estimator is always the Cox proportional hazard model. The first five columns of the table offer preliminary evidence for the effects of trade costs on cartel duration(discipline). Specifically, the single covariate in column (1) is the logarithm of internal distance. Column (2) adds the logarithm of internal tariffs. Columns (3) and (4) use external trade costs. Column (5) combines all trade cost covariates. Column (6) introduces additional controls for cartel discipline, which are borrowed from the related literature. Finally, column (7) adds controls for cartel discovery. See text for further details.

Table 2: Cartels, Cartel Discipline and International Trade

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			CARTEL DISCIPLINE				CARTEL DURATION		
	GRAV	COMMN	INTRA	FEs	TRFF	COMMN	INTRA	FEs	TRFF
DIST	-0.747	-0.747	-0.747	-0.722	-0.873	-0.747	-0.747	-0.722	-0.873
	(0.042)**	(0.048)**	(0.043)**	(0.053)**	(0.049)**	(0.040)**	(0.043)**	(0.064)**	(0.047)**
CNTG	0.511	0.511	0.510	0.516	0.413	0.511	0.511	0.517	0.413
	(0.112)**	(0.109)**	(0.101)**	(0.086)**	(0.107)**	(0.093)**	(0.097)**	(0.094)**	(0.117)**
CLNY	0.276	0.276	0.275	0.281	0.181	0.276	0.275	0.281	0.180
	(0.114)*	(0.120)*	(0.092)**	(0.121)*	(0.105)+	(0.109)*	(0.101)**	(0.128)*	(0.094)+
LANG	0.069	0.069	0.070	0.060	0.041	0.069	0.069	0.059	0.041
	(0.075)	(0.095)	(0.083)	(0.096)	(0.058)	(0.074)	(0.095)	(0.090)	(0.087)
RTA	0.254	0.255	0.254	0.334	0.392	0.255	0.254	0.333	0.390
	(0.101)*	(0.125)*	(0.077)**	(0.144)*	(0.156)*	(0.106)*	(0.094)**	(0.152)*	(0.172)*
CRTL		1.156				1.089			
		(0.232)**				(0.252)**			
CRTL_DSCPLN		-0.103				-0.231			
		(0.020)**				(0.053)**			
CRTL_INTRA			2.541	2.278	2.211		2.588	2.954	2.948
			(0.429)**	(0.471)**	(0.618)**		(0.438)**	(0.372)**	(0.513)**
CRTL_DSCPLN_INTRA			-0.218	-0.182	-0.175		-0.521	-0.570	-0.563
			(0.039)**	(0.040)**	(0.052)**		(0.087)**	(0.078)**	(0.106)**
CRTL_EXTRNL			0.798	0.808	0.706		0.721	0.729	0.760
			(0.290)**	(0.300)**	(0.090)**		(0.250)**	(0.251)**	(0.347)*
CRTL_DSCPLN_EXTRNL			-0.074	-0.071	-0.068		-0.159	-0.151	-0.173
			(0.026)**	(0.026)**	(0.009)**		(0.053)**	(0.054)**	(0.071)*
TARIFF					-0.186				-0.186
					(0.055)**				(0.031)**
Observations	231887	231887	231887	231887	185054	231887	231887	231887	185054

Notes: This table reports estimates of the relationship between cartel discipline and international trade. The dependent variable is always the logarithm of bilateral trade and the estimator is OLS. The estimates in the first three columns are obtained with importer, exporter, sector and time fixed effects. The estimates of the fixed effects are omitted for brevity. The first column reports estimates with only standard variables from the gravity trade literature. Column (2) introduces cartels and cartel discipline and constraints the effects of cartels and cartel discipline on internal and on external trade to be equal. Column (3) allows for heterogeneous effects of cartels and cartel discipline on internal and on external trade. Column (4) uses exporter-time, importer-time, and sector-time fixed effects. The estimates of the fixed effects are omitted for brevity. Column (5) adds import tariffs to the specification from column (4). Finally, columns (6)-(9) reproduce the specifications from columns (2)-(5) but using actual 'cartel duration' as proxy for cartel discipline. See text for further details.

For Online Publication - Appendix A: Theoretical Analysis

Proposition A1: *(Bond and Syropoulos, 2008) Suppose $\tau \geq \bar{\tau}$, so that there is no trade with ROW. Then the minimum discount factor that sustains the monopoly outcome, $\delta^M(t, \bar{\tau}, \beta)$, has the following properties:*

a) $\underline{\delta} \equiv \delta^M(0, \bar{\tau}, \beta) = \frac{9}{17}$ *whereas* $\delta^M(t, \bar{\tau}, \beta) = \frac{18(\bar{t}-t)}{13A+22t}$ *for* $t \in (0, \bar{t}]$

b) $\widehat{\delta} \equiv \lim_{t \to 0} \delta^M(0, \bar{\tau}, \beta) = \frac{9}{13}$, $\lim_{t \to \bar{t}} \delta^M = 0$ *and* $d\delta^M/dt < 0$ *for* $t \in (0, \bar{t}]$.

Proof of Propositions A1 and 1. To describe the dependence of δ^M on trade costs and market size, we need to specify Π^D, Π^C and Π^N in the definition of Φ in (ICC) for $q = q^M$ (or, equivalently, in (8)). Recall from our discussion in the main text that the value of Π^D varies depending on whether $t = 0$ or $t > 0$. If $t = 0$ then $q^M = (x, y, \frac{A-\tau}{4\beta})$ for any $x + y = Q^M$ and $\Pi^D = \frac{(A-y)^2}{4} + \frac{(A-x)^2}{4} + \frac{9(A-\tau)^2}{64\beta}$. In this case Π^D is lowest when $x = y = Q^M/2$; hence, $\Pi^D = \frac{9A^2}{32} + \frac{9(A-\tau)^2}{64\beta}$ for $t = 0$. On the other hand, if $t > 0$ then $q^M = (\frac{Q^M}{2}, 0, \frac{A-\tau}{4\beta})$ and thus $\Pi^D = \frac{A^2}{4} + \frac{(A/2-t)^2}{4} + \frac{9(A-\tau)^2}{64\beta}$. Next, note that $\Pi^C = \Pi^M$, with Π^M satisfying (4) regardless of the value of t. Lastly, note that Π^N conforms to (2).

Define the local variable $\Psi = \Psi(t, \tau, \beta) \equiv 72\Phi(q^M(\tau, \beta), t, \tau, \beta, \delta)$. Applying the above ideas onto Φ in (ICC), simplifying the resulting expression and searching for the lowest discount factor that ensures $\Psi = 0$ implies the following: First, for $t = 0$ and $\tau \geq \bar{\tau}$, we find $\Psi = (\delta^M - \underline{\delta}) \left[\frac{17}{4} A^2\right] = 0$ where $\underline{\delta} = \frac{9}{17}$; therefore, $\delta^M(0, \tau, \beta) = \underline{\delta}$ as stated in part (a) of Proposition 1. Similarly, for $t = 0$ and $\tau < \bar{\tau}$, we have $\Psi = (\delta^M - \underline{\delta}) \left[\frac{17}{4} A^2 + \frac{17(\bar{\tau}-\tau)^2}{8\beta}\right] = 0$ which, once again, implies $\delta^M(0, \tau, \beta) = \underline{\delta}$, as stated in part $(a.i)$ of Proposition 1. Second, if $t \geq \bar{t}$ $(= A/2)$ and $\tau < \bar{\tau}$, then $\Psi = (\delta^M - \underline{\delta}) \left[\frac{17(\bar{\tau}-\tau)^2}{8\beta}\right] = 0$ which demands $\delta^M = \underline{\delta}$, as required in part $(a.i)$ of Proposition 1.

Let us now focus on $t \in (0, \bar{t})$. If $\tau \geq \bar{\tau}$, then

$$\Psi = \left[\delta^M - \frac{18(\bar{t}-t)}{13A+22t}\right](\bar{t}-t)(13A+22t) = 0.$$

This helps prove the remainder of Proposition $A.1$. On the other hand, if $\tau < \bar{\tau}$, as required in

Proposition 1, we find (after some algebra)

$$\Psi = \left[\delta^M - \frac{18(\bar{t}-t)}{13A+22t}\right](\bar{t}-t)(13A+22t) + \left(\delta^M - \underline{\delta}\right)\left[\frac{17(\bar{\tau}-\tau)^2}{8\beta}\right] = 0.$$

The above expression can be rewritten as

$$\Psi = \frac{504}{17}(t-t_1)(\bar{t}-t) + \left(\delta^M - \underline{\delta}\right)\left[(\bar{t}-t)(13A+22t) + \frac{17(\bar{\tau}-\tau)^2}{8\beta}\right] = 0, \tag{A.1}$$

where $t_1 \equiv A/14$. Solving $(A.1)$ for δ^M and simplifying the resulting expression gives

$$\delta^M = \frac{18(\bar{t}-t)^2 + \frac{9(\bar{\tau}-\tau)^2}{8\beta}}{(\bar{t}-t)(13A+22t) + \frac{17(\bar{\tau}-\tau)^2}{8\beta}} = \kappa\left[\frac{18(\bar{t}-t)}{13A+22t}\right] + (1-\kappa)\left[\frac{9}{17}\right], \tag{A.2}$$

where $\kappa \equiv \frac{(\bar{t}-t)(13A+22t)}{(\bar{t}-t)(13A+22t)+\frac{17(\bar{\tau}-\tau)^2}{8}} < 1$. The last expression in $(A.2)$ is the weighted sum of the minimum discount factors that would arise in the hosts of the cartel and in ROW if firms did not pool their incentives constraints in these regions. One can verify that $\delta^M < 1$.

Remainder of parts (a), (b) and (c) of Proposition 1. Since the focus is on $t < \bar{t}$, part $(a.ii)$ follows readily from $(A.1)$. We will demonstrate part $(a.iii)$ shortly. First note though that $d\delta^M/d\gamma = -\Psi_\xi/\Psi_\delta$, for $\xi \in \{t, \tau, \beta\}$. Differentiating $(A.1)$ and simplifying terms gives

$$\begin{aligned}
\Psi_\delta &= (\bar{t}-t)(13A+22t) + \frac{17(\bar{\tau}-\tau)^2}{8\beta} > 0,\\
\Psi_t &= -2(A+22t)\left[\delta^M - \frac{18(\bar{t}-t)}{A+22t}\right] = 4\left[\frac{9}{4}A\left(3-\delta^M\right) + \left(9+11\delta^M\right)(t_1-t)\right],\\
\Psi_\tau &= -\left(\delta^M - \underline{\delta}\right)\left[\frac{17(\bar{\tau}-\tau)}{4\beta}\right] \gtreqless 0 \;\text{ if }\; \delta^M \lesseqgtr \underline{\delta},\\
\Psi_\beta &= -\left(\delta^M - \underline{\delta}\right)\left[\frac{17(\bar{\tau}-\tau)^2}{8\beta^2}\right] \gtreqless 0 \;\text{ if }\; \delta^M \lesseqgtr \underline{\delta}.
\end{aligned}$$

Parts (b) and (c) follow from inspection of the above expressions and from studying the limits of δ^M in $(A.2)$ as $\beta \to 0$ and $\beta \to \infty$, respectively.

To prove part $(a.iii)$, note the following. First, $\Psi_t(t,\tau,\beta) > 0$ for any $t \in (0, t_1]$; therefore, $\delta^M_t < 0$ for $t \in (0, t_1]$. Second, from $(A.2)$ we have $\lim_{t\to\bar{t}} \delta^M \to \underline{\delta}$ as $t \to \bar{t}$ from below. Moreover, $\lim_{t\to\bar{t}} \delta^M_t > 0$ since $\lim_{t\to\bar{t}} \Psi_t(t,\tau,\beta) < 0$. By the continuity of δ^M in $t \in (0, \bar{t})$, there will exist a

trade cost $t_2 \equiv \arg\min_t \delta^M(t,\tau,\beta) \in (t_1, \bar{t})$ for any $\tau < \bar{\tau}$. Setting $\Psi_t = 0$, utilizing the definition of δ^M in the resulting expression, and solving for t gives

$$t_2(k) \equiv \frac{1}{6A}\left[3A^2 + 7k - \sqrt{k(18A^2+49k)}\right] \quad \text{where} \quad k = k(\tau,\beta) \equiv \frac{17(A-\tau)^2}{8\beta}.$$

Differentiating $t_2(\cdot)$ appropriately gives $\partial t_2/\partial\xi = t_2'(k)\, k_\xi$ for $\xi \in \{\tau,\beta\}$ where

$$t_2'(k) = -\left[\frac{27A^3}{2k(18A^2+49k)}\right]\left[7 + \frac{9A^2+49k}{\sqrt{k(18A^2+49k)}}\right]^{-1} < 0 \quad \text{and} \quad k_\xi < 0.$$

Thus $\partial t_2/\partial\xi > 0$ for $\xi \in \{\tau,\beta\}$. $\lim_{\tau\to\bar{\tau}} t_2 = \lim_{\beta\to\infty} t_2 = \bar{t}$ because $\lim_{\tau\to\bar{\tau}} k = \lim_{\beta\to\infty} k = 0$. ||

Proof of Lemma 1: Henceforth, we simplify notation by defining $\tilde{x} \equiv x^D$, $\tilde{y} \equiv y^D$, $\tilde{z} \equiv z^D$. Further, to avoid cluttering, we drop superscript "*". The active ICC requires $\Phi^1(\theta,\delta,t,\tau,\beta) = 0$ and, as noted in the text, $1-\delta-\theta > 0$. Recalling from (9) that $\Phi_j^1 = \Pi_j^C - (1-\delta)\Pi_j^D$ for $j = x, y, z$, taking into account (10) and defining $\Phi_\theta^1 \equiv d\Phi^1/d\theta$ yields

$$\begin{aligned}\Phi_\theta^1 &= (1-\delta-\theta)\left[\left(-\Pi_x^D\right)x_\theta^1 + \left(-\Pi_y^D\right)y_\theta^1 + \left(-\Pi_z^D\right)z_\theta^1\right] \quad \text{from (7)}\\ &= (1-\delta-\theta)\left[\tilde{y}x_\theta^1 + \tilde{x}y_\theta^1 + \beta\tilde{z}z_\theta^1\right] \quad \text{from (5).}\end{aligned} \tag{A.3}$$

We will argue that $\Phi_\theta^1 > 0$ which is tantamount to showing that $\Pi^D\left(q^1(\theta,\cdot),\cdot\right)$ is decreasing in θ. Differentiation of the expressions in (10a) with respect to θ yields

$$Q_\theta^1 = \frac{3(2A-t)}{(8+\theta)^2} > 0, \tag{A.4a}$$

$$x_\theta^1 = \frac{1}{2}\left(Q_\theta^1 - \frac{t}{\theta^2}\right), \tag{A.4b}$$

$$y_\theta^1 = \frac{1}{2}\left(Q_\theta^1 + \frac{t}{\theta^2}\right) > 0, \tag{A.4c}$$

$$z_\theta^1 = \frac{6(A-\tau)}{\beta(8+\theta)^2} > 0. \tag{A.4d}$$

The above equations enable us to transform the expression inside the square brackets of $(A.3)$ into

$$\begin{aligned}\tilde{y}x_\theta^1 + \tilde{x}y_\theta^1 + \beta\tilde{z}z_\theta^1 &= \tilde{y}\left(Q_\theta^1 - \frac{t}{\theta^2}\right) + \tilde{x}\left(Q_\theta^1 + \frac{t}{\theta^2}\right) + \tilde{z}\frac{6\,(A-\tau)}{(8+\theta)^2} \\ &= (\tilde{x}+\tilde{y})\,Q_\theta^1 + (\tilde{x}-\tilde{y})\frac{t}{\theta^2} + \tilde{z}\frac{6\,(A-\tau)}{(8+\theta)^2} \\ &= \frac{9(2A-t)^2}{(8+\theta)^3} + \frac{t^2}{\theta^3} + \frac{18\,(A-\tau)^2}{\beta\,(8+\theta)^3} > 0,\end{aligned}$$

where the last term was obtained from $(A.4)$ and the facts that

$$\tilde{x} = \frac{1}{2}\left[\frac{3(2A-t)}{8+\theta} + \frac{t}{\theta}\right], \tag{A.5a}$$

$$\tilde{y} = \frac{1}{2}\left[\frac{3(2A-t)}{8+\theta} - \frac{t}{\theta}\right], \tag{A.5b}$$

$$\tilde{z} = \frac{3\,(A-\tau)}{\beta\,(8+\theta)}, \tag{A.5c}$$

which imply $\tilde{x}+\tilde{y} = \frac{3(2A-t)}{8+\theta}$ and $\tilde{x}-\tilde{y} = t/\theta$.[53] For clarity, we rewrite $(A.3)$ as

$$\Phi_\theta^1 = (1-\delta-\theta)\left[\frac{9(2A-t)^2}{(8+\theta)^3} + \frac{t^2}{\theta^3} + \frac{18\,(A-\tau)^2}{\beta\,(8+\theta)^3}\right] > 0. \tag{A.3$'$}$$

The positive sign of $(A.3')$ establishes that weaker cartel discipline $(\theta\uparrow)$ relaxes the ICC.

To take a closer look at the solution θ^{1*} to $\Phi^1 = 0$, substitute (10) into the ICC and simplify the resulting expression to obtain

$$\Phi^1 = \frac{(1-\theta)\,(17+\theta)}{(8+\theta)^2}\Omega^1 = 0, \tag{A.6a}$$

where

$$\Omega^1 = -\frac{9\,(1-\theta)}{17+\theta}\left[\frac{4t^2\,(4-\theta)\,(2+\theta)}{9\theta^2} + \Pi^N\right] + \delta\left[\frac{8t^2\,(4+5\theta)}{\theta^2(17+\theta)} + \Pi^N\right] \tag{A.6b}$$

for $t > 0$ and $\delta < \delta^M$. One can see from $(A.6a)$ that, indeed, $\theta^{1*} = 1$ is a generic solution, as noted in the text. Moreover, the ICC is active as $\delta \to 0$ only if $\lim_{\delta\to 0}\Omega^1 = 0$ for $t \leq \bar{t}$, which is possible

[53] Direct comparison of (10c) and $(A.5b)$ reveal that $\tilde{y} > 0$ for all values of t that ensure $y^1 > 0$; therefore, keeping track of the non-negativity constraint on y^1 also takes care of the non-negativity constraint on $\tilde{y}$.

only if $\lim_{\delta\to 0}\theta^{1*} = 1$.

Now suppose $t = 0$. If $\delta \in [\underline{\delta}, \widehat{\delta})$, maximal collusion will be sustainable, so $\theta^{1*} = 0$. On the other hand, if $\delta \in [0, \underline{\delta})$ the ICC will bind, so there will exist a θ that ensures $\Omega^1 = 0$. Utilizing $(A.6b)$ one can show that $\theta^{1*} = \theta_g$, where $\theta_g \equiv 17(\underline{\delta} - \delta)/(9 + \delta) > 0$ and $\underline{\delta} = 9/17$. In short, $\theta^{1*} = \max(0, \theta_g)$ for $t = 0$ and $\delta \in [0, \widehat{\delta})$.

Let us now focus on $t \in (0, \bar{t})$. From $(A.6b)$ one can verify that $\Omega^1 < 0$ as θ becomes arbitrarily small whereas $\lim_{\theta\to 1-\delta}\Omega^1 > 0$. Since Ω^1 is continuous and increasing in θ on $(0, 1-\delta)$ there exists a unique solution $\theta^{1*} \in (0, 1-\delta)$ to $\Omega^1 = 0$ (and thus to $\Phi^1 = 0$) as claimed in Lemma 1. Inspection of $(A.6b)$ also reveals that we can rearrange $\Omega^1 = 0$ to obtain

$$(t/\theta)^2 = \frac{\left[\delta - \frac{9(1-\theta)}{17+\theta}\right]\Pi^N}{\frac{4(1-\theta)(4-\theta)(2+\theta)}{17+\theta} - \delta\frac{8(4+5\theta)}{17+\theta}}.$$

Since $\lim_{t\to 0}\theta^{1*} = \theta_g$ for $\delta \in [0, \underline{\delta})$ the above equation readily implies $\lim_{t\to 0}(t/\theta^{1*})^2 = 0$ in this case. In contrast, because $\lim_{t\to 0}\theta^{1*} = 0$ for $\delta \in [\underline{\delta}, \widehat{\delta})$, we will have

$$\lim_{t\to 0}(t/\theta^{1*})^2 = \frac{17}{32}\left[\frac{\delta - \underline{\delta}}{1-\delta}\right]\Pi_0^N, \text{ where } \Pi_0^N = \frac{2A^2}{9} + \frac{(A-\tau)^2}{9\beta}. \tag{A.6c}$$

The above observations will prove helpful in some of the proofs that will follow.

Part (a). Since $d\theta^{1*}/d\delta = -\Phi_\delta^1/\Phi_\theta^1$ by the implicit function theorem and we know $\Phi_\theta^1 > 0$, to prove this part it suffices to prove that $\Phi_\delta^1 > 0$. But this is trivially true because $\Phi_\delta^1 = \Pi^D - \Pi^N > 0$.

Part (b). Since $d\theta^{1*}/dt = -\Phi_t^1/\Phi_\theta^1$, to prove part (b) we must show that $\Phi_t^1 < 0$ for $t > 0$. Differentiating Φ^1 with respect to t and utilizing (10a) together with the fact that $\Pi_j^C - (1-\delta)\,\Pi_j^D = (1-\delta-\theta)\,(-\Pi_j^D) > 0$ for $j = x, y$ gives

$$\begin{aligned}\Phi_t^1 &= \Pi_t^C - (1-\delta)\,\Pi_t^D - \delta\Pi_t^N + (1-\delta-\theta)\left[-\Pi_x^D x_t^1 - \Pi_y^D y_t^1\right] \\ &= -y^1 + (1-\delta)\,\tilde{y} - \delta\Pi_t^N + (1-\delta-\theta)\left[\tilde{y}x_t^1 + \tilde{x}y_t^1\right].\end{aligned} \tag{A.7}$$

For clarity and future reference, note that

$$Q_t^1 = -\frac{2+\theta}{8+\theta} < 0, \tag{A.8a}$$

$$x_t^1 = \frac{1}{2}\left(Q_t^1 + \frac{2-\theta}{\theta}\right) = \frac{8-4\theta-\theta^2}{\theta(8+\theta)} > 0, \tag{A.8b}$$

$$y_t^1 = \frac{1}{2}\left(Q_t^1 - \frac{2-\theta}{\theta}\right) = -\frac{4-\theta}{\theta(8+\theta)} < 0. \tag{A.8c}$$

Equation $(A.7)$ reveals that, for given cartel discipline, changes in t affect Φ^1 through four channels. The first three channels involve the direct effects of t on Π^C, Π^D and Π^N, respectively. The fourth channel is indirect and is associated with the effect of t on x^1 and y^1. The direct effects of t on Φ^1 through Π^C and Π^D are clear. Since $\Pi_t^C = -y^1$ and $\Pi_t^D = -\tilde{y}$, the former effect on Φ^1 is negative whereas the latter effect on Φ^1 is positive (see $(A.7)$). The direct effect of t on Φ^1 through Π^N depends on the level of t. Since $\arg\min_t \Pi^N = A/5$, as discussed earlier, the punishment effect on the ICC is positive for low t levels and negative at high t levels.[54] One can verify (by utilizing $(A.5)$ and $(A.8)$ in $(A.7)$) that $\tilde{y}x_t^1 + \tilde{x}y_t^1 = \tilde{y}Q_t^1 + (\tilde{x}-\tilde{y})y_t^1 < 0$, which implies that the fourth (and indirect) effect of t on Φ^1 is negative. It is worth pointing a feature of Φ_t^1 from $(A.7)$ and $(A.8)$ that helps prove part (d) below: Φ_t^1 is invariant to changes in β and τ.

Interestingly, despite the apparent ambiguity in the sign of Φ_t^1 noted above, it is possible to determine its sign by using the fact that the ICC is binding (i.e., $\Phi^1 = 0$). Substituting the value of δ implied by this constraint in $(A.7)$ and simplifying expressions yields:

$$\begin{aligned}\Phi_t^1 &= -\frac{8\,(1-\theta)^3\,t\left[\Pi^N - t\Pi_t^N/2\right]}{\left[8t^2\,(4+5\theta)+\theta^2\,(17+\theta)\,\Pi^N\right]} \\ &= -\frac{8\,(1-\theta)^3\,t\left[A\,(2A-t)+(A-\tau)^2/\beta\right]}{9\left[8t^2\,(4+5\theta)+\theta^2\,(17+\theta)\,\Pi^N\right]} < 0.\end{aligned} \tag{A.7$'$}$$

This affirms the idea that the direct effect of t on Π^C, together with its indirect effect on Π^D through (x^1, y^1), dominate the positive direct effects on Π^D and Π^N, thereby tightening the ICC. Thus, $d\theta^{1*}/dt = -\Phi_t^1/\Phi_\theta^1 > 0$ for $t > 0$.

[54] Natuarlly, if the punishment payoff is invariant to changes in trade costs, this effect vanishes.

Differentiation of $(A.6b)$ gives $d\theta^{1*}/dt = -\frac{\theta\Omega_t^1}{\theta\Omega_\theta^1}$, where

$$-\theta\Omega_t^1 = \theta\Pi_t^N \left[\frac{9\,(1-\theta)}{17+\theta} - \delta\right] + (t/\theta)\,\frac{8}{17+\theta}\left[(1-\theta)\,(4-\theta)\,(2+\theta) - 2\delta\,(4+5\theta)\right]$$

and

$$\theta\Omega_\theta^1 = \theta\frac{162}{(17+\theta)^2}\left[\Pi^N + \frac{4}{9}\,(t/\theta)^2\,(4-\theta)\,(2+\theta)\right] + (t/\theta)^2\,\frac{8\,(8+\theta)}{17+\theta}\left[1-\theta-\delta\frac{17+10\theta}{17+\theta}\right].$$

Because $\lim_{t\to 0}\theta^{1*} = \theta_g > 0$ for $\delta \in (0, \underline{\delta}]$, we have $\lim_{t\to 0}\left(-\theta\Omega_t^1\right) = 0$ and $\lim_{t\to 0}\left(\theta\Omega_\theta^1\right) = \frac{162\Pi_0^N(9+\delta)^2}{269(9+\underline{\delta})^2} > 0$, where Π_0^N was defined in $(A.6c)$; therefore, $\lim_{t\to 0}\left(d\theta^{1*}/dt\right) = 0$ in this case. Turning to $\delta \in (\underline{\delta}, \widehat{\delta})$, recall that $\lim_{t\to 0}\theta^{1*} = 0$ and $\lim_{t\to 0}(t/\theta^{1*})^2 = \frac{17}{32}\left[\frac{\delta-\underline{\delta}}{1-\delta}\right]\Pi_0^N > 0$ (from $(A.6c)$), imply $\lim_{t\to 0}\left(-\theta\Omega_t^1\right) = \left[\lim_{t\to 0}(t/\theta)\right]\frac{64}{17}\left[1-\delta\right]$ and $\lim_{t\to 0}\left(\theta\Omega_\theta^1\right) = \left[\lim_{t\to 0}(t/\theta)^2\right]\frac{64}{17}\left[1-\delta\right]$; therefore, $\lim_{t\to 0}\left(d\theta^{1*}/dt\right) = \lim_{t\to 0}\left(\theta^{1*}/t\right) = \left[\frac{17}{32}\left(\frac{\delta-\underline{\delta}}{1-\delta}\right)\Pi_0^N\right]^{-1/2} > 0$.

Part (c). Since $\theta^{1*} = \max(\theta_g, 0)$ for $t = 0$ and $\delta \in [0, \widehat{\delta})$, θ^{1*} is invariant to changes in external trade costs (τ) and market size (β) in this case. For $t \in (0, \bar{t})$ and $\delta \in [0, \delta^M)$, however, θ^{1*} depends on variables related to ROW's market through their impact on Π^C, Π^D and Π^N. Differentiation of Φ^1 with respect to τ gives

$$\begin{aligned}\Phi_\tau^1 &= \Pi_\tau^C - (1-\delta)\,\Pi_\tau^D - \delta\Pi_\tau^N + (1-\delta-\theta)\left[-\Pi_z^D z_\tau^1\right] \\ &= -z^1 + (1-\delta)\,\tilde{z} + \delta\frac{2\,(A-\tau)}{9\beta} + (1-\delta-\theta)\left[\beta\tilde{z}z_\tau^1\right], \end{aligned} \tag{A.9}$$

where $\tilde{z}$ is defined in $(A.5c)$ and thus $z_\tau^1 = -\frac{2+\theta}{\beta(8+\theta)} < 0$. Inspection of the terms in $(A.9)$ reveals that the channels of transmission of changes in τ are similar to the ones associated with internal trade cost t changes. One difference is that now the impact of τ on Φ^1 through the punishment payoff Π^N is unambiguously positive. Still, the sign of Φ_τ^1 seems ambiguous. However, this ambiguity disappears when we substitute the values of $\tilde{z}$, z^1 and z_τ^1 into Φ_τ^1. Doing so gives

$$\Phi_\tau^1 = \frac{2(9+\delta)\,(A-\tau)}{9\beta\,(8+\theta)^2}\,(1-\theta)\,(\theta_g-\theta), \tag{A.9$'$}$$

where, again, $\theta_g \equiv 17(\underline{\delta}-\delta)/(9+\delta) \gtreqless 0$ as $\delta \lesseqgtr \underline{\delta}$. Since part (b) implies $\theta^{1*} > \theta_g$ for $t \in (0, \bar{t})$, we will have $\Phi_\tau^1 < 0$ for changes along the ICC. Thus, an increase in external trade costs tightens the

ICC and relaxes cartel discipline. The analysis of the effect of market size β on θ^{1*} is qualitatively similar and thus omitted.

Part (d). As noted earlier, $\theta_t^{1*} = -\Phi_t^1/\Phi_\theta^1$, where $\Phi_t^1 < 0$ and Φ_θ^1. In the proof of part (b) we noted that $\partial\Phi_t^1/\partial\beta = \partial\Phi_t^1/\partial\tau = 0$. On the other hand, one can see from $(A.3')$ that $sign\left(\Phi_{\theta\beta}^1\right) = sign\left(\Phi_{\theta\tau}^1\right) < 0$; therefore, $\theta_{t\xi}^{1*} > 0$ for $\xi \in \{\beta,\tau\}$, as claimed in this part. ||

Lemma A1: $\Phi^2(\theta, t, \cdot)$ is strictly concave in $(t,\theta) \in [0,\bar{t}] \times [0,1]$ and is maximized at $(t_{\max}, \theta_{\max}) = \left(\frac{A}{2}\left[\frac{9+\delta-2\delta^2}{9+16\delta-5\delta^2}\right], 1-\delta\right)$. Moreover,

$$\Phi_{\max}^2 \equiv \Phi^2(\theta_{\max}, t_{\max}, \cdot) = \delta^2\left[\frac{A^2(5-\delta)}{4(9+16\delta-5\delta^2)} + \frac{(\bar{\tau}-\tau)^2}{9\beta(9-\delta)}\right] > 0 \text{ for } \delta > 0.$$

Proof: Utilizing a procedure similar to the one in the proof of Lemma 1, we may differentiate Φ^2 with respect to θ and use (11) to obtain

$$\Phi_\theta^2 = (1-\delta-\theta)\left[\tilde{y}x_\theta^2 + \beta\tilde{z}z_\theta^2\right].$$

To sign this expression — and several others to follow — note that

$$\tilde{y} = \frac{2(A/2-t)}{4+\theta} \quad \text{and} \quad \tilde{z} = \frac{3(A-\tau)}{\beta(8+\theta)}, \tag{A.10a}$$

$$x_\theta^2 = \frac{4(A/2-t)}{(4+\theta)^2} > 0 \quad \text{and} \quad z_\theta^2 = \frac{6(A-\tau)}{\beta(8+\theta)^2} > 0, \tag{A.10b}$$

$$x_t^2 = -\frac{\theta}{4+\theta} < 0, \quad z_\tau^2 = -\frac{2+\theta}{\beta(8+\theta)} < 0 \quad \text{and} \quad z_\beta^2 = -\frac{z^2}{\beta} < 0. \tag{A.10c}$$

The partial derivatives of x^2 and z^2 in $(A.10b)$ and $(A10c)$ were obtained by differentiating (12). With the help of the above expressions we find

$$\Phi_\theta^2 = (1-\delta-\theta)\left[\frac{8(A/2-t)^2}{(4+\theta)^3} + \frac{18(A-\tau)^2}{\beta(8+\theta)^3}\right] \Rightarrow \Phi_\theta^2 \gtreqless 0 \text{ if } \theta \lesseqgtr 1-\delta. \tag{A.11a}$$

In due course we will recognize that $1-\delta-\theta > 0$ (for the reasons outlined in our study of Φ^1 which require $\theta < \theta_o(t)$). However, to obtain a complete view of the properties of Φ^2 we initially abstract from this possibility.

Differentiating Φ^2 with respect to t gives

$$\begin{aligned}\Phi_t^2 &= \Pi_t^C - (1-\delta)\,\Pi_t^D - \delta\Pi_t^N + (1-\delta-\theta)\left(-\Pi_x^D x_t^2\right)\\ &= 0 + (1-\delta)\,\tilde{y} + \delta\frac{10}{9}\,(A/5-t) + (1-\delta-\theta)\left(\tilde{y}x_t^2\right)\\ &= \delta\frac{10}{9}\left(\frac{A}{5}-t\right) + \frac{2\left[4\,(1-\delta)+\theta^2\right]}{(4+\theta)^2}\left(\frac{A}{2}-t\right).\end{aligned}$$

To obtain the last expression for Φ_t^2 we used $(A.10)$. It now follows that

$$\Phi_t^2 \lesseqqgtr 0 \;\text{ if }\; t \lesseqqgtr \frac{A}{2}\left[\frac{\frac{2\delta}{9}+\frac{4(1-\delta)+\theta^2}{(4+\theta)^2}}{\frac{5\delta}{9}+\frac{4(1-\delta)+\theta^2}{(4+\theta)^2}}\right] < \bar{t} \equiv \frac{A}{2}. \tag{A.11b}$$

Differentiating Φ_θ^2 and Φ_t^2 appropriately gives

$$\Phi_{\theta\theta}^2 = -\left[\frac{8\,(A/2-t)^2\,(7-3\delta-2\theta)}{(4+\theta)^4} + \frac{18\,(A-\tau)^2\,(11-3\delta-2\theta)}{\beta\,(8+\theta)^4}\right] < 0,$$

$$\Phi_{tt}^2 = -\left[\frac{10}{9}\delta + \frac{2\left[4(1-\delta)+\theta^2\right]}{(4+\theta)^2}\right] < 0,$$

$$\Phi_{\theta t}^2 = -\frac{16\,(1-\delta-\theta)\,(A-t)}{(4+\theta)^3}.$$

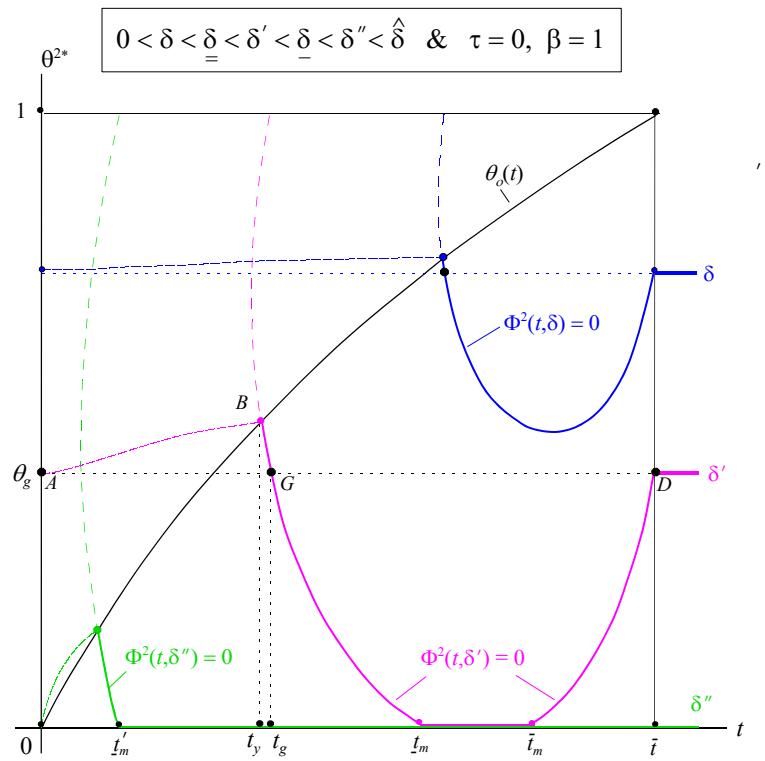
It is tedious but straightforward for one to show that $\Phi_{\theta\theta}^2\Phi_{tt}^2 - (\Phi_{\theta t}^2)^2 > 0$. The strict concavity of Φ^2 in (t,θ) follows from this inequality and $\Phi_{\theta\theta}^2 < 0$ and $\Phi_{tt}^2 < 0$.[55] The solution to $\Phi_\theta^2 = 0$ and $\Phi_t^2 = 0$, which is given by $(t_{\max},\theta_{\max}) = \left(\frac{A}{2}\left[\frac{9+\delta-2\delta^2}{9+16\delta-5\delta^2}\right], 1-\delta\right)$, is the unique maximizer of Φ^2. Substituting this solution back into Φ^2 and simplifying the resulting expression gives $\Phi_{\max}^2 > 0$. ||

Fig. $A.1$ illustrates several contours associated with $\Phi^2 = 0$ under the assumption of equally sized countries ($\beta = 1$). Panel (a) captures the role of time preferences under the assumption that external trade is free ($\tau = 0$). Panel (b) highlights the dependence of cartel discipline on external trade costs τ. In both panels only the thick, solid-line parts of the curves are relevant.[56]

[55] In contrast, Φ^1 studied earlier need not be concave in (t,θ).

[56] Points on the $\Phi^2 = 0$ contour that are above $\theta_o\,(t)$ must be discarded because they violate the $y = 0$ constraint. Points below the horizontal axis must also be ignored because they are associated with t values that sustain the fully collusive outcome (so $\theta^{2*} = 0$ in this case). The effect of an increase in ROW size ($\beta \downarrow$) is similar to the effect of external trade cost cuts ($\tau \downarrow$).

(a)
Discount Factors



(b)
External Trade Costs

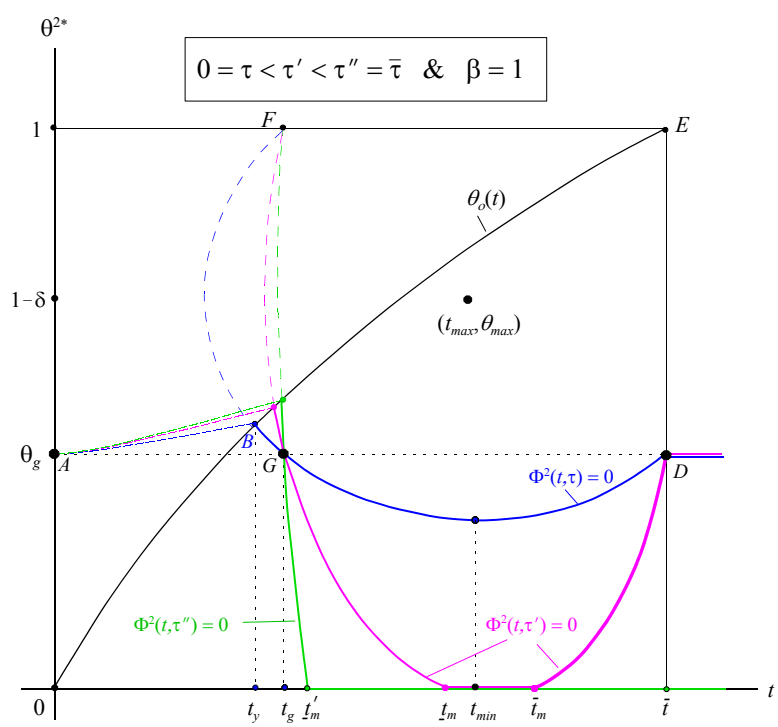


Figure A.1: Incentive Constraint Contours in the Absence of Cross Hauling ($\Phi^2 \geq 0$)

The following traits of the figures in these panels stand out. Naturally, $\theta^{2*} = \theta^{1*}$ at $t = t_y$. Further, even though there is no cross-hauling for $t \geq t_y$, internal trade costs matter for cartel discipline in this case because they affect deviation and punishment payoffs. However, the resulting relationship differs markedly from the one studied in Lemma 1 where cross-hauling was present. Now increases in internal trade costs t improve cartel discipline ($\theta^{2*} \downarrow$) when these costs are close to t_y. At higher t levels, though, the dependence of θ^{2*} on t hinges on the value of the discount factor δ, the level of external trade costs τ, and market size β. Panel (a) of Fig. $A.1$ depicts the behavior of θ^{2*} when $\tau = 0$, for discount factor values in three distinct ranges: (i) $(0, \underline{\delta})$, (ii) $[\underline{\delta}, \underline{\delta})$, and (iii) $[\underline{\delta}, \widehat{\delta})$. In case (i), cartel discipline θ^{2*} is U-shaped in t because maximal collusion is unsustainable. In case (ii), the dependence of θ^{2*} on t differs in that $\theta^{2*} = 0$ for an intermediate range of t values as they sustain the most collusive outcome. In case (iii), increases in t beyond t_y strengthen cartel discipline up to $\underline{t}'_m$ with $\theta^{2*} = 0$ for $t > \underline{t}'_m$.

Higher δ values reduce the range of internal trade costs under which cartel discipline varies with internal trade costs. On average, increases in δ strengthen cartel discipline. Next, we investigate the role of external trade costs (and ROW market size) captured in panel (b) of Fig. $A.1$.

Lemma A2: For given $\delta < \widehat{\delta}$, $\tau \leq \bar{\tau}$ and $\beta < \infty$, $\Phi^2(\theta, t, \cdot) = 0$ implicitly defines a contour over the (t, θ) plane that goes through four (pivot) points that are independent of τ and β. These points are given by: $D = (\bar{t}, \theta_g)$, $E = (\bar{t}, 1)$, $F = (t_f, 1)$ and $G = (t_g, \theta_g)$, where

$$\theta_g = \frac{17(\underline{\delta} - \delta)}{9 + \delta}, \quad t_g = \frac{A}{2}\left[\frac{(2 + \theta_g)\left(4 + 10\theta_g + \theta_g^2\right)}{56 - 9\theta_g^2 - 2\theta_g^3}\right], \quad t_f = \frac{A}{2}\left[\frac{45 - 61\delta}{45 + 89\delta}\right].$$

Proof: The impact of τ on Φ^2 is captured by

$$\Phi^2_\tau = -\frac{2(A - \tau)(9 + \delta)}{9\beta(8 + \theta)^2}(\theta - \theta_g)(1 - \theta). \tag{A.12a}$$

Changes in τ do not affect Φ^2 if: (i) $\theta = \theta_g$, or (ii) $\theta = 1$. The impact of β on Φ^2 is similar since

$$\Phi^2_\beta = -\frac{(A - \tau)^2(9 + \delta)}{9\beta^2(8 + \theta)^2}(\theta - \theta_g)(1 - \theta). \tag{A.12b}$$

To find the values of t that are associated with the pivot points noted in the lemma, we sequentially

consider cases (i) and (ii). Starting with case (i), invert $\theta = \theta_g(\delta)$ to obtain $\delta_g = 9(1-\theta)/(17+\theta)$. Substituting δ_g into Φ^2 yields, after some algebraic manipulation,

$$\Phi^2(\cdot) = -\frac{2\left(56 - 9\theta^2 - 2\theta^3\right)}{(4+\theta)^2(17+\theta)}(t_g - t)(\bar{t} - t) = 0.$$

The solutions to the above equation deliver the values of internal trade costs t_g and $\bar{t}$ associated with $\theta = \theta_g$ noted in the lemma. Since $dt_g/d\delta = (dt_g/d\theta_g)(d\theta_g/d\delta)$ and $dt_g/d\theta_g > 0$ while $d\theta_g/d\delta < 0$ we will have $dt_g/d\delta < 0$.

Turning to case (ii), we set $\theta = 1$ in $\Phi^2 = 0$ and simplify the resulting expression to obtain

$$\Phi^2(\cdot) = -\frac{(45 + 89\delta)}{225}(t_f - t)(\bar{t} - t) = 0,$$

where $dt_f/d\delta < 0$. ||

Lemma $A2$ establishes that, for $\delta < \underline{\delta}$, the $\Phi^2 = 0$ contours go through four stationary points (captured by D, E, F, and G) that are independent of the levels of external trade costs τ and market size β. Panel (b) of Fig. $(A.1)$ depicts three contours under the assumptions that $\beta = 1$ and $\delta < \underline{\underline{\delta}}$ for $\tau = 0$ initially. These contours are associated with free external trade ($\tau = 0$), costly external trade ($\tau' \in (0, \bar{\tau})$), and the absence of external trade ($\tau'' = \bar{\tau}$), respectively. Importantly, $\partial\theta^{2*}/\partial t < 0$ at $t = t_y$ and at point G. Moreover, point G is a pivot with θ^{2*} rotating clockwise around it when external trade costs τ rise.[57] Additionally, higher external trade cost levels τ (and, using similar logic, higher values in β) reduce the range of internal trade cost levels that affect cartel discipline. The impact of τ and β on cartel discipline differs from the corresponding impact of δ in that higher τ and/or β values weaken cartel discipline for $t < t_g$ but not for $t \in [t_g, \bar{t}]$.

In Lemma $A3$ below, we describe the dependence of cartel discipline on internal trade costs t along the ICC defined by $\Phi^2(t, \theta, \cdot) = 0$.

Lemma A3: Suppose the conditions of Lemma $A2$ are satisfied. Then the contour defined by $\Phi^2(t, \theta, \cdot) = 0$ for $(t, \theta) \in (0, \bar{t}) \times (-\infty, 1-\delta)$ is a convex function $\theta_s(t, \cdot)$ such that $\partial\theta_s/\partial t \lesseqqgtr 0$ as $t \lesseqqgtr t_{\min}$, where $t_{\min} = \arg\min_t \theta_s(t, \cdot) \in (t_g, \bar{t})$.

[57] $\theta = \theta_g$ at points A, G and D. When only external trade is present (i.e., $t \geq \bar{t}$ and $\tau < \bar{\tau}$), we have $\theta^* = \theta_g$. When both internal and external trade are absent, all points in $[\bar{t}, \infty) \times [0, 1]$ are acceptable as they imply $\Phi^2 \geq 0$.

Proof: The proof follows from the properties of $\Phi^2(t,\theta,\cdot)$ described in Lemma $A2$ and can be visualized with the help of Fig. $(A.1)$. It's important to note that, as defined, θ_s can take negative values — which, in due course, will be discarded (see Lemma 2 below) because they imply the monopoly solution is sustainable (i.e., $\theta = 0$). These portions of θ_s are not drawn in Fig. $(A.1)$ to avoid cluttering. Also note that, depending on market size β and external trade costs τ, $\theta_s(t,\cdot)$ may intersect the vertical axis below $1-\delta$. But this is inconsequential since all points of $\theta_s(t,\cdot)$ above $\theta_o(t)$ are irrelevant in this case (because they imply $y > 0$, which is a contradiction). ||

Lemmas $A1 - A3$ have prepared the ground for our in depth analysis of cartel discipline when cross hauling is absent. With the help of these lemmas we characterize cartel discipline when $y = 0$:

Lemma 2 *(Cartel Discipline 2) For $\delta < \widehat{\delta}$, $\beta < \infty$ and $t \in [t_y, \bar{t}]$, cartel discipline is captured by $\theta^{2*} \equiv \max(\theta_s, 0)$, where $\theta_s \equiv \theta_s(t,\cdot)$ solves $\Phi^2(\theta,t,\cdot) = 0$. In this case, increases in δ do not weaken cartel discipline θ^{2*} (i.e., $d\theta^{2*}/d\delta \leq 0$). θ^{2*} depends on trade costs and market size as follows:*

a) ***Internal Trade Costs (t)***

i) If $\delta \leq \underline{\underline{\delta}}$, then $\theta^{2*} = \theta_s$ and $d\theta^{2*}/dt \lesseqgtr 0$ for $t \lesseqgtr t_{\min} \equiv \arg\min_t \theta_s(t,\cdot)$.

ii) If $\delta \in (\underline{\underline{\delta}}, \underline{\delta}]$, there is a subset $[\underline{t}_m, \bar{t}_m] \subset (t_y, \bar{t})$ such that:

- *$\theta^{2*} = \theta_s$ and $d\theta^{2*}/dt < 0$ for $t \in (t_y, \underline{t}_m)$;*
- *$\theta^{2*} = 0$ for $t \in [\underline{t}_m, \bar{t}_m]$;*
- *$\theta^{2*} = \theta_s$ and $d\theta^{2*}/dt > 0$ for $t \in (\bar{t}_m, \bar{t}]$.*

iii) If $\delta \in (\underline{\delta}, \widehat{\delta}]$, there exists a $\underline{t}'_m \in (t_y, \bar{t})$ such that:

- *$\theta^{2*} = \theta_s$ and $d\theta^{2*}/dt < 0$ for $t \in (t_y, \underline{t}'_m)$;*
- *$\theta^{2*} = 0$ for $t \in [\underline{t}'_m, \bar{t}]$.*

b) ***External Trade Costs (τ) and Market size (β)***

i) $d\theta^{2*}/d\xi > 0$ for $t < \min(t_g, \underline{t}'_m)$ if $\underline{t}'_m$ exists, and $d\theta^{2*}/d\xi \leq 0$ for all other t where $\xi \in \{\tau, \beta\}$.

ii) Increases in τ or β expand the range of internal trade costs that imply $\theta^{2*} = 0$.

Proof: Our proof relies on Lemmas $A1 - A3$ which establish the key properties of the ICC when internal trade is absent ($y = 0$). Since $t \in [t_y, \bar{t}]$ in this case, only the portion of $\theta_s(t,\cdot)$ that lies below $\theta_o(t)$ is potentially admissible. Moreover, whenever $\theta_s < 0$, maximal collusion will be

sustainable, so $\theta^{2*} = 0$ in this case because the ICC is inactive.

Part (a). Panel (a) of Fig. $(A.1)$ illustrates the various cases that arise for alternative values of δ. The condition $\delta \leq \underline{\underline{\delta}}$ in $(a.i)$ ensures that maximal collusion is unsustainable for all $t \in [t_y, \bar{t}]$, so $\theta^{2*} = \theta_s$, as depicted by the blue, solid-line curve in panel (a). The proof to this part then follows from Lemma $A3$.[58]

If $\delta \in (\underline{\underline{\delta}}, \underline{\delta}]$, there will exist a range of internal trade costs $[\underline{t}_m, \bar{t}_m]$ that imply $\theta^{2*} = 0$ for all t in this range and $\theta^{2*} = \theta_s$ for all other values of t. The pink, solid-line curve in panel (a) illustrates θ^{2*} in this case. Part $(a.iii)$ is illustrated by the green, solid-line curve in the same figure.

Part (b). This part follows from Lemmas $A2$ and $A3$. The key point here is that, for given δ, increases in external trade costs $(\tau \uparrow)$ or decreases in market size $(\beta \downarrow)$ weaken cartel discipline if internal trade costs are sufficiently close to t_y and may strengthen it if these costs are sufficiently high. Panel (b) of Fig. $(A.1)$ sheds further light on this case. ||

Before we integrate our analysis of cartel discipline and trade costs, we state explicitly how $t_y \equiv t_y(\delta, \tau, \beta)$ (i.e., the lowest internal trade cost level that implies $y = 0$) depends on parameters.

Lemma A4: *For given $\delta < \widehat{\delta}$, $\tau < \bar{\tau}$ and $\beta < \infty$, there exists a unique internal trade cost level $t_y \equiv t_y(\delta, \tau, \beta) \in (0, \bar{t})$, such that $y > 0$ for $t \in [0, t_y)$ and $y = 0$ otherwise. Moreover,*

a) $dt_y/d\delta < 0$ *with* $\lim_{\delta \to \widehat{\delta}} t_y = 0$ *and* $\lim_{\delta \to 0} t_y = \bar{t}$;

b) $sign(dt_y/d\tau) = sign(dt_y/d\beta) > 0$.

Proof: The conditions of the lemma, the properties of $\theta^{1*}(t, \cdot)$ noted in Lemma 1 and of $\theta_s(t, \cdot)$ described in Lemma $A3$ (including the facts that $\partial\theta^{1*}/\partial t > 0$ and $\partial\theta_s/\partial t < 0$) imply that these functions intersect each other at a unique point t_y along $\theta_o(t)$, so that $\theta^{1*}(t_y) = \theta_s(t_y) = \theta_o(t_y)$. The proofs to parts (a) and (b) then follow from Lemma 1 (and/or Lemma 2) and can be visualized with the help of the two panels in Fig. $(A.1)$ and Fig. 3. ||

Proof of Proposition 2: The proofs to all parts follow readily from Lemmas 1 and 2. Two additional properties of θ^* for $t \in [0, t_y]$ ought to be emphasized. First, if $\delta \in [0, \underline{\delta}]$, then $\theta^*_{tt} > 0$

[58] Figs. 3(a) and 3(b) also illustrate this case. Additionally, Fig. 3(a) depicts the various ranges within which the discount factors lie.

for t close to 0 but $\theta^*_{tt} < 0$ for t close to t_y. Second, if $\delta \in (\underline{\delta}, \widehat{\delta})$, then $\theta^*_{tt} < 0$ for $t \in [0, t_y]$.[59] ||

Proof of Proposition 3: We first establish several properties of $Q^i(\theta, t)$ for $i = 1, 2$ which facilitate the proof of part (a). From (10a) and (12) one can see that $Q^i(\theta, t)$ is twice differentiable in θ and t. Ignoring for the moment the nature of the domains of these functions, define the bordered Hessians of order 1 and 2 of Q^i as

$$H_1^i \equiv \begin{pmatrix} 0 & Q^i_\theta \\ Q^i_\theta & Q^i_{\theta\theta} \end{pmatrix} \quad \text{and} \quad H_2^i \equiv \begin{pmatrix} 0 & Q^i_\theta & Q^i_t \\ Q^i_\theta & Q^i_{\theta\theta} & Q^i_{\theta t} \\ Q^i_t & Q^i_{t\theta} & Q^i_{tt} \end{pmatrix},$$

respectively, and let D_1^i and D_2^i $(i = 1, 2)$ be their corresponding determinants. One can see from $(A.4a)$, $(A.8a)$, $(A.10b)$ and $(A.10c)$ that $Q^i_\theta > 0$ and $Q^i_t < 0$ $(i = 1, 2)$ for $t < \bar{t}$. It follows that $D_1^i < 0$. Additionally, it is easy for one to show that $Q^i_{tt} = 0$, $Q^i_{\theta\theta} < 0$ and $Q^i_{t\theta} < 0$, so Q^i is linear in t and concave in θ. Furthermore, the determinants of the bordered Hessians of order 2 are:

$$D_2^1 = \frac{12(2A - t)(2 + \theta)}{(8 + \theta)^4} > 0 \quad \text{and} \quad D_2^2 = \frac{4(A - 2t)\theta}{(4 + \theta)^4} > 0 \text{ for } t < \bar{t}.$$

Because $D_1^i < 0$ and $D_2^i > 0$ for all $(t, \theta) \in (0, \bar{t}) \times (0, 1)$ one might infer that $Q^i(\theta, t)$ is strictly quasi-concave in (θ, t) or, equivalently, that every upper level set of Q^i $(i = 1, 2)$ is strictly convex. It turns out that this is true for $Q^2(\theta, t)$ but not for $Q^1(\theta, t)$. The reason for this is simple: The domain of Q^2 is a strictly convex set whereas the domain of Q^1 is not.[60] However, because we are primarily interested in the behavior of Q^* (which coincides with the values of Q^i along $\theta^*(t, \cdot)$), the just described issue is inconsequential.

Part (a). First note that $sign\left(dQ^{1*}/dt\right) = sign\left(\frac{\theta^{1*}_t}{-Q^1_t/Q^1_\theta} - 1\right)$. But, from Lemma 1 (b), we have $\lim_{t\to 0} \theta^{1*}_t = 0$ for $\delta \in [0, \underline{\delta})$ and $\lim_{t\to 0} \theta^{1*}_t = \lim_{t\to 0}\left(\theta^{1*}/t\right) = \left[\frac{32}{17}\left(\frac{1-\delta}{\delta-\underline{\delta}}\right)/\Pi_0^N\right]^{1/2}$ for $\delta \in [\underline{\delta}, \widehat{\delta})$, where $\Pi_0^N \equiv \Pi^N|_{t=0}$ (see $(A.6c)$). Moreover, from $(A.4a)$ and $(A.8a)$ we have $\lim_{t\to 0}(d\theta/dt)|_{dQ^1=0} = -Q^1_t/Q^1_\theta = \frac{(2+\theta)(8+\theta)}{12A} > 0$. It follows that $\lim_{t\to 0}\left(dQ^{1*}/dt\right) < 0$ for $\delta \in [0, \underline{\delta})$, so local output Q^{1*} rises as t falls for t close to 0.

[59] These properties of θ^* can be established with the help of tedious algebra and numerical analysis. They can be visualized with the help of Fig. 2.

[60] This follows from the facts that $\theta_o(t)$ is concave in t and $Q^2(\theta, t)$ is defined for $t < \bar{t}$ and $\theta \in (0, \theta_o(t))$ whereas $Q^1(\theta, t)$ is defined for $t < \bar{t}$ and $\theta \in (\theta_o(t), 1)$. Thus, we could describe $Q^1(\theta, t)$ as a piecewise quasi-concave function.

In contrast, for $\delta \in [\underline{\delta}, \widehat{\delta})$ we have

$$R \equiv \frac{\lim_{t\to 0} \theta_t^{1*}}{\lim_{t\to 0} (d\theta/dt)\,|_{dQ^1=0}} = \left[\frac{18A^2}{17\Pi_0^N}\left(\frac{1-\delta}{\delta-\underline{\delta}}\right)\right]^{1/2}.$$

Furthermore, because $R_\delta < 0$, we also have $R > \lim_{\delta\to\widehat{\delta}} R = 3 > 1$. Thus, $\lim_{t\to 0}\left(dQ^{1*}/dt\right) > 0$ in this case, so trade cost reductions decrease local output Q^{1*}.

As explained in the text, the second portion of part $(a.i)$ follows from the facts that $(d\theta/dt)\,|_{dQ^2=0} = -Q_t^2/Q_\theta^2 > 0$ and $\theta_t^{2*} < 0$ for t larger than but close to t_y. Since $sign\left(dQ^{2*}/dt\right) = sign\left(\frac{\theta_t^{2*}}{-Q_t^2/Q_\theta^2} - 1\right)$, trade cost reductions expand output Q^{2*} in the absence of cross hauling for t close to t_y.

The easiest way to establish parts $(a.ii)$ and $(a.iii)$ is with the use of numerical methods. But the intuition behind these is relatively easy to understand. For example, the uniqueness of t_Q in part $(a.ii)$ is due to the fact that θ^* is concave in $t \in [0, t_y]$ for $\delta \in [\underline{\delta}, \widehat{\delta})$ (as noted in the proof of Proposition 2) and the contours of Q^1 are strictly convex in $t \in [0, t_y]$. Additionally, the various components of part $(a.iii)$ (which treats the case of $\delta \in (0, \underline{\delta})$) can be understood by observing the strictly convex contours of Q^1 may be tangent to θ^* at several points because θ^* is convex in t for t close to 0 but concave in t for t close to t_y.

Part $(a.iv)$ follows from the facts that $dQ^*/d\xi = Q_\theta^i \theta_\xi^*$ for $\xi \in \{\delta, \beta, \tau\}$ and $Q_\theta^i > 0$ $(i = 1, 2)$.

Part (b). We establish the first portion of part $(b.i)$ via exhaustive numerical analysis. The second portion of part $(b.i)$ and part $(b.ii)$ follow readily from the fact that $dy^*/d\xi = y_\theta^* \theta_\xi^*$ for $\xi \in \{\delta, \beta, \tau\}$ and the observation that $y_\theta^* > 0$.

Part (c). Parts (i) and (iii) can be established by noting that $dz^*/d\xi = z_\theta^* \theta_\xi^*$ for $\xi \in \{\delta, t\}$, recalling that $z_\theta^* > 0$ and invoking Proposition 2. Part (ii), which is easiest to prove with the use of numerical methods, asserts that the direct effects of β and τ on z^* dominate their possibly opposing effects on z^* through cartel discipline. ||

Lemma A5: *(Welfare under Competition) In the Cournot-Nash equilibrium, ROW welfare is invariant to changes in internal trade costs t. In contrast, when t takes the form of tariffs (resp., transportation costs), reciprocal reductions in t enhance (resp., affect ambiguously) the welfare of countries that host the cartel. Moreover, if external trade costs τ are transportation costs, reductions in τ raise global profits and welfare levels in all countries. For cartel hosts, we also have*

a) $\arg\min_t V^N(t,\tau,\beta) = \frac{4A}{11} \in (0,\bar{t})$.

b) $V^N(t,\tau,\beta) \gtreqless V^N(\bar{t},\tau,\beta)$ *if* $t \lesseqgtr t_V$, *where* $t_V \equiv \frac{5A}{22} \in (0,\bar{t})$.

c) $W^N(0,\tau,\beta) = V^N(0,\tau,\beta) > V^N(\bar{t},\tau,\beta) = W^N(\bar{t},\tau,\beta)$.

d) $W^N(t,\tau,\beta) > V^N(t,\tau,\beta)$ *for all* $t \in (0,\bar{t})$.

Proof: From (13b) one can see that W^N_{ROW} depends on z^N which is decreasing in τ and β but does not depend on t. Thus internal trade cost reductions do not affect W^N_{ROW}. In contrast, external trade cost reductions and increases in the size of ROW's market raise W^N_{ROW}.

From the definitions of welfare in (13a) under tariffs and transport costs one can show, after rearranging terms, that

$$V^N = \frac{3A^2}{8} + \frac{(A/2-t)(5A+2t)}{36} + \frac{(A-\tau)^2}{9\beta}, \tag{A.13a}$$

$$W^N = \frac{3A^2}{8} + \frac{(A/2-t)(5A-22t)}{36} + \frac{(A-\tau)^2}{9\beta}. \tag{A.13b}$$

for $t \in [0,\bar{t}]$. Inspection of $(A.13b)$ reveals that, in the case of tariffs, $sign\left(\partial W^N/\partial t\right) = sign\left(\partial W^N/\partial \tau\right) = sign\left(\partial W^N/\partial \beta\right) < 0$. Thus, reciprocal reductions in any trade costs and/or increases in ROW's market size unambiguously benefit cartel hosts. Also, for $t > \bar{t}\,(A/2)$, the above expressions become

$$W^N = V^N = \frac{3A^2}{8} + \frac{(A-\tau)^2}{9\beta}. \tag{A.14}$$

Part (a). Differentiating $(A.13a)$ partially gives $\partial V^N/\partial t = (-4A+11t)/9$ and $\partial^2 V^N/\partial t^2 > 0$, which readily implies $\arg\min_t V^N = 4A/11 \in (0,\bar{t})$.

Part (b). This part follows by utilizing $(A.13a)$ to form the difference $V^N(t,\tau,\beta) - V^N(\bar{t},\tau,\beta) = \frac{11}{18}(\bar{t}-t)(\frac{5A}{22}-t)$ for $t < \bar{t} \equiv \frac{A}{2}$.

Parts (c) and (d). These parts follow from inspection and direct comparison of the payoffs in $(A.13a)$, $(A.13b)$ and $(A.14)$. ||

Parts (a) and (b) of Lemma $A5$ confirm the ideas that $V^N(t,\tau,\beta)$ is U-shaped in transportation costs t under Cournot-Nash competition and that internal trade liberalization could harm cartel hosts if t is sufficiently large. This possibility arises for the same reason as in the 2-country model

of Brander and Krugman (1983): For t close to $\bar{t}$, the welfare cost of cross hauling (due to shipping) outweighs the benefit due to increased competition. In contrast, when t takes the form of tariffs reciprocal reductions in these tariffs always enhance W^N as no resources are wasted in shipping goods.

Lemma A6: *(Competition vs Monopoly) Suppose $\tau < \bar{\tau}$ and interpret internal trade costs t as "tariffs". Then*

a) $W^M > W^N$ *for* $t \geq \bar{t}$.

b) If $t \in [0, \bar{t})$, *then* $W^M \gtreqless W^N$ *for* $\beta \lesseqgtr \breve{\beta}$, *where* $\breve{\beta} \equiv \frac{(A-\tau)^2}{2(A/2-t)(5A+2t)}$.

c) $W^M_{ROW} < W^N_{ROW}$ *for all* $t \geq 0$.

Proof: The proof to parts (a) and (b) follows readily by noting that

$$W^M = V^M = \frac{3A^2}{8} + \frac{(A-\tau)^2}{8\beta} \tag{A.15}$$

for any t and by comparing W^N in $(A.13b)$ to W^M in $(A.15)$ for the different values of t considered.[61] Part (c) follows from the fact that $z^M < z^N$ and the discussion in the text which pointed out that welfare in ROW is increasing in z. ||

Part (a) of Lemma $A6$ may appear counter-intuitive. $W^M > W^N$ in this case, because (i) the presence of prohibitive internal tariffs implies that each firm is de facto a monopolist in its own market, and (ii) profits in ROW under monopoly exceed profits under competition. Part (b) points out that the $W^M > W^N$ ranking remains intact in the presence of internal trade if ROW's relative market size is sufficiently large (specifically, if $\beta \leq \breve{\beta}$) and gets reversed when the size of ROW's market is relatively small. In the former case, the magnitude of monopoly rents in ROW outweighs the losses in consumer surplus (due to the exercise of monopoly power) in the hosts. Exactly the opposite is true in the latter case. One can also verify (by differentiating $\breve{\beta}$ appropriately) that $\breve{\beta}_t > 0$ and $\breve{\beta}_\tau < 0$. Thus, the larger the volume of internal (external) trade the stronger (weaker) the size requirement on β for pure monopoly to dominate Cournot-Nash competition. Part (c) underscores the point that ROW always prefers competition over monopoly.

[61] See also Lemma $A7$ and Fig. $A.2$ for a discussion and illustration of the ranking between W^N and W^M.

In Lemma $A7$ below we maintain the view that t stands for "tariffs" and characterize "optimal" cartel discipline θ_W^i and its dependence on parameters. This serves as a valuable benchmark relative to which one can assess the welfare consequences of cartels with endogenous discipline.

Lemma A7: *There exist unique optimal cartel-discipline functions $\theta_W^i(\cdot)$ for $i = 1, 2$ (i.e., functions that maximize welfare W^i). These functions have the following traits:*

a) $\theta_W^1 \in (\theta_o(t), 1)$ *for* $\beta \in (\underline{\beta}^1, \overline{\beta}^1)$ *and* $\theta_W^1 = 1$ *for* $\beta \geq \overline{\beta}^1$ *where*

$$\overline{\beta}^1 \equiv \frac{(A-\tau)^2}{(2A-t)(A+t)} \text{ and}$$

$$\underline{\beta}^1 \equiv \frac{3(A-\tau)^2 \theta_o}{(2A-t)[A(4-\theta_o)+t(2+\theta_o)]} \quad \text{for} \quad t < \bar{t}.$$

b) $\theta_W^2 \in (0, \theta_o(t))$ *for* $\beta \in (0, \overline{\beta}^2)$ *where*

$$\overline{\beta}^2 \equiv \frac{9(A-\tau)^2 \theta_o (4+\theta_o)^3}{(2A-t)(8+\theta)^3(2A+t\theta)} \quad \text{and } \underline{\beta}^2 = 0 \quad \text{for} \quad t < \bar{t}.$$

c) *Suppose* $\beta \in (\underline{\beta}^i, \overline{\beta}^i)$ *for* $i = 1, 2$. *Then*

i) $\partial\theta_W^1/\partial t > 0$ *and* $\partial\theta_W^2/\partial t < 0$.

ii) $sign\left(\partial\theta_W^i/\partial\beta\right) = sign\left(\partial\theta_W^i/\partial\tau\right) > 0$.

Proof: First note that differentiation of (13a) gives

$$W_\theta^1 = \frac{6(2A-t)[A(4-\theta)+t(2+\theta)]}{(8+\theta)^3} - \frac{18(A-\tau)^2\theta}{\beta(8+\theta)^3}, \tag{A.16a}$$

$$W_t^1 = -\frac{(2+\theta)[A(4-\theta)+t(2+\theta)]}{(8+\theta)^2} < 0 \tag{A.16b}$$

and

$$W_\theta^2 = \frac{2(2A-t)[2A+t\theta]}{(4+\theta)^3} - \frac{18(A-\tau)^2\theta}{\beta(8+\theta)^3}, \tag{A.17a}$$

$$W_t^2 = -\frac{\theta(2A+t\theta)}{(4+\theta)^2} < 0. \tag{A.17b}$$

Moreover, differentiation of the above expressions gives

$$W^1_{\theta\theta} = -\frac{36\left(A-\tau\right)^2\left(4-\theta\right)}{\beta\left(8+\theta\right)^3} - \frac{12\left(2A-t\right)\left[9A+\left(A-t\right)\left(1-\theta\right)\right]}{\left(8+\theta\right)^3} < 0, \tag{A.18a}$$

$$W^1_{tt} = -\frac{\left(2+\theta\right)^2}{\left(8+\theta\right)^2} < 0, \tag{A.18b}$$

$$W^1_{\theta t} = \frac{6\left[3A\theta - 2t(2+\theta)\right]}{\left(8+\theta\right)^3} > 0 \text{ (since } t < t_y) \tag{A.18c}$$

and

$$W^2_{\theta\theta} = -\frac{36\left(A-\tau\right)^2\left(4-\theta\right)}{\beta\left(8+\theta\right)^3} - \frac{4\left(A-2t\right)\left(3A-2t+t\theta\right)}{\left(8+\theta\right)^3} < 0, \tag{A.19a}$$

$$W^2_{tt} = -\frac{\theta^2}{\left(4+\theta\right)^2} < 0, \tag{A.19b}$$

$$W^2_{\theta t} = -\frac{\left[2A\left(4-\theta\right)+8t\theta\right]}{\left(4+\theta\right)^3} < 0. \tag{A.19c}$$

Equations $(A.16b)$ and $(A.17b)$ imply that W^i is decreasing in t and $(A.18b)$ and $(A.19b)$ imply that W^i is strictly concave in t. W^i attains a maximum at $t = 0$. Now observe from $(A.18a)$ and $(A.19a)$ that W^i is concave in θ and keep in mind that $\theta_o\left(t,\cdot\right)$ is the lower (upper) bound of possible θ values for W^1 (W^2) and $t \in [0, \overline{t}]$.[62] For clarity, we illustrate the welfare contours (the pink curves) in Fig. $A.2$ under the assumptions that $\beta = 0.45$ in panel (a) and $\beta = 0.15$ in panel (b). Turning to the welfare-maximizing values of θ, the concavity of W^i in θ ensures that θ^i_W $(i = 1, 2)$ are unique.

Parts (a) and (b). Temporarily suppose that $(A.16a)$ and $(A.17a)$ hold with equality. The values of β that ensure $W^1_\theta = 0$ and $W^2_\theta = 0$ are

$$\beta^1 = \frac{3\left(A-\tau\right)^2\theta}{\left(2A-t\right)\left[A\left(4-\theta\right)+t\left(2+\theta\right)\right]}, \tag{A.20a}$$

$$\beta^2 = \frac{9\left(A-\tau\right)^2\theta\left(4+\theta\right)^3}{\left(2A-t\right)\left(8+\theta\right)^3\left(2A+t\theta\right)}. \tag{A.20b}$$

Differentiation of β^i readily gives $\partial\beta^i/\partial\theta > 0$ for $i = 1, 2$. Thus, the upper and lower bounds for β^1 identified in part (a) can be obtained by setting θ equal to 1 and θ_o, respectively, in $(A.20a)$.

[62] It is not difficult to show that W^1 is piecewise concave in its arguments – we say "piecewise" because its domain is not a convex set for the reasons noted in the previous footnote. In contrast, W^2 is strictly concave in (θ, t) only if *ROW*'s market size is sufficiently large.

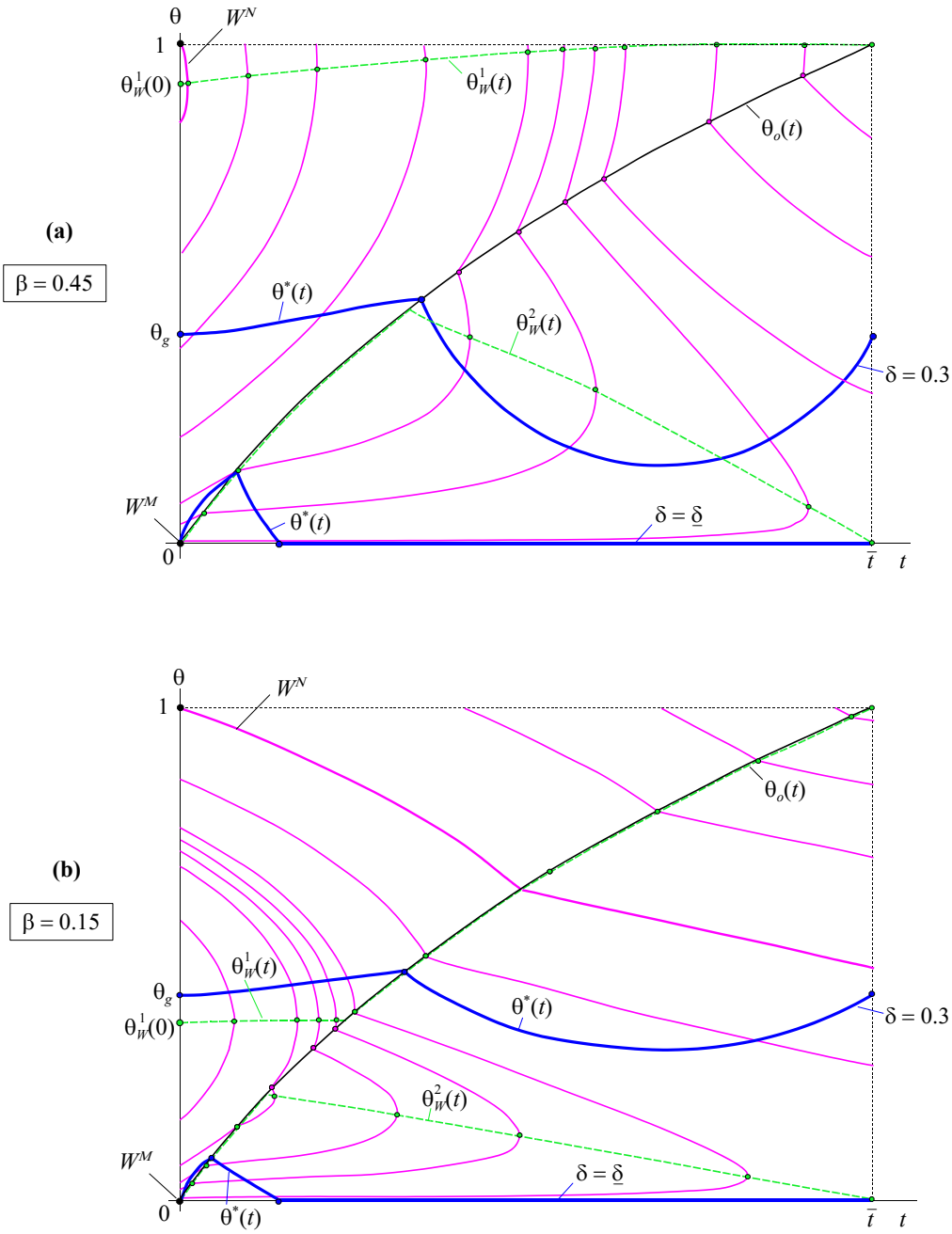


Figure A.2: Incentive Constraint Contours in the Absence of Cross Hauling ($\Phi^2 \geq 0$)

Similarly, $\overline{\beta}^2$ and $\underline{\beta}^2$ in part (b) is obtained by setting $\theta = \theta_o$ and $\theta = 0$ in $(A.20b)$.

Part (c). The effect of $\xi \in \{t, \beta, \tau\}$ on θ_W^i can be found by differentiating $W_\theta^i = 0$ $(i = 1, 2)$ and using the implicit function theorem to obtain: $\partial\theta_W^i/\partial\xi = -W_{\theta\xi}^i/W_{\theta\theta}^i$. Since $W_{\theta\theta}^i < 0$, we will have $sign\left(\partial\theta_W^i/\partial\xi\right) = sign\left(W_{\theta\xi}^i\right)$. But $(A.18c)$ and $(A.19c)$ reveal that $W_{\theta t}^1 > 0$ and $W_{\theta t}^2 < 0$. This substantiates part (i). Part (ii) follows from the fact that $W_{\theta\xi}^i > 0$ $(i = 1, 2)$ for $\xi \in \{\beta, \tau\}$. ||

For additional insight, suppose $t = 0$ (which implies $\theta_o = 0$) and $\tau = 0$. Then, $\overline{\beta}^1 = 0.5$ and $\underline{\beta}^1 = \overline{\beta}^2 = \underline{\beta}^2 = 0$ in this case. Thus, if $\beta < 0.5$, then $\theta_W^1(0) \in (0, 1)$, as shown in both panels of Fig. $A.2$. Consistent with part (c), reductions in β move $\theta_W^1(0)$ in the direction of the origin. Fig. $A.2$ also depicts the dependence of the welfare-maximizing functions θ_W^i (captured by the green dashed-line curves) on t. Depending on the values of β and t, these functions may coincide with $\theta_o(t)$ or equal 1. Lastly, ROW size determines the comparison among the welfare levels associated with the Cournot-Nash equilibrium (i.e., W^N at $\theta = 1$), monopoly (i.e., W^M at $\theta = 0$) and at θ_W^1.

Fig. $A.2$ also sets the stage for our analysis of welfare W^* in the presence of endogenous cartel discipline, the focus of Proposition 4. To facilitate this pursuit, we superimposed $\theta^*(t)$ on this figure for two discount factor values: $\delta = \underline{\delta}$ and $\delta = 0.3 < \underline{\delta}$. It's useful to keep in mind that functions $\theta_W^i(\cdot)$ do not depend on δ. Moreover, while $\theta^*(t)$ responds to changes in the relative size of ROW (as detailed in Proposition 2), point θ_g remains stationary.

Proof of Proposition 4: *Part (a).* From (14b), $dW_{ROW}^*/dt = (\partial W_{ROW}^*/\partial z)(\partial z^*/\partial\theta)\theta_t^*$, where $\partial W_{ROW}^*/\partial z > 0$ and $\partial z^*/\partial\theta > 0$ (from $(A.4d)$ and/or $(A.10b)$). Therefore, the qualitative effect of internal trade cost reductions $(t \downarrow)$ on welfare in ROW is determined by the effect on cartel discipline that as described in Proposition 2. This completes the proof to part (a).

Part (b). This part explains how the discount factor conditions the effect of internal trade liberalization on a cartel host's welfare when this liberalization has already advanced significantly. Accordingly, we prove it by studying the behavior of W^* in the neighborhood of $t = 0$. But, as noted in the text, W^* depends on Q^* and z^*. Further, as noted in Proposition 3, the dependence of Q^* hinges on whether $\delta \in (\underline{\delta}, \widehat{\delta})$ or $\delta \in (0, \underline{\delta})$. From (14b) we have

$$\lim_{t\to 0}\frac{dW^*}{dt} = \lim_{t\to 0} p\left(dQ^*/dt\right) - \lim_{t\to 0}\left[\frac{3(A-\tau)\theta^*}{8+\theta^*}\left(\partial z^*/\partial\theta\right)\left(d\theta^*/dt\right)\right]. \tag{A.21}$$

Now consider part (i), which focuses on $\delta \in (\underline{\delta}, \widehat{\delta})$. From Proposition $3\,(a)$, we know that $\lim_{t\to 0}(dQ^*/dt) > 0$ so the first term is positive. Moreover, from $(A.4d)$ we know that $\partial z^*/\partial\theta > 0$ and, from part $(b.ii)$ of Lemma 1, we know that $\lim_{t\to 0}(d\theta^*/dt) > 0$. However, we also know from Lemma 1 that $\lim_{t\to 0}\theta^* = 0$ in this case. This causes the second term in the right-hand side of $(A.21)$ to vanish. Thus, $\lim_{t\to 0}(dW^*/dt) > 0$, so it must be the case the internal trade liberalization is necessarily welfare-reducing when t is sufficiently low to start with.

Let us now turn to part (ii), which deals with $\delta \in (0, \underline{\delta})$. From Proposition $3\,(a)$, we have $\lim_{t\to 0}(dQ^*/dt) < 0$. Moreover, from part $(b.i)$ of Lemma 1, we know that $\lim_{t\to 0}(d\theta^*/dt) = 0$. Thus, once again, the second term in the right-hand side of $(A.21)$ vanishes and we are left with the first term which is negative. In this case, internal trade liberalization is welfare-improving when t is sufficiently low initially.

While parts (a) and (b) deal with the behavior of W^* locally in the neighborhood of $t = 0$, additional insight on the dependence of W^* on reciprocal tariffs can be generated with the help of Fig. $A.2$. In particular, the shapes of the welfare contours in this figure in relation to $\theta^*(t)$ for various ROW size (β) and discount factor (δ) parameter values. For example, one can see why $W^*(t)$ may have multiple peaks when β is large (i.e., the size of ROW is small). One can also see why this is no longer an issue (and why $W^*(t)$ is monotonic in t) when β is small.

Parts (c) and (d). These parts follow readily upon inspection of Fig. $A.2$. For example, to understand and explain part (c), focus on $t = 0$ and suppose $\beta = 0.15$ (as shown in panel (b)) which is consistent with the idea that ROW's size is relatively large and, consequently, export opportunities to it are extensive. Starting at $\delta = \underline{\delta}$ (so that $W^* = W^M$) let δ fall. By Proposition $2\,(a)$, cartel discipline weakens (i.e., $\theta^* = \theta_g$ will rise) thus causing W^* to rise until $\theta_W^1(0)$ is reached where W is maximized. The non-monotonicity of W^* in δ becomes apparent when $\theta_W^1(0)$ is crossed and W^* begins to fall. Part (d) also follows upon inspection of Fig. $A.2$. ||

For Online Publication - Appendix B: Data

Our sample covers the period 1988-2012 for the 34 members of the Organization for Economic Co-operation and Development (OECD) at the 6-digit Harmonized System (HS) level. We perform the analysis at the 6-digit HS product level because this is the most disaggregated level for which there exist internationally consistent data on bilateral trade flows.[63] Availability of trade flows data determined the span of the period of investigation to 1988-2012. Moreover, the current study is going to focus on cartels comprised of OECD country members only for several reasons. First of all, bilateral trade flows data at the 6-digit HS level of aggregation are more reliable for OECD nations. Second, 165 of the 173 private international cartels in the data set include participants exclusively from OECD countries. Third, trade between OECD countries accounts for about two-thirds of world trade. Moreover, non-cartel OECD countries represent the most appropriate reference group for our analysis of the effects of collusion on trade. Next, we describe the main covariates that we use to capture the effects of collusion and trade costs in bilateral trade and the data sources that we employ.

International Cartels. The focus of this dataset will be on discovered and prosecuted private international cartels defined by Connor (2006) as "... a conspiracy in restraint of trade that has or is alleged to have one or more corporate or individual participants with headquarters, residency, or nationality outside the jurisdiction of the investigating antitrust authority."[64] Thus far, the cartel dataset covers 173 private international cartels that existed between 1958 and 2010. A total of 48 countries (28 of which are OECD members) have participated in at least one of these cartels. However, due to limitations imposed by the trade data, we have to drop all cartels that were functional exclusively prior to 1988 (which amounts to about 2% of all cartels in our sample). Also, any cartels that operated in the services sectors (transportation, insurance, banking, cargo shipping, etc.) are deleted due to the lack of reliable (and highly disaggregated) trade services data.

[63] The Harmonized Commodity Description and Coding System (or Harmonized System) has been developed and maintained by the World Customs Organization and is an international nomenclature that comprises more than 5,000 commodity groups defined by a 6-digit code (HS code). Internationally traded goods and services are categorized according to qualities, purpose of use, and type. For more information: http://www.wcoomd.org/en/topics/nomenclature/overview/what-is-the-harmonized-system.aspx

[64] The initial data on private international cartels have been kindly provided by John M. Connor and Jeffrey E. Zimmerman. Substantial modifications have been made to the dataset by both expanding the list of international cartels, adding new variables, and verifying the existing information.

To fit the purposes of this study, we have included additional information on the countries of nationality, residence, or headquarters of the firms and/or individuals that have participated in these cartels.[65] Furthermore, we have created several variables that describe the instruments of collusion, i.e. price fixing, customer and/or market share allocation, sales quotas, sharing of commercially important and confidential information, bid-rigging, guaranteed buy-back, and recidivism. The data contain the specific duration of each of the cartels as reported by the available sources[66] as well as the 6-digit HS product code corresponding to each of the cartelized products. The mapping of the relevant products to HS codes proved straightforward in some instances and relatively challenging in others. For instance, in the Hydrogen Peroxide and Perborate cartel[67] the 6-digit HS codes corresponding to hydrogen peroxide and perborate are, respectively, 284700 and 284030. On the other hand, the HS codes linked to the products of the Carbon Electrodes cartel[68] are both 854511 and 854519 (one for the kind used for furnaces and one for the kind used for electrolytic purposes, respectively). Thus, in some cases a single cartel is linked to more than one HS code depending on the number and the variety of the cartelized products.[69] Additional variables such as the number of firms, subsidiaries, and/or individuals that participated in each cartel and the country of discovery are also provided. Furthermore, we have verified and continuously updated information regarding the market share controlled by the cartel, the existence of a dominant cartel-member or a cartel leader, as well as the presence of a multiple offender.

Cartel Characteristics. First, it is important to distinguish between two different types of cartel participants: groups of firms (i.e., a parent company and its multiple subsidiaries) and just single firms. Therefore, the data includes not only the number of participating groups of firms, but also

[65] Following Levenstein and Suslow (2010), we use the nationality of the parent company to identify the country of origin for each cartel member, unless any foreign subsidiaries were actually convicted of violating antitrust laws.

[66] The main sources of information include (but are not limited to) the Department of Justice, the European Commission, the Canadian Competition Bureau, U.K.'s Office of Fair Trading, books, different journal articles and/or newspaper articles.

[67] European Commission - Case COMP/F/38.620:
*http://ec.europa.eu/competition/antitrust/cases/dec_docs/*38620/38620_380_4.*pdf*

[68] European Commission - Case COMP/E-1/36.490: *http://eur−lex.europa.eu/legal−content/EN/TXT/?uri = CELEX* : 32002*D*0271

[69] In a few instances, firms colluded in the production or distribution of an entire line of products and we had to use a more aggregated HS product category (such as 2-digit HS product codes or 4-digit HS product codes). Some examples include the Automobile Parts cartel (HS code - 8708), the Ferrosilicon cartel (HS code - 7202), the Haberdashery Products cartel (HS codes - 7319, 9606, 9607), and a few more. Only in the Toys and Games cartel, we had to use the 2-digit HS product code as no specifics regarding the cartelized products were provided by the U.K.'s Office of Fair Trading. Insufficient details regarding the specific type and characteristics of the cartelized products prevents us from using 6-digit HS codes in these few instances.

the total number of cartel members, including the subsidiaries of these firms that have also been addressees to the authorities' decisions. Thus, $FIRMS_k$ denotes the total number of groups of firms that participated in cartel k, while $SUBSIDIARIES_k$ denotes the total number of subsidiaries that participated in cartel k. Metz et al. (2013) and Levenstein and Suslow (2010) find the number of cartel members to exert a positive impact on the hazard rate. In Dick (1996) and in Zhou (2012), the number of cartel members is shown to have a negative and statistically significant impact on the hazard of dissolution. Brenner (2005) finds that the number of cartel members affects cartel duration negatively in most of his specifications, but the estimates are not statistically significant.

Second, theoretical models of collusion have emphasized the importance of market concentration for the existence of cartels. To capture this, in the data $LGMRKSHR_k$ is an indicator variable that takes the value of one if the market share of cartel k in the relevant sector exceeds 50%, while $MRKSHR_k$ reports a precise estimate of cartel k's share of the appropriate geographic market.[70] Metz et al. (2013) find $LGMRKSHR_k$ to have a positive effect on the hazard rate. Levenstein and Suslow (2010) show that a higher industry concentration, as measured by the industry four-firm concentration ratio, increases the risk of cartel dissolution. Dick (1996) shows that cartels that covered more than 50% of the industry's exports had a longer duration (the estimate on the dummy variable he uses is negative and significant). De (2010) finds $MRKSHR_k$ to exert a positive, but insignificant effect on the hazard ratio. Moreover, the dummy variable $RCDVST_k$ takes the value of one if at least one of the members of cartel k has also participated in a different collusive episode and is zero otherwise. This variable captures the experience of cartel k's members in engaging in collusive activities. Firms that have been found guilty of participating in multiple cartels usually received larger fines from the anti-trust authorities. On the other hand, in some cases, recidivists provided the investigating authorities with information regarding other cartels in which they were involved and had their fines therefore reduced.

Collusive Practices. $PRCFIX_k$ is a dummy variable that takes the value of one if cartel k's members fixed prices or agreed upon simultaneous price increases. Dick (1996) finds that $PRCFIX_k$ has a positive, but insignificant impact on the risk of cartel death. $ALLCTN_k$ is another indicator variable that takes the value of one if cartel k's members allocated customers

[70] Such an estimate was reported by the anti-trust authorities only in a minority of the cases and these numbers usually correspond to a given year only.

and/or market shares among each other. Levenstein and Suslow (2010) find that market allocation tends to increase the risk of cartel death, although the estimate is insignificant. Zhou (2012), on the other hand, finds a negative and significant effect of $ALLCTN_k$ on the hazard rate. $QUOTA_k$ is an indicator variable that takes the value of one if cartel k's members assigned production quotas. $INFRMN_k$ is an indicator variable that takes the value of one if cartel k's members shared commercially important and confidential information. $BIDRGG_k$ is a dummy variable that takes the value of one if cartel k's members rigged bids. Metz et al. (2013) find this variable to have a negative impact on the hazard rate. Moreover, in some instances, a single firm took the responsibility of scheduling secret meetings, monitoring the adherence to the cartel agreement, and initiating punishment, if necessary. Usually, such firms received larger sanctions by the anti-trust authorities. In order to capture this cartel characteristic, we include a dummy variable $DOMFIRM_k$, which takes the value of one if there was a dominant firm (or a leader) in cartel k. Metz et al. (2013) and Zhou (2012) find this variable to exert a positive impact on the hazard rate. Further, some cartel agreements were based on the determination of sales quotas and promoted compliance to these quotas using "guaranteed buy-backs": a firm that exceeded its quota in the previous period had to buy output from the cartel member who was below the quota. In the data, the implementation of such a punishment strategy by cartel k is captured by $BUYBCK_k$ - an indicator variable that takes the value of one when the agreement stipulated guaranteed buy-backs and is zero otherwise.

Causes of Cartel Death. In addition, the variable $BREAKUP_k$ captures the reasons for cartel k's dissolution using five possible indicators: L stands for cartel death due to a leniency application by one of the members; US stands for a cartel break-up due to an investigation by the United States' Department of Justice; EU stands for cartel death due to an investigation by the European Commission; C stands for cartel death due to a complaint by an affected buyer or a non-cartel competitor; ND stands for natural death of the cartel; and $OTHER$ stands for cartel death due to other reasons (investigation by the Competition Bureau of Competition, for instance). Moreover, we capture which anti-trust authority was responsible for first uncovering cartel k using five different dummy variables: $DSCVR_US_k$, $DSCVR_EU_k$, $DSCVR_CA_k$, $DSCVR_JOINT_k$, $DSCVR_OTHER_k$, which take the value of one if cartel k was discovered by, respectively, the US

authorities, EU authorities, Canadian authorities, jointly by multiple anti-trust bodies, or other anti-trust authorities (Australian Competition and Consumer Commission, for instance). Similarly, Metz et al. (2013) include dummy variables to control for the region of discovery - US, EU, and other in their case - and find them all to decrease the risk of cartel dissolution.

Other Cartel-Related Variables. Similarly to Connor and Zimmerman (2005), we also include a variable that captures the cultural diversity of each cartel. $CLTRDV_k$ is defined as the ratio of the number of countries over the number of firms that participated in cartel k. Thus, this variable reflects the difficulty of sustaining collusion when all cartel members are from different countries and exhibit diverse cultural characteristics, work ethic, customs. This variable also appears in Metz et al. (2013) and in most of their estimation specifications exerts a positive impact on the hazard rate.

Bilateral Trade Flows. Bilateral trade flows data at the 6-digit HS level come from the United Nation's COMTRADE database. We use cif imports, which is the theoretically correct trade variable, as the base for our analysis. Import data is available for 42% of our observations. To increase the number of non-missing observations, we employ a mirror procedure to map bilateral exports to imports. This increases the percentage coverage of our sample to 53%. In the sensitivity analysis we experiment with only import data.

Bilateral Trade Costs. Following our theory and the extensive empirical gravity literature, we proxy for bilateral trade costs using standard gravity variables such as the logarithm of bilateral distance between trading partners i and j, $\ln DIST_{ij}$; a binary variable, which takes the value of one if i and j share a common language, $LANG_{ij}$; a binary variable, which takes the value of one if i and j share a contiguous border, $CNTG_{ij}$; a binary variable, which takes the value of one if i and j share a colonial ties, $CLNY_{ij}$; a binary variable, which takes the value of one if i and j have a regional trade agreement at time t, $RTA_{ij,t}$. Data on the standard gravity proxies for trade costs are from the CEPII database. Data on regional trade agreements are from Mario Larch's Regional Trade Agreements Database from Egger and Larch (2008).

The current empirical analysis is subject to at least two important caveats. First, due to data availability the study inherently suffers from a sample selection bias. This is due to the fact, that we have information only on discovered and prosecuted international cartels and we know

nothing about any cartels that were never discovered or prosecuted by the anti-trust authorities. However, the direction of the bias is unclear. If only the most effective cartels are caught, because the least effective ones fall apart on their own and are really short-lived, then the average effect of international cartels will be overestimated. On the other hand, if anti-trust authorities only discover and prosecute the least effective cartels, because the most effective ones are extremely successful at colluding, then the average impact of cartels will be underestimated.

Second, despite all our efforts to collect precise and consistent information on international cartels, the exact dates marking the beginning and the end of the collusive period as reported by the anti-trust authorities might not always be accurate. In some cases, the exact period of collusion may be negotiated as part of a plea agreement as pointed out by Miller (2009). Moreover, sometimes the anti-trust authorities suspected (but did no have enough evidence to prove) that cartels had existed for a longer period. Therefore, the documents provided by the European Commission on numerous cartel cases state "...cartels existed from as early as ..." or "...colluding at least from ..." Thus, the reader should keep in mind these potential limitations of the empirical analysis.

Table 3: Summary Statistics - First Stage

Variable	Mean	Std. Dev.	Min.	Max.	N
TRADE COSTS					
DIST_INTRL	-12.174	1.555	-14.913	-5.821	153
TRFF_INTRL	0.986	0.813	0	4.312	119
DIST_EXTRL	-13.707	1.145	-15.934	-10.424	153
TRFF_EXTRL	0.86	0.816	0	4.076	123
Δ % TRFF_INTRL	0.445	0.844	-2.406	2.773	113
Δ % TRFF_EXTRL	0.409	0.789	-3.819	2.416	114
DISCPLN CNTRLS					
MONTHS	97.915	79.312	4	419	153
FIRMS	6.5	5.71	2	42	153
LGMRKSHR	0.791	0.408	0	1	153
ALLCTN	0.529	0.501	0	1	153
DOMFIRM	0.281	0.451	0	1	153
PRCFIX	0.935	0.248	0	1	153
INFRMN	0.654	0.477	0	1	153
QUOTA	0.399	0.491	0	1	153
BIDRGG	0.144	0.352	0	1	153
RCDVST	0.739	0.441	0	1	153
BUYBCK	0.196	0.398	0	1	153
CLTRDV	0.838	0.354	0.2	2	153
DSCVR_US	0.497	0.502	0	1	153
DSCVR_CA	0.013	0.114	0	1	153
DSCVR_EU	0.471	0.501	0	1	153
DSCVR_OTHER	0.078	0.27	0	1	153

Notes: This table reports the summary statistics for the variables used in the main specifications in the first stage analysis.

Table 4: Summary Statistics - Second Stage

Variable	Mean	Std. Dev.	Min.	Max.	N
TRADE	8756.929	218700.359	0.001	50465896	447306
DIST	7.834	1.161	5.081	9.880	447306
CNTG	0.112	0.316	0	1	447306
LANG	0.101	0.302	0	1	447306
CLNY	0.061	0.239	0	1	447306
RTA	0.673	0.469	0	1	447306
CRTL_INTRNL	0.011	0.106	0	1	447306
CRTL_INTRNL _DSCPLNE	0.162	1.423	0	14.421	324011
CRTL_EXTRNL	0.042	0.201	0	1	447306
CRTL_EXTRNL_DSCPLN	0.565	2.598	0	14.421	324011
CRTL	0.054	0.225	0	1	447306
CRTL_DSCPLN	0.727	2.931	0	14.421	324011

Notes: This table reports the summary statistics for the variables used in the main specifications in the second stage analysis.

Table 5: Countries Cartel-Members

Country	**OECD Member**
Angola	No
Australia	Yes
Austria	Yes
Belgium	Yes
Brazil	No
Burkina Faso	No
Cameroon	No
Canada	Yes
Central African Republic	No
China	No
Congo	No
Czech Republic	Yes
Denmark	Yes
Finland	Yes
France	Yes
Gabon	No
Germany	Yes
Greece	Yes
Guinea	No
Hong Kong	No
India	No
Ireland	Yes
Israel	Yes
Italy	Yes
Japan	Yes
Korea	Yes
Kuwait	No
Luxembourg	Yes
Malawi	No
Malaysia	No
Mali	No
Mexico	Yes
Niger	No
Netherlands	Yes
Norway	Yes
Poland	Yes
Portugal	Yes
Senegal	No
Singapore	No
Slovenia	Yes
Slovak Republic	Yes
Spain	Yes
Sweden	Yes
Switzerland	Yes
Taiwan	No
Togo	No
United Kingdom	Yes
United States	Yes

Notes: This table lists all countries present in the International Cartels Data and also specifies whether they are OECD members or not.

For Online Publication - Appendix C: Robustness Analysis

This appendix presents estimates and offers details and discussion for a series of sensitivity experiments that we performed in order to test the robustness of our results about the relationships between trade costs and cartel discipline and between cartel discipline and international trade. The presentation follows the exposition from the main text.

On the Effects of Trade Costs on Cartel Discipline

To examine the robustness of the first-stage results, we perform a series of sensitivity experiments. And in order to easy the comparison with our main results, we include in column (1) of Table 6 the main estimates presented in column (8) of Table 1. Distance Aggregates: To verify the robustness of our results to the use of various proxies for trade costs and different aggregation methods, we experiment with two additional constructs of internal and external distance. First, instead of using population-weighted distance as a proxy for trade costs, we obtain an aggregate of bilateral distance using GDP weights. The results are presented in column (2) of Table 6 and remain in line with our main estimates and in support of our theoretical model. Both internal and external trade costs have a positive effect on the hazard of cartel dissolution and therefore are inversely related to cartel discipline. Next, we construct the distance aggregates using population weights again, but multiply them with bilateral distance, instead of the inverse of bilateral distance. The estimates of both internal and external trade costs in column (3) of Table 6 are still positive and highly statistically significant.

$CRTL_EXTRNL^{k,g}_{i-j,t}$ *Definition:* Our theory is quite specific about the definition of a cartel outsider. However, given the flexibility of our cartels dataset, we experiment with several different possible definitions of an external market, ranging from 'liberal' to 'conservative', in order to test the robustness of the main results. The results are presented in columns (4)-(6) of of Table 6. First, we use a quite liberal definition of $CRTL_EXTRNL^{k,g}_{i-j,t}$, where the variable takes the value of 1 as long as country i is a member of cartel k in sector g, but country $-j$ is not. The results in column (4) remain qualitatively unchanged. Then, in column (5) we use a more conservative definition of an outsider, such that $CRTL_EXTRNL^{k,g}_{i-j,t}$ takes the value of 1 as long as the non-cartel importer $-j$ trades with 3 or more of the cartel exporters i. Essentially, now we define the importer $-j$ as a

market where 3 or more cartel members meet. Again, the estimates of both internal trade costs and external trade costs remain positive and significant. However, the coefficient on $TRFF_INTRL$, although still positive, is no longer statistically significant. Lastly, in column (6), we use an even more restrictive definition of $CRTL_OUT^{k,g}_{i-j,t}$, which now takes the value of 1 as long as country i is a member of cartel k in sector g, but country $-j$ is not and all outsiders import from all cartel members. The results in column (6) show that internal trade costs continue to exert a positive and statistically significant impact on the risk of cartel death, whereas the estimates on external trade costs and on internal tariffs remain positive, but lose their statistical significance. This could be explained by the fact that moving from the liberal to the most conservative definition of $CRTL_EXTRNL^{k,g}_{i-j,t}$ leads to a loss of 60% in the non-zero observations of external distance.

Tariffs: Having experimented with different distance aggregates for our proxies for internal and external trade costs, it is only natural that we do the same with the internal and external tariff constructs. Thus, we examine the sensitivity of our main estimates not only to changes in the trade costs and trade liberalization proxies, but also to changes in the number of observations in our sample (due to the relatively sparse tariff data). Therefore, in column (7), we proceed by including only our proxies for internal trade costs and external trade costs without any of the tariff-related variables in order to employ the maximum number of observations in our sample. Again, the results show that both $DIST_INTRL$ and $DIST_EXTRL$ have a positive and significant impact on the risk of cartel death and are, therefore, inversely related to cartel discipline. Next, in column (8) of Table 6 we use the initial tariff level to proxy for trade liberalization and while the results are unchanged for internal and external distance, $TRFF_INTRL$ loses its statistical significance, but remains positive. In column (9), we use most favored nation (MFN) weighted average tariffs instead of the effectively applied weighted average tariff rates in order to proxy for trade liberalization and the results remain qualitatively unchanged.

Industry Fixed Effects: Lastly, we control for various observable and unobservable sector-specific characteristics that could potentially affect the duration of collusion by including industry fixed effects to our main specification from column (8) of Table 1. The results presented in column (10) of Table 6 show that we still find that both internal and external distance have a positive and significant effect on the hazard ratio. Overall, our sensitivity experiments show that the first-stage

estimates are qualitatively unchanged and robust to the use of various proxies for trade costs and trade liberalization and the inclusion of controls for unobserved sectoral heterogeneity.

On the Effects of Cartel Discipline on International Trade

Table 7 and Table 8 present a series of robustness checks for our second-stage estimates. In both tables, we include in column (1) our main estimates from column (4) of Table 2 to ease comparison.

Cartel Discipline Definition: Although the definition of our inverse index of cartel discipline, θ, presented in the theoretical model is quite precise, due to the lack of data on cartel discipline in the empirical analysis we experiment with several such proxies, constructed using our first-stage estimates. The results are presented in columns (2)-(4) of Table 7. In column (2) of Table 7 we use a more conservative measure of cartel discipline, constructed using only the first-stage estimates of and actual data on our proxies for trade costs and trade liberalization (distance and effectively applied tariff rates) without including any of the cartel controls. The estimates remain qualitatively similar to the main findings. Quantitatively, we find that the effects of cartels and cartel discipline have doubled in magnitude to the extent that the estimate of the presence of cartels on internal trade is implausibly large. This result casts doubt on this specification. Then, in column (3) of Table 7, we construct our proxy for cartel discipline using only the estimates of and data on the controls for cartel discipline for which we obtained significant estimates. Once again we confirm our main findings. Next, we use a more liberal proxy for discipline – the predicted hazard ratio from the first-stage estimation including the effects of the industry fixed effects. We still find that the estimates of the presence of cartels and cartel discipline are significant and with expected signs. However, the estimates on external trade are no longer significant.

$CRTL_EXTRNL^{k,g}_{i-j,t}$ *Definition:* Similarly to the robustness experiments for our first-stage analysis, we also experiment with various definitions of a cartel outsider in the creation of $CRTL_DSCPLN_EXTRL$ for our second-stage estimations. In columns (6)-(8) of of Table 7, we use alternative definitions of a cartel non-member country. First, we define the external market $-j$ as a market where at least one of the cartel members exports to. The results in column (6) remain qualitatively unchanged. Then, in column (7) we use a more conservative definition of a cartel outsider and require it to trade with 3 or more of the cartel exporters. Again, the estimates of

both $CRTL_DSCPLN_INTRL$ and $CRTL_DSCPLN_EXTRL$ remain negative and significant and all the other coefficients are qualitatively unchanged. Lastly, in column (8), we use an even more restrictive definition of $CRTL_EXTRNL^{k,g}_{i-j,t}$, which now takes the value of 1 as long as all members of cartel k in sector g export to the same outsider simultaneously. This is the most restrictive definition of a cartel non-member, yet we still find that both $CRTL_DSCPLN_INTRL$ and $CRTL_DSCPLN_EXTRL$ have a negative and significant impact on bilateral trade.

PPML: Then, in column (2) of Table 8 we employ the Poisson Pseudo Maximum Likelihood (PPML) technique to verify the robustness of our main results. The use of the PPML estimator has been advocated by Santos-Silva and Tenreyro (2006) as it accounts for the heteroskedasticity present in the trade data as well as for the existence of zero trade flows and thus delivers unbiased and consistent estimates of the variables of interest. Once again, the results shown in column (6) remain qualitatively in line with our main findings and support the predictions of the theoretical model. Namely, $CRTL_DSCPLN_INTRL$ and $CRTL_DSCPLN_EXTRL$ both affect bilateral trade in a negative and statistically significant manner.

Fixed Effects: In column (3) of Table 8, we estimate our main model again with OLS, but now we also include symmetric bilateral fixed effects, which not only control for any country-pair-specific unobserved heterogeneity, but also account for all bilateral time-invariant trade costs.[71] More importantly for our purposes, the bilateral fixed effects also control for any potential endogeneity in the cartel variables. Again, the results show that cartel discipline is inversely related to both internal and external trade. In column (4) of Table 8 we allow these pair fixed effects to also be asymmetric across exporter-importer pairs. The results remain qualitatively unchanged and again support our theoretical predictions. The specification in column (5) of Table 8 uses exporter-sector-time and importer-sector-time fixed effects. These fixed effects will account for any sector-country-time characteristics, e.g. size, consternation etc., that may affect trade but have been omitted from our model. Most of the estimates in column (5) are similar to our main results. Importantly, we find that the effects of cartels and cartel discipline on internal trade remain significant and with expected signs. However, we note that the effects of cartels and cartel discipline on external markets become insignificant. This result is consistent with out finding that the effects of cartels on

[71] Note that these bilateral time-invariant fixed effects absorb the standard gravity proxies for trade costs used in our previous specifications (distance, contiguity, common language, etc).

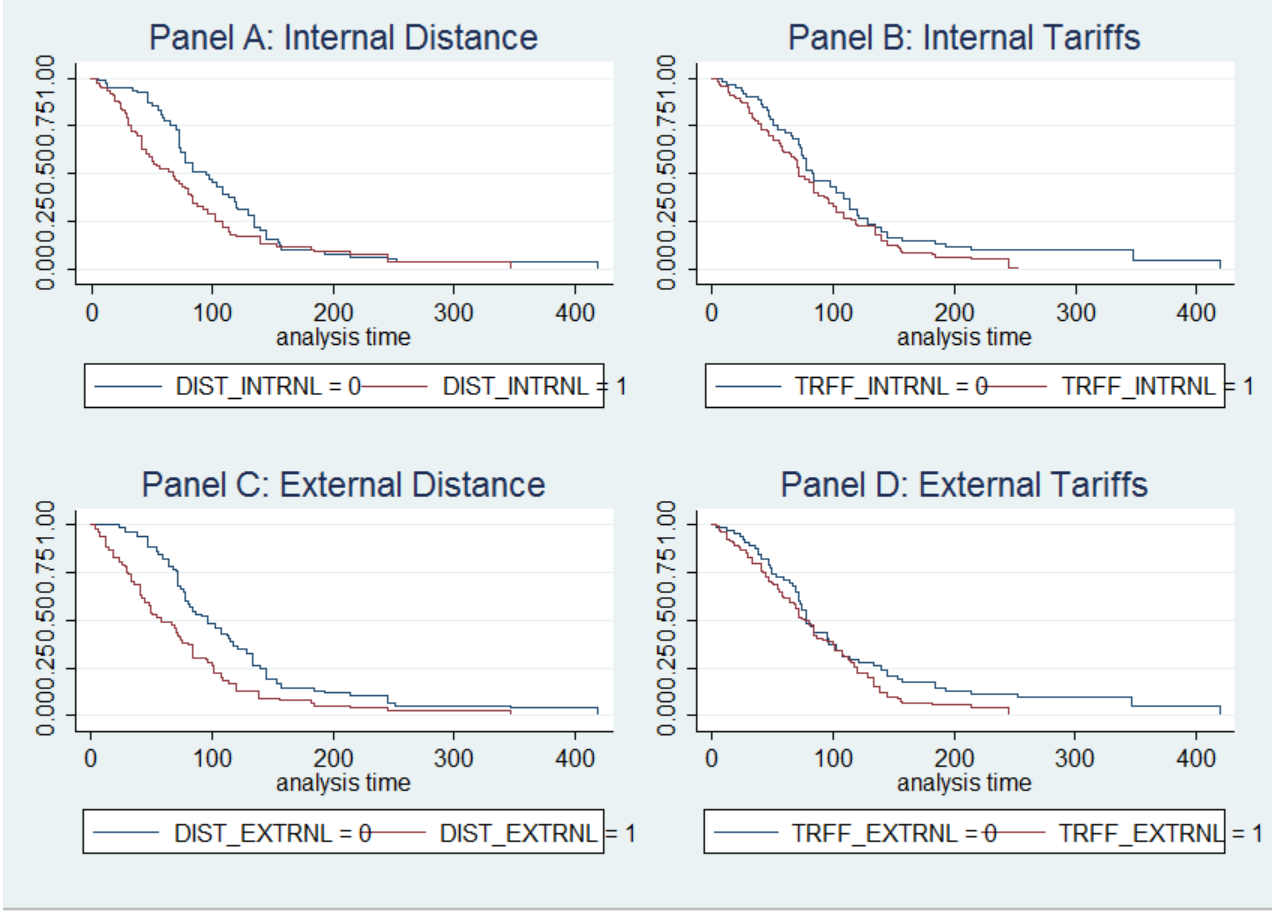
exports to third markets were always smaller as compared to the impact on internal trade. Finally, in column (6) we allow for the effects of trade costs to vary at the most disaggregated 6-digit HS product level. The new results are virtually identical to those from column (5).

No Duplicates: In column (7) of Table 8, we estimate our main specification with OLS again, but now we modify the dataset. In the original cartels-trade data, there are instances of multiple cartels in the same 6-digit HS product category. For instance, there are three different cartels, taking place at different periods of time and among different participants, in the beer sector (HS code 220300). In the first-stage analysis, we obtain a unique measure of the discipline of each of these cartels. Then, in the second-stage estimation, we combine each of the cartels with trade data from the corresponding product sector, which generates duplicating trade observations. To make sure that our main findings are robust to this data construction, we collapse the data to remove the non-unique observations, taking the average of the cartel discipline variables across cartels in the same product category. The results from an OLS estimation of our main specification with exporter-year, importer-year, and sector-year fixed effects are presented in column (7) of Table 8. Importantly, all of the estimates remain qualitatively unchanged with minor quantitative changes. Namely, we still find that cartel discipline has a negative and significant effect on internal trade and on external trade, while the mere presence of cartels tends to promote both internal trade and external trade. The estimates of the standard proxies for trade costs also preserve their respective signs and statistical significance.

Sample Size: Next, we test the sensitivity of our main results to the sample selection. First, we expand our sample by including all cartels, where the cartelized product was assigned a 4-digit HS code, which increases the number of observations by about 37%, and present the results in column (7) of Table 8. We still find that cartel discipline is inversely related to internal and external trade, but the estimate on internal trade, $CRTL_DSCPLN_INTRL$, is no longer significant. These findings remain intact when we focus on the entire sample of cartels and even include the only 2-digit cartel ("Toys and Games Cartel") in our data. This exercise increases the number of observations in our sample by about 39% relative to the main specification in column (1). Still, the effect of discipline on internal trade remains negative and insignificant, while $CRTL_DSCPLN_EXTRL$ is negative and significant, as shown in (8) of Table 8. In columns (9)-(11) of Table 8 we experiment

with different time intervals: 2-year, 3-year, and 5-year intervals, respectively. Cheng and Wall (2005) advise against the use of fixed effects with "... data pooled over consecutive years on the grounds that dependent and independent variables cannot fully adjust in a single year's time."(p.8). The main results remain robust throughout with the only exception being the fact that the estimate of $CRTL_DSCPLN_INTRL$ loses its significance, but remains negative, when we employ 5-year intervals, as shown in column (11). This could be explained by the significant number of observations lost when we switch from 4-year intervals to the more sparse 5-year intervals. Overall, our second-stage estimates do not seem sensitive to the use of various proxies for cartel discipline, different definitions of a cartel outsider, the estimation procedure, the set of fixed effects, or the sample size.

Kaplan-Meier Curves



This figure presents the Kaplan-Meier curves for our main variables of interest, which we have transformed into binary variables that take the value of 1 for observations above the mean and are zero otherwise. Panel A presents the curves for internal distance, $DIST_INTRL$. Panel B presents the curves for internal tariffs, $TRFF_INTRL$. Panel C presents the curves for external distance, $DIST_EXTRL$. Panel D presents the curves for external tariffs, $TRFF_EXTRL$.

Table 6: Cartel Discipline and International Trade Costs: Robustness Experiments

	(1) MAIN RSLTS	(2) DIST GDP	(3) DIST POP I	(4) CRTL OUT I	(5) CRTL OUT II	(6) CRTL OUT III	(7) NO TRFF	(8) TRFF INIT	(9) TRFF MFN	(10) SCTR FES
TRADE COSTS										
DIST_INTRL	0.525	0.579	0.664	0.472	0.567	0.548	0.157	0.565	0.560	0.659
	(0.157)**	(0.153)**	(0.163)**	(0.158)**	(0.156)**	(0.157)**	(0.084)+	(0.155)**	(0.162)**	(0.226)**
TRFF_INTRL	0.642	0.635	0.443	0.731	0.570	0.230		0.162	0.890	0.356
	(0.367)+	(0.368)+	(0.347)	(0.363)*	(0.382)	(0.423)		(0.332)	(0.480)+	(0.507)
DIST_EXTRL	0.546	0.528	0.465	0.794	0.293	0.018	0.217	0.479	0.550	0.674
	(0.175)**	(0.174)**	(0.204)*	(0.200)**	(0.141)*	(0.129)	(0.097)*	(0.164)**	(0.171)**	(0.249)**
TRFF_EXTRL	-0.185	-0.127	-0.414	-0.301	-0.095	0.278		0.473	-0.478	1.067
	(0.396)	(0.399)	(0.372)	(0.391)	(0.416)	(0.466)		(0.391)	(0.466)	(0.650)
Δ%TRFF_INTRL	-0.203	-0.198	-0.055	-0.116	-0.313	-0.558		-0.366	-0.284	-0.195
	(0.203)	(0.201)	(0.213)	(0.207)	(0.197)	(0.228)*		(0.245)	(0.207)	(0.349)
Δ%TRFF_EXTRL	0.268	0.271	-0.215	0.242	0.280	0.449		-0.014	0.235	-0.151
	(0.199)	(0.198)	(0.212)	(0.197)	(0.204)	(0.243)+		(0.303)	(0.209)	(0.347)
DISCPLN										
FIRMS	-0.017	0.003	0.072	-0.021	-0.021	-0.105	-0.015	-0.017	-0.034	-0.090
	(0.056)	(0.057)	(0.061)	(0.055)	(0.057)	(0.072)	(0.023)	(0.055)	(0.060)	(0.079)
LGMRKSHR	0.088	0.085	-0.093	0.192	-0.023	-0.369	-0.257	0.115	-0.040	-0.848
	(0.366)	(0.362)	(0.361)	(0.365)	(0.371)	(0.386)	(0.274)	(0.361)	(0.368)	(0.533)
ALLCTN	-0.341	-0.313	-0.105	-0.378	-0.329	-0.099	-0.410	-0.256	-0.002	-0.104
	(0.263)	(0.261)	(0.258)	(0.264)	(0.269)	(0.262)	(0.224)+	(0.254)	(0.271)	(0.392)
DOMFIRM	0.241	0.195	1.046	0.213	0.348	0.561	0.246	0.338	0.124	1.315
	(0.313)	(0.314)	(0.331)**	(0.309)	(0.312)	(0.333)+	(0.252)	(0.308)	(0.321)	(0.400)**
PRCFIX	1.396	1.381	1.312	1.493	1.108	0.797	1.402	1.333	1.544	2.300
	(0.605)*	(0.599)*	(0.579)*	(0.602)*	(0.579)+	(0.564)	(0.488)**	(0.616)*	(0.627)*	(0.967)*
INFRMN	0.557	0.542	0.869	0.494	0.549	0.867	0.046	0.667	0.722	1.094
	(0.347)	(0.347)	(0.332)**	(0.344)	(0.352)	(0.380)*	(0.238)	(0.345)+	(0.353)*	(0.619)+
QUOTA	-1.569	-1.570	-1.844	-1.622	-1.521	-1.612	-1.274	-1.705	-1.875	-2.037
	(0.449)**	(0.440)**	(0.457)**	(0.449)**	(0.447)**	(0.460)**	(0.344)**	(0.461)**	(0.468)**	(0.735)**
BIDRGG	0.689	0.684	-0.160	0.764	0.493	0.449	-0.145	0.809	0.567	0.686
	(0.414)+	(0.410)+	(0.441)	(0.416)+	(0.398)	(0.477)	(0.284)	(0.424)+	(0.425)	(0.682)
RCDVST	-0.016	-0.017	0.519	-0.048	0.028	0.328	0.127	0.010	0.109	0.799
	(0.340)	(0.342)	(0.357)	(0.341)	(0.338)	(0.372)	(0.235)	(0.343)	(0.356)	(0.758)
BUYBCK	-0.141	-0.230	0.690	-0.134	-0.175	-0.008	0.012	-0.185	0.309	1.948
	(0.421)	(0.420)	(0.422)	(0.422)	(0.425)	(0.430)	(0.324)	(0.427)	(0.446)	(0.796)*
CLTRDV	1.120	1.292	1.814	0.973	1.174	0.775	0.959	1.123	0.848	0.904
	(0.541)*	(0.547)*	(0.558)**	(0.542)+	(0.544)*	(0.619)	(0.371)**	(0.540)*	(0.563)	(0.756)
DSCVR_US	1.451	1.494	2.019	1.441	1.392	1.441	1.148	1.706	1.492	2.148
	(0.716)*	(0.707)*	(0.714)**	(0.713)*	(0.716)+	(0.741)+	(0.576)*	(0.738)*	(0.728)*	(0.907)*
DSCVR_CA	-5.176	-5.327	-7.141	-5.034	-5.201	-5.644	-3.609	-5.590	-6.016	-6.072
	(1.787)**	(1.762)**	(1.786)**	(1.771)**	(1.795)**	(1.850)**	(1.412)*	(1.870)**	(1.782)**	(2.535)*
DSCVR_EU	1.031	1.032	1.797	1.048	0.979	1.104	0.624	1.319	1.042	0.767
	(0.690)	(0.685)	(0.689)**	(0.685)	(0.695)	(0.736)	(0.560)	(0.724)+	(0.707)	(0.997)
DSCVR_OTHR	3.192	3.309	4.863	3.211	3.034	3.138	1.737	3.302	3.413	5.608
	(1.232)**	(1.214)**	(1.163)**	(1.211)**	(1.237)*	(1.284)*	(0.771)*	(1.234)**	(1.205)**	(2.027)**
Observations	110	110	110	110	110	100	153	110	106	110

Notes: This table reports estimates from a series of robustness experiments testing the relationship between cartel discipline and trade costs. The dependent variable is always cartel duration measured in months. The estimator is always the Cox proportional hazard model. The first two columns of the table report estimates with alternative definitions of distance. Specifically, column (2) uses GDP-weighted distance and in column (3) we construct the distance aggregates using population weights, but multiply them with bilateral distance, instead of the inverse of bilateral distance. The next three columns use alternative measures for external distance based on different definitions of the external market for the cartel. Column (4) defines the external market as a market where at least one of the cartel members exports. Column (5) defines the external market as a market where all three or more cartel members meet. This definition also includes markets where the two firms from two-firm cartels meet. Column (6) defines the external market as a market where all cartel members export simultaneously. In column (7) we use only our proxies for internal trade costs and external trade costs in order to maximize the number of observations in our sample. We experiment with initial tariffs in column (8) and with most favored nation (MFN) tariffs in column (9). Finally, in column (10) we introduce sector fixed effects. See text for further details.

Table 7: Cartels, Cartel Discipline and International Trade: Robustness Checks I

	(1) MAIN	(2) DSCPLN1	(3) DSCPLN2	(4) DSCPLN3	(5) CRTLOUT1	(6) CRTLOUT2	(7) CRTLOUT3
DIST	-0.722	-0.722	-0.722	-0.722	-0.722	-0.722	-0.722
	(0.046)**	(0.048)**	(0.046)**	(0.056)**	(0.050)**	(0.061)**	(0.049)**
CNTG	0.516	0.515	0.516	0.516	0.516	0.516	0.516
	(0.105)**	(0.119)**	(0.084)**	(0.096)**	(0.101)**	(0.123)**	(0.108)**
CLNY	0.281	0.282	0.281	0.281	0.281	0.281	0.281
	(0.120)*	(0.103)**	(0.121)*	(0.103)**	(0.103)**	(0.093)**	(0.121)*
LANG	0.06	0.059	0.06	0.059	0.06	0.06	0.060
	(0.073)	(0.080)	(0.095)	(0.069)	(0.082)	(0.084)	(0.086)
RTA	0.334	0.334	0.334	0.333	0.334	0.334	0.334
	(0.135)*	(0.120)**	(0.126)**	(0.135)*	(0.122)**	(0.144)*	(0.140)*
CRTL_INTRA	2.278	5.35	2.698	2.168	2.303	2.237	2.179
	(0.461)**	(0.904)**	(0.542)**	(0.397)**	(0.574)**	(0.614)**	(0.496)**
CRTL_DSCPLN_INTRA	-0.182	-0.354	-0.225	-0.145	-0.184	-0.179	-0.174
	(0.039)**	(0.062)**	(0.048)**	(0.028)**	(0.049)**	(0.053)**	(0.043)**
CRTL_EXTRNL	0.808	1.941	0.672	0.202	0.818	0.745	1.313
	(0.325)*	(0.533)**	(0.253)**	(0.245)	(0.319)*	(0.287)**	(0.361)**
CRTL_DSCPLN_EXTRNL	-0.071	-0.134	-0.06 0	-0.014	-0.071	-0.068	-0.114
	(0.028)*	(0.037)**	(0.023)**	(0.019)	(0.029)*	(0.026)**	(0.032)**
Observations	231887	231887	231887	231887	231887	231887	231887

Notes: This table reports estimates from two sets of experiments related to the key cartel variables used to study the relationship between cartels, cartel discipline, and international trade. The first column reproduces our main results from column (4) of Table 2. In columns (2) to (4) we experiment with alternative definitions of cartel discipline, as described in the text. In columns (5) to (7) we use alternative definitions of cartel external market in order to construct the covariates $CRTL_EXTRNL$ and $CRTL_DSCPLN_EXTRNL$. Column (6) defines the external market as a market where at least one of the cartel members exports. Column (7) defines external market as a market where all three or more cartel members meet. This definition also includes markets where the two firms from two-firm cartels meet. Column (8) defines the external market as a market where all cartel members export simultaneously. See text for further details.

Table 8: Cartels, Cartel Discipline and International Trade: Robustness Checks II

	(1) MAIN	(2) PPML ESTMTR	(3) PAIR FEs	(4) ASYMM FEs	(5) ALL FEs	(6) COSTS HS6	(7) NO DPLCTS	(8) 4DIGIT HS	(9) ALL HS	(10) 2YRS INTRVLS	(11) 3YRS INTRVLS	(12) 5YRS INTRVLS
DIST	-0.722	-0.713			-0.863		-0.751	-0.820	-0.825	-0.720	-0.728	-0.701
	(0.062)**	(0.071)**			(0.055)**		(0.046)**	(0.049)**	(0.043)**	(0.059)**	(0.053)**	(0.050)**
CNTG	0.516	0.274			0.574		0.525	0.482	0.476	0.516	0.522	0.568
	(0.106)**	(0.121)*			(0.107)**		(0.110)**	(0.093)**	(0.107)**	(0.095)**	(0.103)**	(0.114)**
CLNY	0.281	0.463			0.261		0.275	0.294	0.298	0.303	0.312	0.328
	(0.109)**	(0.122)**			(0.109)*		(0.089)**	(0.094)**	(0.107)**	(0.115)**	(0.090)**	(0.109)**
LANG	0.060	-0.041			0.144		0.062	0.145	0.147	0.059	0.053	0.058
	(0.093)	(0.125)			(0.081)+		(0.072)	(0.062)*	(0.079)+	(0.091)	(0.089)	(0.075)
RTA	0.334	0.580	-0.230	-0.203	0.255		0.349	0.368	0.370	0.357	0.343	0.383
	(0.142)*	(0.134)**	(0.065)**	(0.066)**	(0.130)*		(0.124)**	(0.116)**	(0.107)**	(0.130)**	(0.135)*	(0.120)**
CRTL_INTRNL	2.278	3.140	2.016	2.041	1.262	1.348	2.151	0.734	0.719	2.163	2.206	1.503
	(0.471)**	(1.145)**	(0.532)**	(0.533)**	(0.475)**	(0.479)**	(0.499)**	(0.473)	(0.511)	(0.443)**	(0.508)**	(0.470)**
CRTL_IN_DISCIPLINE	-0.182	-0.241	-0.165	-0.168	-0.101	-0.108	-0.168	-0.041	-0.042	-0.175	-0.171	-0.115
	(0.042)**	(0.097)*	(0.047)**	(0.047)**	(0.041)*	(0.042)**	(0.044)**	(0.042)	(0.046)	(0.039)**	(0.044)**	(0.043)**
CRTL_EXTRNL	0.808	0.933	0.863	0.861	-0.006	-0.009	0.603	0.865	0.853	0.933	0.666	0.988
	(0.307)**	(0.897)	(0.291)**	(0.291)**	(0.214)	(0.208)	(0.306)*	(0.237)**	(0.219)**	(0.280)**	(0.292)*	(0.208)**
CRTL_OUT_DISCIPLINE	-0.071	-0.108	-0.074	-0.073	-0.004	-0.003	-0.052	-0.075	-0.074	-0.082	-0.059	-0.084
	(0.027)**	(0.067)	(0.026)**	(0.026)**	(0.019)	(0.018)	(0.028)+	(0.022)**	(0.020)**	(0.025)**	(0.026)*	(0.020)**
N	231887	231887	231887	231887	231028	231028	178613	318617	324011	431874	312704	193434

Notes: This table reports estimates from a series of robustness experiments testing the relationship between cartel discipline and international trade. The first column reproduces our main results from column (4) of Table 2. Column (2) uses the PPML estimator. Columns (3) and (4) introduce symmetric and asymmetric pair-fixed effects, respectively. Column (5) uses exporter-sector-time and importer-sector-time fixed effects. In column (6) we also use exporter-sector-time and importer-sector-time fixed effects and we also allow for the effects of the trade cost covariates (e.g. distance, etc.) to vary at the 6-digit HS level. Column (7) uses merged cartels-trade data without any duplicating observations. Column (8) adds to our main specification cartels for which we only had data at the 4-digit HS level. Column (9) uses all cartels for which we have data. Finally, in columns (10), (11), and (12) we experiment with 2-year, 3-year, and 5-year interval data, respectively. See text for further details.