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The Effect of Competition on Trade: Evidence from the Collapse of International Cartels*

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Abstract

How do changes in competitive intensity affect trade patterns? Some cartels may find it advantageous to eliminate cross-hauling and divide markets geographically. We exploit a quasi-natural experiment associated with increased antitrust enforcement to determine if market division strategies were used in seven recently-prosecuted international cartels. Since antitrust activity is unlikely to affect spatial patterns of demand and supply (other than through its effect on the competitive environment), enforcement-induced changes are ideally suited to study the effect of competition on trade patterns. Analyzing the cartels individually and as a group, we find no significant change in spatial patterns of trade following cartel breakup; in particular, there is no significant change in the effect of distance on trade. These results suggest that cross-hauling is not uncommon under collusion and hence that the existence of cross-hauling by itself does not provide evidence of effective competition.

JEL Codes: F12, F23, D43, D21

Keywords: Multimarket collusion, gravity, cross-hauling, cartels, market allocation, antitrust policy

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1. Introduction

The willingness of antitrust authorities, particularly in Europe and the United States, to prosecute international cartels has led to the detection and collapse of a large number of cartels.[1] What impact does this increase in competition have on trade patterns? We analyze seven international cartels -- broken up by antitrust intervention -- in order to improve our understanding of the relationship between collusion and trade.[2]

Brander and Krugman's (1983) seminal work demonstrates that Cournot duopolists may engage in intra-industry trade in homogeneous goods, as it is in each duopolist's self-interest to maintain prices so high that it attracts entry into its home market.[3] Pinto (1986) and Fung (1991) extend this model to a repeated game environment and show that collusion is possible: there exists a collusive Nash equilibrium characterized by geographic specialization and enforced by a threat of Cournot reversion to the Brander-Krugman equilibrium. Baake and Normann (2002) and Bond and Syropoulos (2008) present models in which colluding firms rely on a market sharing arrangement where firms participate in both geographic markets. The intuition from this set of papers is that, if firms are sufficiently patient, trade costs are high, and products are differentiated, a market division collusive arrangement is stable. A collusive equilibrium may still exist for homogenous products, or where transportation costs are low, or firms are less patient, but cartel stability then requires market-sharing. Market-sharing reduces the profits of collusion, but it reduces the incentive to deviate more and so stabilizes collusion.[4]

Following the collapse of a cartel, the "geographic specialization" collusive equilibrium implies a significant change in trade patterns. The demise of a cartel will be associated with a weakening in the relationship between distance and trade, as under collusion firms would have

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[1] See Evenett, Levenstein and Suslow (2001) and Levenstein and Suslow (2006) for an overview of international cartel prosecutions.

[2] Following a similar approach, Symeonidis (e.g., 2007, 2008) exploits changes in antitrust policy in the UK as a source of exogenous variation in competition to examine the effect of competition on productivity, innovation, concentration and profitability.

[3] The Brander-Krugman model in turn drew upon Smithies's (1942) model of basing-point pricing.

[4] Bond and Syropoulos (2008), p. 1081; note that the relationship between the discount factor and transportation costs in sustaining collusion is non-monotonic. Their model demarcates the regions in which we are likely to see different competitive interactions (p. 1091). Baake and Normann (2002) highlight the implications of their model of collusion in homogenous goods for the relationship between trade and antitrust policy: "Fung's (1991) conclusion is that differentiated goods are a necessary condition for collusive intra-industry trade. … antitrust authorities responsible for promoting competition in free-trade areas need not be concerned about industries which trade in homogenous goods. Our paper shows that … [i]ntra-industry trade in homogenous goods is not a reliable indicator of competition" (p. 483).

been assigned markets based on distance. There will also be a decline in concentration as formerly forbearing cartel members enter one another's markets. On the other hand, if the collusive equilibrium was "market sharing," then we should see little to no effect on trade patterns, as cross-hauling is observed both before and after cartel breakup.

We selected seven cartels based on four criteria that establish both the appropriateness of the cartel to these models and the availability of data for empirical analysis. First, the cartel must be international in membership. Second, the cartel must have collapsed because of antitrust intervention. Third, there must be a close match between the product affected by collusive behavior and the trade data. Fourth, we must have a reliable measure of the date of cartel breakup. Seven commodity chemical cartels operating in the late twentieth century satisfy these criteria.

Finally, in order to assure that these cartels were strong enough to have affected trade patterns, we verify that they were successful in raising prices. If observed prices were not higher during the cartel period, we would infer that the cartel was ineffective and would expect no measurable change in trade patterns following its collapse regardless of the intended collusive behavior. As Figure 1 shows, there were significant declines in prices following the breakup of each of the cartels selected for analysis.[5]

We examine the effect of cartel breakup on spatial market share patterns, specifically the effect of distance on trade, by estimating a gravity equation.[6] In general, our results are consistent with market sharing during collusion in that we find no significant change in the coefficient on distance in our gravity estimates. We also look for changes in concentration following cartel breakup. We consider several measures of concentration, including the number

[5] Figure 1 shows prices four years before and after the breakup of each cartel. A cartel might also be considered effective if it had stemmed declining prices, raising price relative to the counterfactual price. That was not the case for any of these seven cartels. Note that in some cases, such as Vitamin A, prices had begun to fall prior to the reported cartel breakup. This often reflects related antitrust activity. In Vitamin A, FBI agents intervened in March 1997 almost two years before the official breakup. For a more general discussion of the effect of cartels on prices, see, for example, Levenstein and Suslow (2006) and Connor and Bolotova (2006).

[6] The gravity equation is a well-established relationship between trade, national income and geographic distance (Tinbergen 1962). Some papers have examined the effect of particular factors on the distance coefficient (e.g., Freund and Weinhold (2004) on the effect of the internet) while others have examined changes in the coefficient on distance over time (e.g., Berthelon and Freund 2008). Another influential literature uses the gravity equation to examine border effects (e.g., McCallum 1995, Anderson and van Wincoop 2003). Helpman, Melitz and Rubinstein (2008) provide an overview of empirical estimates of the gravity equation.

of countries from which a country imports and the Herfindahl-Hirschman Index (HHI) of importers in a national market. We find slight decreases in concentration, particularly in the long run. These changes in concentration appear to be similar to patterns in other similar non-cartelized products, indicating that they reflect broader changes in trade rather than changes in the nature of competition in these seven markets. For each dependent variable – price, gravity, and concentration – each cartel is examined individually and also jointly in a meta-analysis of all seven cartels.

Our estimates suggest that market sharing and trade are not inconsistent with collusion.[7] While this finding is specific to this set of cartels -- which are relatively typical of contemporary international cartels more generally -- there may be others that use market division agreements. The optimal collusive arrangement depends on transportation costs and the discount rate. Our results also suggest that econometric screens that examine trade patterns to detect collusion may be ineffective in industries such as these in which collusion involves market sharing. For example, Harrington (2007) proposed that a "collusive marker" would include the observation that prices rose and imports simultaneously declined.[8] While nothing in our work suggests that this marker would give rise to false positives, it would miss collusion such as that found in the industries studied here.

2. Theoretical motivation

In this section we present a formal symmetric, two-country model based on Bond and Syropoulos (2008) and discuss the applicability of the results in more general multi-country contexts. Consider a symmetric two-country, Cournot model of trade. We refer to the two countries, i and j, as "home" and "foreign," with (symmetric) demand in each country given by a linear demand function $P_i = A_i - Q_i$, where Q_i represents the total quantity sold in country i. Assume constant marginal cost for each firm, normalized to zero without loss of generality.

[7] For other case studies examining the relationship between collusion and trade, see Hummels, Lugovskyy and Skiba (2009) and Asker (2010).

[8] "A common feature to implementing a collusive allocation is the "home-market principle" whereby cartel members reduce supply in each other's home markets … where, ideally, each cartel member takes control of their home market and then share the global demand that was not part of any cartel member's home market. … In a competitive market, one would expect a rise in a firm's price to result in more imports, ceteris paribus. However, an allocation scheme based on the home-market principle would result in the suspicious combination of a higher price and fewer imports"(Harrington 2007, p. 6). Harrington goes on to argue that a simultaneous increase in prices and a decline in imports is a "collusive marker."

Trade cost per unit exported is τ (which can be thought of as transport costs, or more generally transportation costs plus tariffs). Let q_i represent the quantity sold by the firm in country i in its home market and x_i represent the quantity it exports. The total quantity sold in country i is $Q_i = q_i + x_j$, and the total quantity sold by firm i is $S_i = q_i + x_i$. The aggregate profit of firm i is the sum of profits earned in its home and export markets:

$$\Pi_i = \{[A - (q_i + x_j)]q_i + [A - (q_j + x_i) - \tau]x_i\}$$

As in Brander and Krugman, the one-shot non-cooperative game yields a reciprocal dumping equilibrium. (As the firms/countries are symmetric, we drop the *i* and *j* subscript for brevity.) In particular, as long as trade costs are not prohibitive (i.e., $\tau \leq \frac{A}{2}$), the symmetric non-collusive Nash equilibrium strategies (q, x) are $q = (A+\tau)/3$ and $x = (A-2\tau)/3$. This yields non-collusive profit, Π^N:

$$\Pi^N = \frac{2A^2 - 2A\tau + 5\tau^2}{9} \quad (1)$$

Turning to the repeated game, profit in the collusive equilibrium, Π^E is:

$$\Pi^E = \{[A - (q + x)](q + x) - \tau x\} \quad (2)$$

If a firm deviates from the collusive agreement, the payoff from deviation is:

$$\Pi^D = \frac{1}{4}\{(A - x)^2 + (A - q - \tau)^2\} \quad (3)$$

Note that deviation profits are strictly convex in (q, x) for all admissible output pairs.

The maximum collusive profit that can be sustained must satisfy the non-deviation constraint. Assuming the punishment phase is reversion to the non-collusive Nash equilibrium above, an agreement (q, x) is sustainable if and only if:

$$Z(q, x, \tau, \delta) = \Pi^E(q, x, \tau) - (1 - \delta)\Pi^D(q, x, \tau) - \delta\Pi^N(\tau) \geq 0 \quad (4)$$

where δ is the discount factor.

Figure 2 depicts change in the collusive equilibria with variation in transport costs and the discount rate. When the discount factor is above a threshold ($\delta > \underline{\delta}$, i.e., the players are sufficiently patient) firms can sustain an efficient collusive equilibrium in which they do not have to bear transportation costs.[9] Bond and Syropoulos (2008) show that the no-trade equilibrium obtains when transportation costs are above a certain threshold, corresponding to

[9] See Bond and Syropoulos (2008) for proof. They also generalize the results to the case of multiple firms in a country and consider the welfare impact of changes in tariffs and transportation costs.

Region A in Figure 2.[10] Note that the output level in each market ($q^* = A/2$) is identical to the monopoly outcome. When the discount factor and transport costs are below these thresholds, collusion requires trade and market sharing.[11] An equilibrium with cross-hauling yields the same collusive profits, but is less susceptible to deviation than one without trade. Thus, even in a range of discount factors where efficient collusion is not sustainable in the Pinto (1986) model, a collusive equilibrium with market-sharing can be sustained.

The optimality of market-sharing is driven by the convexity of the deviation profits in Equation (3). Consider region E where transport costs are zero and the discount factor is above the threshold $\delta^c(0)$. When firms share output equally in each market, the deviation profits $\left(\Pi^D\left(\frac{A}{4},\frac{A}{4},0\right)=\frac{9A^2}{32}\right)$ are lower than the deviation profits with maximal geographic specialization $\left(\Pi^D\left(\frac{A}{2},0,0\right)=\frac{10A^2}{32}\right)$, due to the strict convexity of the deviation payoffs. Thus there is less incentive to deviate, and higher collusive profits can be maintained. The same intuition applies in regions C and D, except that in these regions the combination of low transport costs and discount factors means that the cartel is forced to set output levels above the monopoly level (i.e., $q^* + x^* > \frac{A}{2}$) in order to sustain collusion.

This model can be extended in a straightforward way to the case of a symmetric three-country oligopoly. Each firm sells output q in the home market and output x in each of the other two (equidistant) markets. With less than prohibitive trading cost, (i.e.,$\tau \leq \frac{A}{2}$), the symmetric non-cooperative Nash equilibrium is:

(i) output levels: q=(A+2τ)/4 and x=(A-2τ)/4

(ii) aggregate profit: $\Pi^N = \frac{3A^2-4A\tau+12\,\tau^2}{16}$

The profit of each firm under a symmetric collusive equilibrium agreement (q, x) is:

$$\Pi^E = \{[A-(q+2x)](q+2x) - 2\tau x\} \quad (5)$$

If a firm deviates from an agreement (q, x, x), the payoff from deviation is:

$$\Pi^D = \frac{1}{4}\{(A-2x)^2 + 2(A-q-x-\tau)^2\} \quad (6)$$

[10] In Region F, the discount factor is sufficiently high to maintain monopoly profits (and output level, A/2), so that with zero transport costs the oligopoly solution is a correspondence, with $q^* + x^* = \frac{A}{2}$ and $x^* \in \left[0,\frac{A}{2}\right]$.

[11] An exception is region B, where there is still geographic specialization, but to meet the binding no-deviation constraint, the collusive equilibrium involves output levels above the monopoly level.

Here too deviation profits are strictly convex in (q, x) for all admissible output combinations. As before, assuming the game in the punishment phase is the non-collusive Nash equilibrium, a collusive agreement (q, x, x) is sustainable if and only if:

$$Z(q,x,x,\tau,\delta) = \Pi^E(q,x,x,\tau) - (1-\delta)\Pi^D(q,x,x,\tau) - \delta\Pi^N(\tau) \geq 0 \qquad (7)$$

where δ is the discount factor.

The key results of the baseline model extend to the multi-country context. In particular, for sufficiently low transport costs and discount factors, market sharing will be the only sustainable collusive equilibrium (while no-trade may still be the optimal collusive outcome with sufficiently high discount or transport costs). As long as transport costs are high enough to rule out entry into non-adjacent markets, the structure of the problem for each firm is exactly the same as in the symmetric three-country case as discussed above. To extend the model to the case of *N* countries, consider a set of countries located symmetrically around a circle (in a variant of Salop's (1979) model). The circular model is stylized relative a world where countries are asymmetrically located around the globe. However, all markets close to a single cartel member country can be treated as the "home market." In our sample, cartel members often had foreign production locations. In the context of the *N*-country circular model, additional locations can be treated as additional members (i.e., increasing *N*). Assuming that all cartel members have the same *k* number of production locations located symmetrically around the circle, the baseline results hold, as all of the key profit equations are simply scaled by *k*.

3. Cartel and trade data

Until the early 1990s, international price-fixing conspiracies were considered outside the legal jurisdiction of most competition authorities. Following the Archer Daniels Midland lysine scandal, both the United States and the European Commission began actively prosecuting international cartels, using amnesty policies to encourage cartel members to report collusive activities to the authorities (Levenstein and Suslow 2011). Information from these cases is the basis for the data in this paper. We select seven international chemical and food additive cartels for this multi-case study: Citric Acid, Methionine, Monocholoroacetic Acid, and Vitamins A, B3, B4, and E. Each ended as a result of antitrust intervention in the 1990s (Table 1).[12] This intervention constitutes an exogenous shock to industry behavior. Even though the formation

[12] See Levenstein and Suslow (2011) for classification of the immediate cause of dissolution of each of these cartels as well as analysis of the economic determinants of cartel breakup.

and maintenance of a cartel are endogenous, the shift from collusion to competition was a result of a policy change driven by exogenous events.

We collect data on cartel membership, corporate nationality, start and end dates, and detailed product descriptions for individual cartels, and use the product descriptions to link cartel-specific information to import and export data. These cartel agreements covered global markets, and most cartel members were large, multinational firms from Europe, North America, and Asia. In some analyses below, we make use of the cartel "home country," defined as the country in which the cartel member firm had its corporate headquarters. [13]

We select cartels whose product unambiguously matches the classification in the UN Comtrade database, which contains annual, bilateral (country pair) trade data. [14] The most detailed reliable data are disaggregated at the 6-digit Harmonized System (HS) level (see Table 1 for specific HS codes). For example, the detailed description for HS 291814 is "Citric Acid," corresponding exactly to the cartel's targeted product. For the vast majority of prosecuted international cartels, there is not a clean match to the trade data. For example, the gas insulated switchgear cartel affected products under HS 853530 "Isolating Switches and Make-and-break Switches, Voltage Exceeding 1000v." But it did not affect the large number of non-gas insulated products whose trade is also reported in this category.[15]

These cartels are appropriate for this analysis because, in each case, prices declined after cartel breakup (Figure 1). Price is defined as the ratio of trade value to trade quantity for each product, year, and bilateral trade pair.[16] For each cartel, we create a nine-year panel covering

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[13] The models discussed above are framed in the context of a home market and a foreign market. In the context of our trade data, the "home country" can be thought of as a proxy for "geographically proximate markets" for one (i.e., "home") firm, and the "foreign country" is the set of markets that are geographically proximate to the other (i.e., "foreign") firm.

[14] Commodity descriptions from the "Harmonized Commodity Description and Coding System" (World Customs Organization) are available from several trade-related websites (e.g., http://www.foreign-trade.com/reference/hscode.cfm). The data are available at http://comtrade.un.org/db/default.aspx.

[15] See Gas Insulated Switchgear decision, European Commission Case COMP/F/38.899 (January 24, 2007). Vitamin B1, B2 and C also have close matches in the HS classification; however the predominant cause of the breakup for these cartels was competition from a growing fringe. Because we focus here on changes "exogenous" to or uncorrelated with production patterns, we excluded these cartels from our analysis. They were included in preliminary analyses and the results were qualitatively similar to those reported below.

[16] Note that the price variable is defined for each trade observation, and accordingly the number of observations equals the number of importer-exporter-years in the data. Some small countries or small transactions report values or quantities that are extreme outliers, leading to improbably high or low estimates of price. To minimize such distortions, we truncate observations where the implied price is in the tail of the distribution (2% on either side) and treat the observation as missing.

four years before and four years after the cartel breakup. We exclude the reported breakup year because it may include both periods of collusion and non-collusion. Comparing average price before and after cartel breakup, we find a significant decline in average price for each cartel (Table 2). Mean price declines range from 7.32% (0.076 log points) in the case of Citric Acid to 58.02% (0.868 log points) for Vitamin E.[17] For comparability across products, and to undertake meta-analysis of the effects, we also examine standardized prices (defined as $p_{sd} = (p - \bar{p})/\sigma_p$, where $\bar{p}$ is the overall mean and σ_p is the standard deviation of price in the sample). Results in Table 2 show that standardized prices declined between 0.136 (Citric Acid) and 1.069 (Vitamin E) standard deviations. This suggests that, for these products, there was a change in the intensity of competition at the time of the observed cartel dissolution.[18]

Following the practice in the trade literature, we use data on reported imports. Ideally, properly aggregated export and import data equal one another (except for insurance and freight) and hence can provide data validation. In practice, exports are tracked less carefully. Most countries charge duties on imports but not exports, so export data are much sparser than import data. For example, France reports methionine imports for most years, but reports exports for only one year. France is a large methionine exporter, but those exports are missing in the COMTRADE data. Therefore, we analyze import data and use reported imports to infer exports.[19]

The number of reporting countries in the COMTRADE database increased over the period studied (early 1980s to 2000s). This may reflect genuine increases in trade, but it may also reflect improvement in data collection, either by the UN or by reporting countries. There are many countries that report very little trade. Given this dispersion in the size of trade flows, small outlier countries could have a large impact on the analysis if they are given as much

[17] To calculate the price decline, note that 0.076 log points equals $\log(P_{post}) - \log(P_{pre}) = -0.076$. The percentage decline $[(P_{post} - P_{pre})/ P_{pre}]$ is equal to $e^{(-0.076)} - 1 = -7.318$ percent.

[18] There were other international cartels that ended during this time period for which we found a close match to the Harmonized System (HS) categorization, but for which prices do not significantly decline at the time of the reported cartel breakup. These include Aluminum Fluoride, Sodium Chlorate, and Hydrogen Peroxide and Perborates. This may reflect an ineffective cartel or a misreporting of the date of the cartel's demise. In either case, this suggests that the models discussed above would not be applicable.

[19] This is consistent with the approach taken by Feenstra, Lipsey, Deng, Ma and Mo (2005) in creating the NBER World Trade Flows database (1962-2000).

weight as larger countries. Hence throughout the analysis, we weight observations by trade quantity.[20]

We create two measures of concentration. First, we define import concentration as the HHI of annual import market shares of each product into a country, equal to the sum of the squares of the relative size of all exporters into a country:

$$HHI_{jkt} = \sum_{i=1}^{N_{jkt}} (S_{ijkt})^2$$

where S_{ijkt} is the market share of exporter country i in the total value of imports of product k entering importer country j in period t, and N_{jkt} is the number of countries exporting product k to importer country j in period t.[21] The mean levels of HHI are quite high, ranging from 0.276 to 0.450 (Table 2). For comparison, the U.S. Department of Justice's merger guidelines set an HHI of 0.250 as the threshold for "highly concentrated" markets.[22]

Our second measure of concentration is based on the number of trade partners, N_{jkt} (Table 2). For each of these seven products, the mean number of trade partners (between nine and fifteen) is larger than the number of members of the cartel (between three and six). This difference reflects, in part, the presence of a few small fringe producers. More importantly, most cartel members manufacture and export from more than one country. This suggests that reported measures of import concentration are lower than a calculation based on *firm* level measures, as a single firm may export from multiple countries. On the other hand, import concentration ignores domestic producers, and multiple firms may export from a single country. Both effects imply that our measure overstates concentration. We do not know the net effect of these biases on estimated concentration levels. Our analysis examines the *change* in

[20] It is particularly appropriate to use trade quantity as the weighting variable when calculating average price. For example, suppose country A imports 10,000 kg from country X at a value of $30,000 and 50 kg from country Y at a value of $1000. Then the un-weighted mean price of imports into country A is (3+20)/2= $11.5/kg. The trade-weighted mean price, (10,000*3 +50*20)/10050= $3.08/kg, is a more appropriate reflection of the price faced by consumers in country A. In regressions of log price or other variables such as market share, it is less obvious that trade quantity is the appropriate weight. We check the robustness using trade value weights and find results are generally very similar.

[21] Note that the concentration measures are defined by importer country for each year, and hence the number of observations equals the number of importer-years. More detailed definitions of the variables used in the analysis are given in the Data Appendix.

[22] See http://www.justice.gov/atr/public/guidelines/hmg-2010.html for the U.S. Department of Justice merger guidelines.

concentration, and therefore we expect our estimates to be unbiased despite these measurement issues.

In most cases there is a slight decline in HHI following cartel breakup. Similarly, the average number of trade partners generally increases. This pattern is consistent with cartels that had been dividing markets. These observed changes are generally not statistically significant. We then jointly analyze changes in all seven cartels. The last two rows of Table 2 present a meta-analysis of changes in price, HHI and number of partners across all seven products. We use standardized variables, following the approach in the meta-analysis literature (e.g., Greenwald, Hedges and Laine, 1996; Stavig 1977). We show results using both fixed effects (Sinclair and Bracken 1992) and the DerSimonian and Laird (1986) random effects.[23] Both approaches confirm the conclusions discussed above, that is, a sharp decline in price and a lesser decline (increase) in HHI (number of trade partners).

While these simple mean differences suggest results consistent with market-division agreements, this analysis does not control for a number of potential confounding factors (including pre-existing trends or macroeconomic shocks). In the next section, we undertake before-after and difference-in-differences (DID) analyses to assess if there were indeed changes in trade and market share patterns.

4. Empirical specifications and baseline results

4.1. Prices

We begin by confirming the impact of cartel breakup on price. We do this for each cartel individually and then present a pooled analysis of all seven cartels, examining both short-run and long-run changes in price to determine the appropriate time frame for further analysis. If price adjusts slowly, it may be that the immediate impact of cartel breakup will be small, but will grow over time. It is also possible that a breakup causes intense competition in its

[23] Following the fixed effect approach of Bradburn, Deeks and Altman (1998), the mean difference for each of the cartels is weighted using the inverse of the variance of the differences in means. This approach assumes that the mean difference effect is the same for all cartels. In contrast, the random effects approach assumes that the observed effects are drawn from a random distribution with a parameterized variance. An estimate of this variance is incorporated into the weights for individual cartel results. The weights are the inverse of the sum of the within cartel and the cross-cartel variances. We use the Stata command `metan' to undertake the analysis. Stata technical notes by Bradburn, Deeks and Altman (1998) and Harris et al. (2008) provide more details.

immediate aftermath, but that, over time, tacit collusion re-emerges in these highly concentrated industries.[24] In order to distinguish short-run and long-run changes in price following cartel breakup, we specify the following:

$$p_{ijt} = \alpha_0 + \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{LPOST} + f_{ij} + \epsilon_{ijt} \quad (8a)$$

where p_{ijt} denotes price, D_{SPOST} indicates the short-run post-breakup period (years 1 and 2 after cartel breakup), D_{LPOST} indicates the long-run post-breakup period (years 3 and 4 after cartel breakup), f_{ij} denotes importer-exporter pair fixed effects and ϵ_{ijt} is the error term.[25] Subscript i denotes exporting country, j denotes importing country and t denotes year. Given that the cartel could have broken up at any time during the year, we exclude data for the breakup year (t=0) from this analysis. The coefficient α_{SPOST} reflects the difference in mean price between the short-run post-breakup period (years t+1 and t+2) and the collusive period. Similarly α_{LPOST} reflects the difference in mean price between the long-run post-breakup period (years t+3 and t+4) and the collusive period.

This analysis confirms significant declines in price for this set of seven cartels, both in the short and long run (Table 3).[26] The short-run declines in price vary from 4.40% (0.045 log points) for Citric Acid to as high as 54.93% (0.797 log points) for Vitamin E. The long-run declines are generally larger, ranging from 13.24% (0.142 log points) for Citric Acid to 59.95% (0.915 log points) for Vitamin E. This implies that the short-run price declines were not simply the result of a temporary price war following breakup and that antitrust intervention had a sustained impact on market outcomes.

[24] See Alexander (1994) for a discussion of how an episode of explicit cooperation facilitates future tacit collusion.

[25] One significant advantage of using trade panel data is that we can control for a number of country-specific and country-pair factors in these price regressions using importer or importer-exporter fixed effects. For example, Hummels and Skiba (2004) show that bilateral distance and the income level of the source or destination country generally has an impact on price. Since we are focusing on homogenous, narrowly defined products, this concern may not be serious; nevertheless, inclusion of importer-exporter pair fixed effects controls for these factors so that we do not confound price changes due to changes in competition with price changes resulting from other factors. To allow for arbitrary correlation of residuals across observations within a country (over time and across trade partners), we cluster standard errors by country.

[26] We obtain similar results using price levels rather than log prices.

In the last row of Table 3, we present a meta-analysis of pooled data from all cartels.[27] The pooled analysis confirms both short and long-run declines in price following cartel breakups. The combined effect is a decline of about 0.2 standard deviations in the short run. The long-run effect is 0.348 standard deviations.[28]

We also consider the possibility that a cartel had become less effective immediately prior to its breakup, so that the changes documented in Table 3 reflect a prior trend of price decline rather than the impact of the cartel's breakup. To test this, we estimate the following specification:

$$p_{ijt} = \alpha_{SPRE} D_{SPRE} + \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{LPOST} + f_{ij} + \epsilon_{ijt} \quad (8b)$$

where D_{SPRE} is a dummy for the short-run pre-breakup period defined as equal to 1 during the two years immediately prior to the cartel breakup (years *t-2* and *t-1)*. With the inclusion of $D_{SPRE,}$ all the coefficients capture differences in means relative to the long-run pre-breakup period (years *t*-3 and *t*-4). While in three cases there was a statistically significant decline prior to cartel breakup (Table 4, column 1), in all cases prices fall even more after breakup (i.e., $\alpha_{SPOST} - \alpha_{SPRE}$ is negative, column 2). That is, controlling for any change in price leading up to the breakup increases our estimate of the impact of the cartel breakup on price.[29]

The meta-analysis confirms a decline in price after cartel breakup across these products (column 4), with a magnitude of about 0.25 standard deviations in the pooled data. The pre-

[27] As discussed above, to ensure comparability across cartels, we analyze standardized prices. We weight each observation with the market share of the country for that product-year, so that each cartel is weighted equally in the pooled regression. We use these weights in all pooled meta-analysis estimates.

[28] For all empirical analyses presented in the tables that follow, we have also conducted a meta-analysis of the separate estimates from the seven cartels. Using a weighted least squares approach (Bini, Coelho and Diniz-Filho 2001, Hedges and Olkin 1985, Greenland and Longnecker 1992) the estimated meta-coefficient is a weighted average of the individual coefficients: $\left(b_m = \frac{\sum_{i=1}^{k} w_i b_i}{\sum_{i=1}^{k} w_i}\right)$ where $w_i$is the reciprocal of the variance. The variance of the meta-estimate is given by $Var(b_m) = \frac{1}{\sum_{i=1}^{k} w_i}$. The approach is a reasonable substitute for a pooled analysis if the off-diagonal elements of the covariance matrix (Cov(B)) are close to zero (Becker and Wu, 2007). To make the coefficients comparable across studies, we standardize the dependent variable by subtracting the mean and dividing by the standard deviation in the full sample (Rosenthal 1994). This approach is commonly used in meta-analyses where the underlying raw data are unavailable. In our case, we have access to the underlying data for each cartel, and therefore we undertake and present a pooled analysis, simply stacking the data from all cartels. We have calculated WLS meta-estimates of each our regressions, and the results are consistent with those presented here.

[29] We have considered a variety of specifications to detect any rebound in prices after the breakup of the cartel. These alternative specifications confirm that there were sizable and significant declines in price in the post-period relative to the pre-period. Detailed results are available from the authors on request.

breakup decline in prices is more modest (about 0.05 standard deviations) and not statistically significant. Thus, we conclude that while there was a modest decline in prices prior to the breakup, there was a significantly sharper decline in prices after.

4.2. Impact on trade patterns

Having established that these seven markets underwent a change in competitive intensity, we now examine the effect of this change on trade patterns. As discussed in Section 2, if the cartel were playing a geographic specialization game, we would expect a sharp decline in the effect of distance on trade following cartel collapse. In contrast, if cartel members where sharing markets, we would expect less rearrangement after breakup.

We first let the data speak for itself by calculating the quantity-weighted average distance travelled by each cartelized product, defined as $\bar{L_t} = \frac{\sum_{ij} q_{ijt} L_{ij}}{\sum q_{ijt}}$ where q_{ijt} is the quantity shipped between countries *i* and *j* in year *t*, and $L_{ij}$is the distance between countries *i* and *j*. This average distance is normalized to 0 in the year of the cartel breakup. For example, for Citric Acid, $\bar{L_t}$ = average number of miles traveled by one unit weight (kilogram) of Citric Acid imports. Figure 3 shows the variation over time in average distance travelled for each product. While Figure 3 suggests an increase over time in distance travelled, there is no visible break in trend around the collapse of the cartels (with the exception of Vitamin A).

To examine trade patterns more rigorously, we estimate a gravity equation following the specification of Helpman, Melitz and Rubinstein (2008, hereafter HMR):

$$m_{ijt} = \alpha_l l_{ij} + \alpha_{SPRE} D_{SPRE} l_{ij} + \alpha_{SPOST} D_{SPOST} l_{ij} + \alpha_{LPOST} D_{LPOST} l_{ij} + \beta X_{ijt} + f_i + f_j + f_t + \epsilon_{ijt} \quad (9a)$$

where m_{ijt} is the log of the value of imports from exporting country *i* into importing country *j* in year *t*, $l_{ij}$is the log of the bilateral distance,[30] D_{SPPRE}, D_{SPOST} and D_{LPOST} are defined as above, $X_{ijt}$is a vector of bilateral controls, f_i and f_j denote exporter and importer fixed effects, f_t denotes year effects and ϵ_{ijt} is the residual error term.

[30] We define bilateral distance as the log bilateral population weighted distance (in km). See Data Appendix for detailed definitions of all variables.

To address the issue of zero-trade observations, we adopt the methodology proposed by HMR which requires estimating a first stage propensity-to-trade equation for the selection of trade partners. Following HMR, we use the following selection equation:

$$P(T_{ijt}=1|observed\ variables)=\Phi(\alpha'_{l}l_{ij}+\alpha'_{SPRE}D_{SPRE}l_{ij}+\alpha'_{SPOST}D_{SPOST}l_{ij} +\alpha'_{LPOST}D_{LPOST}\,l_{ij}+\beta'H_{ijt}+f'_{i}+f'_{j}+f'_{t}+\epsilon_{ijt} \quad (9b)$$

where T_{ijt} is a dummy indicating non-zero exports from exporter j to importer i in year t, Φ (.) is the cdf of the unit normal distribution, H_{ijt} is a set of control variables (see Data Appendix for details), and f'_{i} f'_{j} and f'_{t} denote exporter, importer and year effects.[31] We estimate distinct coefficients, α'_{l}, in this propensity equation to measure the impact of a change in competitive intensity on the relationship between distance and the probability of trade. In particular, if the change in competitive intensity induces a switch from specialization to trade, we should see a weakening in the impact of distance on the trading partner selection, i.e., α'_{SPOST} and α'_{LPOST} smaller in absolute value.

The HMR methodology modifies equation (9a) to address bias from sample selection and unobserved firm heterogeneity, respectively: $\ln\{\exp[\delta(\hat{z}^{*}_{ijt}+\hat{\bar{\eta}}^{*}_{ijt})]-1\}+\beta_{u\eta}\hat{\bar{\eta}}^{*}_{ijt}$, where $\hat{\bar{\eta}}^{*}_{ij}=\phi(\hat{z}^{*}_{ij})/\Phi(\hat{z}^{*}_{ij})$, $\hat{z}^{*}_{ij}=\Phi^{-1}(\hat{\rho}_{ij})$, and $\rho_{ijt}=P(T_{ijt}=1|W_{ijt})$ where W_{ijt} is all other observed data. To control for the first term flexibly, we follow an approach suggested by HMR and include a third degree polynomial in $\hat{z}^{*}_{ij}$. Thus we obtain the following sample-selection and unobserved heterogeneity corrected gravity equation:

$$m_{ijt}=\alpha_{l}l_{ij}+\alpha_{SPRE}D_{SPRE}l_{ij}+\alpha_{SPOST}D_{SPOST}l_{ij}+\alpha_{LPOST}D_{LPOST}l_{ij} +\beta X_{ijt}+f_{i}+f_{j}+f_{t}+\gamma\hat{\bar{\eta}}^{*}_{ijt}+\Sigma_{k=1}^{3}\gamma_{k}\left(\hat{z}^{*}_{ijt}\right)^{k}+\epsilon_{ijt} \quad (9c)$$

Our estimates of this equation suggest little or no change in the effect of distance on the propensity to trade, implying that these cartels were sharing geographic markets during collusion whether we consider the short-run ((Table 5, columns 1a and 2a) or long-run (columns 1b and 2b) post-breakup period. [32] These results are confirmed in the pooled analysis.

[31] Because specification (9b) does not include trade-pair fixed effects, the set of variables in H_{ijt} includes bilateral variables that are fixed over time (such as a non-interacted distance term).

[32] In order to address non-convergence in the Probit estimates using the full sample, we drop importers and exporters with less than three observations. This reduces the number of observations by 1.1%. All

The gravity estimates are also generally consistent with market sharing (Table 6). We first use the propensity estimates to calculate the HMR distance coefficient in the gravity equation. We find no statistically significant changes in the distance coefficient for any cartel either relative to the 4-year pre-breakup period (columns 1a and 1b) or the 2-year pre-breakup period (columns 2a and 2b). [33] We then estimate an alternative to the HMR methodology, the pseudo-maximum-likelihood (PML) estimator proposed by Silva and Tenreyro (2006) based on trade shares. The PML estimator addresses both zero-trade and bias from heteroscedasticity in the log linear model. One advantage of the PML estimator is that HMR presumes monopolistic competition, which may not be a valid representation of oligopolistic interaction between firms (either under collusion or competition) for the products we study. Thus the PML estimator addresses concerns about zero-trade observations without explicitly relying on any assumptions about the structure of competition. To address concerns raised by Anderson and van Wincoop (2003), we include exporter-importer fixed effects in the Silva-Tenreyro estimation. The PML estimates for individual cartels show no change in the impact of distance, except for Vitamin B4, while the pooled meta-analysis suggests a slight increase in the importance of distance overall (Table 6, columns 3a-4b).

These propensity and gravity specification results suggest that collusive trade patterns in these markets are more consistent with market-sharing than with geographic specialization. In some ways these results are unsurprising. The theoretical models discussed above show that the characteristics of equilibrium collusion are determined by the size of transportation costs, product homogeneity and firm patience. These chemical products are relatively homogenous and produced by large, and presumably patient, firms, consistent with market division collusion. Their low transportation costs, on the other hand, make it relatively easy to cheat by exporting to another market, suggesting that market sharing is necessary for stable collusion. These results also imply that the observation of significant intra-product trade between countries does not preclude the existence of collusion. Other products with higher transportation costs may be able to maintain a collusive outcome involving geographic specialization. Our result may be quite general, however, as trade only occurs where

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estimates of the distance coefficient in the gravity equation (below) are done on the same sample for consistency.

[33] We follow HMR (and Anderson and van Wincoop 2003) and use exporter and importer fixed effects separately. In principle, it should be possible to apply the HMR methodology even with bilateral fixed effects. However, data for the excluded variables they recommend – entry barriers and religion – are unavailable or invariant during the period in which we are interested.

transportation costs are sufficiently low relative to price. Future research with samples of cartels in which there is more variance in transportation costs is necessary to determine this fundamentally empirical question. [34]

4.3. Concentration

To isolate the impact of changes in competitive intensity on concentration, we examine regression specifications similar to those above, but with a measure of concentration (HHI or number of trade partners) as the dependent variable:[35]

$$CONC_{it} = \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{SPOST} + f_i + \epsilon_{it} \quad (10a)$$

$$CONC_{it} = \alpha_{SPRE} D_{SPRE} + \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{SPOST} + f_i + \epsilon_{it} \quad (10b)$$

When examining individual products, we generally do not find statistically significant changes in HHI (Table 7, columns 1 and 2) or in the number of trade partners (columns 3 and 4). The pooled meta-analysis suggests a secular decline in concentration and increase in the number of trading partners. These cross-cartel results may reflect increasing globalization, particularly the entry of China during this period into several of these product markets. This explanation of these changes in concentration is supported by the difference-in-difference analysis presented below, which suggests that any changes in concentration in these markets were not significantly different from other, similar chemical markets in the same time period.

4.4. An alternative explanation: geographic specialization and Bertrand competition

Our empirical result of little or no change in the sensitivity of distance during and after collusion is also consistent with a model of geographic specialization during collusion, but in which competitive reversion takes the form of Bertrand competition (e.g., Gross and Holahan 2003). In such a model, there is no cross-hauling during collusion or during reversion. As in the markets studied here, there would be no change in trade patterns with the breakup of a cartel.

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[34] We did attempt to examine some cartelized products that have higher transportation costs, including elevators, gas insulated switchgear and carbon cathode blocks. Unfortunately, we found a poor fit between these products and the closest HS or SITC classifications for which data were available.

[35] Note that these concentration estimates differ from the earlier specifications in that the observations here are importer-year specific, and accordingly, we use importer fixed effects. To account for differing market sizes in different countries, regressions are weighted by import quantity.

To distinguish these alternative interpretations of our empirical results, we look for direct evidence of cross-hauling. Table 8 reports the magnitude of imports into cartel home countries as a fraction of their total trade. Under geographic specialization, we would expect these countries to import very little relative to what they export. However, we find that imports are a considerable fraction of trade in cartel home countries during the collusive period, ranging from 18.3% for MCAA to 60% for Vitamin B3 (column 1a). There is also evidence of significant cross-hauling in the post-breakup period (column 1b). Considering only trade between cartel home countries, we still find substantial cross-hauling both before and after the cartel breakup (columns 2a and 2b). For example, 91% of imports of Vitamin A into cartel home countries came from other cartel countries (column 2a). [36]

In a Bertrand world, we would also expect to see significantly higher concentration in markets adjacent to cartel home countries. To determine whether this was the case in these markets, we compare two samples: (i) countries bordering exactly one cartel home country and (ii) countries not bordering any cartel home country. We find little evidence for higher concentration (as measured by mean HHI) in markets adjacent to cartel home countries (Table 8, columns 3a-c). To the contrary, for most cartels there is lower concentration in markets adjacent to cartel home countries.[37] Similarly and not surprisingly given previously reported results, when we make this same comparison in the post-breakup period, the HHI is similar both between countries adjacent and non-adjacent to cartel countries and before and after cartel breakup (Table 8, columns 4a-c). This suggests that trade patterns are more consistent with a Cournot than a Bertrand world in which collusion requires market sharing.

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[36] The European Commission describes the compensation policy of the Vitamin A cartels: "The information for the whole year was maintained on a cumulative monthly basis to ensure that each party kept to its agreed market share … If at the end of the year a producer was substantially ahead of its quota, it had to purchase vitamins from the others in order to compensate them for the corresponding shortfall in their allocation." (European Commission 2003, par. 196) Other cartels with similar arrangements include lysine, organic peroxide, MCAA, and citric acid.

[37] These results could be affected by cartel firms having production facilities in countries other than their headquarters' location. Thus concentration measures may be high even in some markets non-adjacent to cartel home countries if they are reserved for the exports from non-home production locations of a cartel member. Nevertheless, if the Gross-Holahan model holds, *on average*, we expect the HHI of markets adjacent to cartel members to be higher than that of all other countries (even if some of them may be adjacent to other cartel locations), as the firms price to drive out competitors from close-by markets. Note that the results in Table 8, column 3c are also evidence against geographic specialization, as these suggest no significant targeting of geographically proximate markets in the pre-breakup period. The finding of significant imports into cartel home countries from other cartel home countries (column 2a) is also contrary to what would be expected if the cartel were using geographic specialization.

5. Robustness checks

5.1. Difference-in-difference (DID) analysis

One potential concern with the baseline before-after results is that the changes observed in price might have been driven by contemporaneous shocks coincident with cartel breakup. The stability of the distance coefficient would then reflect countervailing influences that were common across these products rather than a change in competition. The availability of panel data allows us to address this concern using difference-in-differences (DID), comparing changes in the cartelized products to other "comparable" products with no known change in competitive intensity. To implement this empirical strategy, we examine two products in closely related markets: enzymes and miscellaneous organic chemicals.[38] There is no evidence of collusive activity nor was there any antitrust intervention in either product market during this period. Enzymes are a useful comparison product because they are used primarily as animal food additives, as are several products in our sample. All seven cartel products are organic chemicals. This suggests that these products would face similar changes in both supply and demand as do the cartelized products. However, any markets will experience idiosyncratic changes that could potentially affect trade patterns. For example, there was a significant merger in enzymes in the late 1990s.[39]

Using the DID approach, the seven cartelized products show significant declines in price following the breakup of their cartels (Table 9, columns 1 and 3). Whether relative to enzymes or miscellaneous organic chemicals, the price of each cartelized product fell more than the comparison product in both the short and long run. In almost all cases, the fall in price is statistically significant. The pooled analysis shows a statistically significant decline in price for the cartelized products using either comparison product.

The DID estimates of the impact of breakup on distance shipped are also generally consistent with the results presented above. Whether using enzymes or miscellaneous organic chemicals as the control, there is no significant change in the propensity to trade after cartel

[38] More specifically the product categories are "enzymes not including rennet," HS 350790, predominantly used as additives in animal feed, and "organic chemicals not elsewhere specified," HS 294200, a residual category within the broad group of organic chemicals.

[39] In 1996, the U.S. Justice Department approved the merger of two of the four participants in the world-wide industrial enzyme business (press release, July 1, 1996, available at http://www.justice.gov/archive/opa/pr/1996/July96/320.at.html).

breakup, either for individual cartels or the pooled analysis (Table 10). Table 11 presents DID estimates of the distance coefficient using both HMR and PML methodologies. As in the baseline specification, the HMR estimates (columns 1a-2b) suggest no change in the impact of distance before and after cartel breakup. The PML estimates relative to other organic chemicals also reinforce the baseline results of no change (columns 4a-b). The PML DID results suggest that distance became more important for some of the cartelized products, relative to enzymes, over this period (columns 3a-3b). This outlier result may reflect the consolidation in enzymes.[40]

Returning to Table 9, the borderline significant declines in concentration noted in the baseline results (Table 7) are even weaker when compared to the controls. Changes in HHI in the cartel products are no different from miscellaneous organic chemicals (Table 9, column 4). Column 2 suggests that concentration fell in the cartel markets more than enzymes, but only if one focuses on the two-year period immediately following cartel breakup. In the long-run, this declining concentration was observed across cartel and non-cartel products, likely due to increasing globalization concomitant with mergers in enzymes, as mentioned above.

5.2. Additional robustness checks

We perform a series of robustness checks to evaluate the sensitivity of our results to changes in specification and data. These robustness checks raise no questions regarding the conclusions drawn from our analyses.

Our price results are robust to several alternative specifications. First, if transportation (insurance and freight) costs for all of these products fell around the time of cartel breakup, this could explain the observed fall in prices as the reported import (CIF) prices we use include transportation costs. In order to control for this possibility, we examine data on *export* quantities and values, which are reported FOB (free on board), and hence do not include insurance and freight costs (Appendix Table A.1, column 1).[41] The results show significant price declines for FOB prices and confirm the baseline results. Second, we re-estimate the price

[40] In results available on request, we find the gravity coefficient on enzymes fell after 1997, around the same time as many of these cartel breakups.

[41] As discussed earlier, a drawback of the data on exports is that it is much sparser (as a number of countries do not report exports for many or all of the years) and is generally viewed as being of poorer quality (Feenstra et al 2005). Nevertheless, there are sufficient observations for most cartels to do a robustness check using the export data. In results not reported here we estimated the change in FOB price controlling for log GDP and log GDP per capita for both importers and exporters. Separately, we re-estimated country-specific trends for both importers and exporters. The results are substantially the same.

analysis restricting the sample to imports from countries where cartel members are headquartered (column 2). Again, the results are qualitatively the same.

Turning to concentration, our results robust are in four different subsamples (Appendix Table A.2, columns 1-4): (i) restricted to Europe to abstract from markets distant from most cartel home countries; (ii) a balanced panel to assure that the results are not driven by increases in trade data coverage over time; (iii) excluding cartel home countries (as these concentration estimates are likely disproportionately upwardly biased because of unmeasured domestic output); and (iv) restricted to imports from cartel home countries to abstract from effects induced by non-cartel (or other production location) exports.[42] In addition, the concentration results are robust to using export rather than import data to measure HHI (column 5).

We reproduce the results for the gravity estimates (Appendix Table A.3) for three subsamples as in the concentration robustness checks: restricted to Europe, a balanced panel, and imports from cartel home countries only.[43] We also replicate our DID results for price and concentration (Table A.4) and gravity (Table A.5) for cartel home countries only, using our two product controls (enzymes and organic chemicals).

6. Discussion

Cartel collapses triggered by increased antitrust enforcement activity provide a quasi-natural experiment to study the effects of changes in competitive intensity on a number of important outcomes. We examine trade patterns in seven markets where firms were prosecuted for explicit price fixing. Each of the cartelized products experienced striking declines in price levels after antitrust intervention, strongly suggesting that there were indeed substantial and meaningful changes in the competitive environment.

We consider different mechanisms used to stabilize collusion in international markets. Previous theoretical work has considered both market-sharing and market-division collusive equilibria. If cartels divide markets, cartel breakup will lead to an increase in cross-hauling, significantly affecting trade patterns and concentration measures. On the other hand, if cartels

[42] Note that for Vitamin E we find some evidence for declines in concentration in most subsamples. In unreported regressions, we examined results excluding imports from Chinese and found results similar to the baseline.

[43] In unreported regressions, we also checked whether the gravity equation results are affected by the rise of Chinese exports by excluding Chinese imports. Our results were robust to this alternative specification.

share markets, there will be little empirical relationship between competition and trade patterns.

For the seven cartels studied here, we find no systematic evidence for significant changes in trading patterns or import concentration following cartel breakup, either for individual cartels or in a meta-analysis of the full sample. There is evidence of cross-hauling during the collusive periods. Thus, our results suggest that these international cartels were able to maintain collusion even while sharing markets.

International trade creates the appearance of competition. Our finding is that the existence of cross-hauling by itself does not provide evidence of the existence of effective competition. To the contrary, in several international cartel cases, cartel members purchased from one another across international borders in order to achieve cartel market share targets.[44] Historically, international cartels, particularly chemical cartels, divided global markets into Europe, North America, and the "Rest of the World."[45] One might reasonably assume that contemporary cartels organized similarly. However, contemporary cartels appear to be able to collude while sharing markets. It may be that they do so by assigning customers, who are themselves global firms, rather than geographic territories. Econometric screens that hinge on geographic market divisions will miss collusive episodes such as these.

The persistence of trade patterns after cartel breakup does not necessarily imply that the observed patterns are unaffected by collusion. Our finding that trade patterns were maintained post-cartel may instead reflect the long-term impact of actions taken by the cartels. Trade patterns can be sticky, for example, because of relationships that are developed between suppliers and customers or other country-specific knowledge that is gained by the supplier. Further research will help us to identify the varied and durable ways in which collusion affects international trade.

[44] See Levenstein and Suslow (2011), p. 476, for examples of firms engaging in cross-purchases in order to compensate one another and maintain cartel shares.

[45] Suslow (2005) reports that 40% of international cartels in the inter-war period used exclusive territories (Table 2, p. 716) and that "chemical-sector cartels used export quotas and exclusive territories (worldwide market sharing agreements) most frequently" (p. 718).

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Table 1
Characteristics of seven international cartels

Product	HS code	Start year	End year	Duration (years)	Number member firms	Home country of member firms	Member Firms
Citric Acid	291814	1991	1995	5	5	Austria, Germany, France, Switzerland, US	F. Hoffman-La Roche LTD, Haarmann & Reimer, Cerestar Bioproducts BV, Jungbunzlauer Int'l, Archer Daniels Midland
Methionine*	293040	1986	1999	14	3	France, Germany, Japan	Aventis SA, Degussa-Huls AG, Nippon Soda
Monochloro-acetic Acid (MCAA)	291540	1984	1999	16	4	Netherlands, France, Germany	Akzo Nobel Chemicals BV, Elf Atochem S.A., Hoechst Aktiengesellschaft, Eka
Vitamin A	293621	1989	1999	11	3	Germany, Switzerland, France	BASF Aktiengesellschaft, F. Hoffmann-La Roche Ltd., Rhone -Poulenc SA
Vitamin B3 (Niacin)	293624	1992	1998	7	4	Germany, US, Switzerland	Lonza, Degussa-Huls, Nepera, Reilly Industries.
Vitamin B4 (Choline Chloride)	292310	1988	1998	11	6	Canada, US, Belgium, Netherlands, Germany	Chinook Group Limited, DuCoa LP, UCB S.A., Akzo Nobel, Bioproducts Incorporated
Vitamin E	293628	1989	1999	11	4	Germany, Switzerland, Japan, France	BASF Aktiengesellschaft, F. Hoffmann-La Roche Ltd., Rhone-Poulenc SA, Eisai Co. Ltd.

*For Methionine, we use data from SITC Revision 3 (code 51544), as coverage is more complete than HS 293040.

Table 2
Price and concentration descriptive statistics

	Price			Concentration				
				HHI			Trade Partners	
		Log Price	Log Price (standardized)		HHI	HHI (standardized)	Number	Number (standardized)
	N	Mean	Mean	N	Mean	Mean	Mean	Mean
Citric Acid								
Pre-Breakup	2,029	0.241	-0.496	232	0.294	-0.542	15.497	1.343
Post-Breakup	3,793	0.165	-0.632	458	0.276	-0.616	14.972	1.239
Diff (Post-Pre)		-0.076**	-0.136**		-0.018	-0.074	-0.524	-0.104
p-value		(0.000)	(0.000)		(0.380)	(0.380)	(0.616)	(0.616)
Methionine								
Pre-Breakup	1,933	1.074	-0.243	338	0.411	-0.35	9.286	1.014
Post-Breakup	2,374	0.784	-0.733	428	0.352	-0.578	9.765	1.155
Diff (Post-Pre)		-0.29**	-0.49**		-0.059**	-0.228**	0.479	0.141
p-value		(0.000)	(0.000)		(0.009)	(0.009)	(0.329)	(0.329)
MCAA								
Pre-Breakup	1,206	0.097	-0.748	280	0.446	-0.787	9.062	1.444
Post-Breakup	1,370	-0.216	-0.97	332	0.447	-0.784	9.167	1.476
Diff (Post-Pre)		-0.313**	-0.221**		0.001	0.004	0.106	0.032
p-value		(0.000)	(0.000)		(0.981)	(0.981)	(0.883)	(0.883)
Vitamin A								
Pre-Breakup	1,974	3.208	-0.319	327	0.417	-0.437	11.576	1.361
Post-Breakup	2,553	2.913	-0.644	422	0.371	-0.613	11.939	1.454
Diff (Post-Pre)		-0.295	-0.325		-0.045	-0.176	0.363	0.093
p-value		(0.194)	(0.194)		(0.334)	(0.334)	(0.718)	(0.718)
Vitamin B3								
Pre-Breakup	1,700	2.72	-0.182	271	0.415	-0.262	11.095	1.177

	Price			Concentration				
				HHI			Trade Partners	
		Log Price	Log Price (standardized)		HHI	HHI (standardized)	Number	Number (standardized)
	N	Mean	Mean	N	Mean	Mean	Mean	Mean
Post-Breakup	2,176	2.356	-0.745	336	0.364	-0.463	11.881	1.383
Diff (Post-Pre)		-0.364**	-0.563**		-0.051	-0.2	0.786	0.205
p-value		(0.000)	(0.000)		(0.307)	(0.307)	(0.197)	(0.197)
Vitamin B4								
Pre-Breakup	1,725	-0.07	-0.647	296	0.45	-0.239	10.246	1.154
Post-Breakup	2,042	-0.304	-0.819	376	0.42	-0.344	10.303	1.169
Diff (Post-Pre)		-0.233**	-0.172**		-0.029	-0.105	0.057	0.015
p-value		(0.000)	(0.000)		(0.531)	(0.531)	(0.916)	(0.916)
Vitamin E								
Pre-Breakup	2,096	2.834	-0.072	317	0.367	-0.51	12.144	1.17
Post-Breakup	2,842	1.966	-1.141	411	0.323	-0.68	14.264	1.65
Diff (Post-Pre)		-0.868**	-1.069**		-0.044	-0.17	2.12**	0.48**
p-value		(0.000)	(0.000)		(0.099)	(0.099)	(0.006)	(0.006)
Pooled Fixed Effects (Post-Pre)			-0.900**			-0.221**		0.151**
p-value			(0.000)			(0.000)		(0.000)
Pooled Random Effects (Post-Pre)			-0.986**			-0.217**		0.148*
p-value			(0.000)			(0.000)		(0.042)

Notes: For price, N equals number of years x number of bilateral pairs. For HHI and trade partners, N equals number of years x number of countries. The pooled estimates of the standardized mean difference are calculated using two alternative approaches: one assumes a fixed (common) effect (Sinclair and Bracken 1992), while the second assumes random effects, allowing for heterogeneity (DerSimonian and Laird 1986) across cartels. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively. All means are weighted by trade quantities.

Table 3

Short and long-run price changes

	Log Price		Standardized Log Price	
	Short-run effect (SPOST)	Long-run effect (LPOST)	Short-run effect (SPOST)	Long-run effect (LPOST)
	1	2	3	4
Citric Acid	-0.045	-0.142**	-0.081	-0.255**
	(0.054)	(0.000)	(0.054)	(0.000)
Methionine	-0.288**	-0.323**	-0.488**	-0.547**
	(0.000)	(0.000)	(0.000)	(0.000)
MCAA	-0.311**	-0.301**	-0.220**	-0.213**
	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin A	-0.331*	-0.272	-0.365*	-0.300
	(0.030)	(0.056)	(0.030)	(0.056)
Vitamin B3	-0.308**	-0.463**	-0.476**	-0.717**
	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin B4	-0.278**	-0.223**	-0.206**	-0.165**
	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin E	-0.797**	-0.915**	-0.982**	-1.126**
	(0.000)	(0.000)	(0.000)	(0.000)
Pooled meta-analysis			-0.222**	-0.348**
			(0.000)	(0.000)

Notes: For price, N equals number of years x number of bilateral pairs. For HHI and trade partners, N equals number of years x number of countries. All regressions include importer-exporter (trade-pair) fixed effects. Observations are weighted by trade quantity, except for the pooled analysis where observations are weighted by trade quantity share of aggregate annual product trade quantity so that each cartel has equal weight. In columns 3 and 4, the dependent variable (log price) is standardized, i.e., demeaned and divided by the standard deviation. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table 4

Short-run price changes and pre-breakup trends

	Log Price		Standardized Log Price	
	Pre-breakup trend	Short term post-breakup relative to short-term pre-breakup	Pre-breakup trend	Short term post-breakup relative to short-term pre-breakup
	SPRE-LPRE	SPOST-SPRE	SPRE-LPRE	SPOST-SPRE
	1	2	3	4
Citric Acid	0.088**	-0.075**	0.158**	-0.135**
	(0.000)	(0.002)	(0.000)	(0.000)
Methionine	-0.064**	-0.259**	-0.109**	-0.438**
	(0.008)	(0.000)	(0.008)	(0.000)
MCAA	-0.122**	-0.254**	-0.086**	-0.179**
	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin A	-0.364	-0.173	-0.401	-0.192
	(0.078)	(0.448)	(0.078)	(0.448)
Vitamin B3	-0.038	-0.291**	-0.058	-0.451**
	(0.553)	(0.000)	(0.553)	(0.000)
Vitamin B4	-0.054	-0.255**	-0.040	-0.188**
	(0.086)	(0.000)	(0.086)	(0.000)
Vitamin E	-0.071*	-0.766**	-0.087*	-0.943**
	(0.012)	(0.000)	(0.012)	(0.000)
Pooled meta-analysis			0.057	-0.248**
			(0.249)	(0.000)

Notes: N equals number of years x number of bilateral pairs. All regressions include importer-exporter (trade-pair) fixed effects. In columns 3 and 4, the dependent variable, log price, is standardized, i.e., demeaned and divided by the standard deviation. Observations are weighted by trade quantity shares, except for the pooled estimates where observations are weighted by trade quantity share of aggregate annual product trade quantity. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table 5

Impact of distance on propensity to trade

	Mean relative to 4-year pre-breakup period		Mean relative to 2-year pre-breakup period	
	SPOST	LPOST	SPOST	LPOST
	1a	1b	2a	2b
Citric Acid	-0.106*	-0.122**	-0.091*	-0.107**
	(0.013)	(0.003)	(0.026)	(0.009)
Methionine	0.006	-0.011	0.001	-0.016
	(0.912)	(0.813)	(0.973)	(0.758)
MCAA	-0.015	-0.039	-0.017	-0.040
	(0.713)	(0.476)	(0.720)	(0.506)
Vitamin A	0.013	0.047	0.006	0.040
	(0.712)	(0.342)	(0.880)	(0.432)
Vitamin B3	0.009	0.007	-0.009	-0.011
	(0.817)	(0.891)	(0.840)	(0.837)
Vitamin B4	-0.008	-0.034	-0.023	-0.048
	(0.818)	(0.466)	(0.562)	(0.308)
Vitamin E	-0.043	0.024	-0.060	0.007
	(0.288)	(0.687)	(0.167)	(0.904)
	-0.018	-0.013	-0.024	-0.019
Pooled meta-analysis	(0.301)	(0.481)	(0.187)	(0.333)

Notes: The numbers of observations for the seven cartels in order are 24,036; 18,333; 12,360; 21,834; 13,228; 13,888; and 19,651. There are more observations reported here, relative to other tables, because the propensity analysis includes zero trade observations. The dependent variable is a dummy = 1 if there is non-zero trade between a country pair. All specifications include importer, exporter and year effects. Other controls are discussed in the text and data appendix; all continuous control variables are standardized. In the pooled meta-analysis, each observation is weighted by the inverse of the number of observations for each product, so that the overall estimate is based on equally weighting each product. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table 6

Distance coefficient in gravity equations: HMR and PML specifications

	HMR				PML			
	Mean relative to 4-year pre-breakup period		Mean relative to 2-year pre-breakup period		Mean relative to 4-year pre-breakup period		Mean relative to 2-year pre-breakup period	
	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST
	1a	1b	2a	2b	3a	3b	4a	4b
Citric Acid	0.048	0.035	0.045	0.031	-0.031	0.041	-0.046	0.027
	(0.217)	(0.425)	(0.189)	(0.427)	(0.578)	(0.513)	(0.387)	(0.673)
Methionine	0.019	-0.003	0.019	-0.003	0.077	0.054	0.068	0.045
	(0.510)	(0.919)	(0.505)	(0.945)	(0.130)	(0.398)	(0.183)	(0.477)
MCAA	-0.052	-0.046	-0.068	-0.061	0.046	0.100	0.036	0.091
	(0.310)	(0.684)	(0.201)	(0.599)	(0.345)	(0.238)	(0.420)	(0.278)
Vitamin A	-0.014	-0.020	-0.004	-0.010	0.031	0.026	0.045	0.039
	(0.676)	(0.716)	(0.895)	(0.834)	(0.588)	(0.701)	(0.521)	(0.564)
Vitamin B3	0.036	-0.009	0.056	0.010	0.123	0.160	0.124	0.161
	(0.348)	(0.830)	(0.175)	(0.814)	(0.151)	(0.112)	(0.164)	(0.130)
Vitamin B4	0.054	0.048	0.058	0.052	0.257*	0.253*	0.238*	0.237*
	(0.249)	(0.356)	(0.218)	(0.360)	(0.011)	(0.012)	(0.017)	(0.014)
Vitamin E	0.032	-0.009	0.042	0.001	0.025	0.060	0.015	0.050
	(0.315)	(0.750)	(0.208)	(0.994)	(0.616)	(0.465)	(0.765)	(0.536)
Pooled meta-analysis	0.029	0.025	0.031	0.027	0.054*	0.076*	0.048	0.07*
	(0.216)	(0.190)	(0.230)	(0.218)	(0.027)	(0.023)	(0.058)	(0.034)

Notes: The dependent variable in the HMR gravity equation is standardized log trade value. The dependent variable in the PML gravity equation is trade share (trade value divided by total trade for the product in the year). The numbers of observations for the seven cartels in the HMR regressions (which excludes no trade observations) are 3285, 2563, 1394, 2781, 2134, 2243, and 2942, respectively. The number of observations for the seven cartels in the PML specification (which includes no trade observations) are 10470, 6965, 4520, 7925, 6223, 6525, and 7833, respectively. All specifications include product-importer-exporter (product-trade-pair) and year fixed effects. Other controls are discussed in the text and data appendix; all continuous control variables are standardized. P-values based on robust standard errors clustered by product-importer-exporter (product-trade-pair) are in parentheses; ** represents significance at 1% level and * represents significance at 5% level.

Table 7

Concentration

	HHI				Number of trade partners			
	Mean relative to 4-year pre-breakup period		Mean relative to 2-year pre-breakup period		Mean relative to 4-year pre-breakup period		Mean relative to 2-year pre-breakup period	
	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST
	1a	1b	2a	2b	3a	3b	4a	4b
Citric Acid	-0.046	0.035	-0.077	0.003	-0.065	-0.012	-0.126	-0.073
	(0.491)	(0.655)	(0.293)	(0.973)	(0.606)	(0.936)	(0.330)	(0.636)
Methionine	-0.143	-0.124	-0.154	-0.134	0.146	0.159	0.241	0.254
	(0.173)	(0.351)	(0.116)	(0.322)	(0.271)	(0.411)	(0.096)	(0.171)
MCAA	-0.013	0.000	0.076	0.089	0.083	0.067	-0.049	-0.066
	(0.863)	(0.999)	(0.224)	(0.143)	(0.631)	(0.687)	(0.670)	(0.676)
Vitamin A	-0.143	-0.271	-0.145	-0.273	0.196	0.418**	0.195	0.416*
	(0.206)	(0.046)	(0.258)	(0.047)	(0.299)	(0.007)	(0.400)	(0.021)
Vitamin B3	-0.139	-0.088	-0.165*	-0.113	0.451**	0.114	0.428**	0.092
	(0.107)	(0.247)	(0.047)	(0.133)	(0.009)	(0.679)	(0.007)	(0.729)
Vitamin B4	-0.019	-0.06	-0.020	-0.060	0.157	0.176	0.145	0.164*
	(0.675)	(0.730)	(0.731)	(0.754)	(0.408)	(0.199)	(0.275)	(0.034)
Vitamin E	-0.172	-0.207*	-0.100	-0.136	0.422**	0.523	0.281	0.384
	(0.050)	(0.016)	(0.328)	(0.149)	(0.002)	(0.004)	(0.073)	(0.051)
Pooled meta-analysis	-0.098*	-0.099*	-0.085	-0.086	0.200**	0.206*	0.159*	0.165
	(0.025)	(0.026)	(0.052)	(0.062)	(0.006)	(0.012)	(0.048)	(0.078)

Notes: N equals number of years x number of countries. All regressions include importer fixed effects; pooled analysis includes product-importer fixed effects. Observations are weighted by import quantity; in the pooled analysis, each observation is weighted by the share of total imports each product, so that the overall estimate is based on equally weighting each product. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table 8

Extent of cross-hauling

	Import share of total trade (cartel home countries)		Share of imports from other cartel home countries		Mean HHI: Pre-breakup period			Mean HHI: Post-breakup period		
	Pre-breakup	Post-breakup	Pre-breakup	Post-breakup	Cartel border	Other	Diff	Cartel border	Other	Diff
	1a	1b	2a	2b	3a	3b	3c	4a	4b	4c
Citric Acid	55.0%	53.5%	36.5%	29.4%	0.293	0.371	-0.078	0.277	0.324	-0.047
							(.386)			(.341)
Methionine	25.4%	20.8%	27.2%	28.4%	0.324	0.454	-0.13*	0.303	0.366	-0.063
							(.026)			(.147)
MCAA	18.3%	16.4%	74.6%	72.7%	0.315	0.52	-0.205*	0.365	0.502	-0.137
							(.030)			(.112)
Vitamin A	22.1%	23.8%	91.0%	83.3%	0.404	0.34	0.064	0.371	0.327	0.044
							(.587)			(.477)
Vitamin B3	60.0%	49.8%	22.2%	15.7%	0.551	0.359	0.192	0.429	0.332	0.097
							(.098)			(.248)
Vitamin B4	38.6%	29.4%	71.1%	71.2%	0.234	0.463	-0.229*	0.256	0.424	-0.168
							(.037)			(.055)
Vitamin E	23.8%	29.7%	76.4%	56.5%	0.325	0.358	-0.033	0.333	0.302	0.031
							(.648)			(.569)
Pooled Fixed Effects							-0.166			-0.126
p-value							(0.057)			(0.075)
Pooled Random Effects							-0.214			-0.149
p-value							(0.226)			(0.228)

Notes: Columns 1 and 2 report averages for cartel home countries (listed in Table 1). The number of observations in column 3a (3b) are 21(160), 18 (182), 24 (225), 21 (221), 27 (173), 18 (197) and 21 (209). The number of observations in column 4a (4b) are 41 (390), 24 (286), 36 (376), 28 (378), 38 (282), 26 (326), 30 (361). The samples in columns 3b and 4b exclude cartel home countries. The meta-estimates of mean HHI are calculated using two alternative approaches: one assuming a fixed (common) effect (Sinclair and Bracken 1992), and another random effect approach which allows for heterogeneity (DerSimonian and Laird 1986) across cartels. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table 9: **Difference-in-differences estimates of price and concentration effects**

	Control	Enzymes		Organic chemicals nes	
		Log price	HHI	Log price	HHI
		1	2	3	4
Citric Acid	Short-run	-0.047	-0.095	-0.169*	0.066
		(0.403)	(0.482)	(0.031)	(0.636)
	Long-run	-0.204**	0.047	-0.388**	0.190
		(0.001)	(0.637)	(0.000)	(0.195)
Methionine	Short-run	-0.421**	-0.112	-0.422**	-0.049
		(0.000)	(0.301)	(0.000)	(0.743)
	Long-run	-0.528**	-0.039	-0.488**	-0.059
		(0.000)	(0.784)	(0.000)	(0.760)
MCAA	Short-run	-0.153**	0.02	-0.153*	0.087
		(0.000)	(0.819)	(0.033)	(0.534)
	Long-run	-0.187**	0.085	-0.146	0.073
		(0.000)	(0.326)	(0.066)	(0.631)
Vitamin A	Short-run	-0.300	-0.108	-0.321*	-0.053
		(0.068)	(0.379)	(0.050)	(0.721)
	Long-run	-0.279	-0.183	-0.254	-0.210
		(0.069)	(0.244)	(0.111)	(0.259)
Vitamin B3	Short-run	-0.441**	-0.105	-0.541**	-0.035
		(0.000)	(0.306)	(0.000)	(0.787)
	Long-run	-0.643**	-0.052	-0.643**	0.042
		(0.000)	(0.570)	(0.000)	(0.801)
Vitamin B4	Short-run	-0.175**	0.014	-0.276**	0.067
		(0.000)	(0.835)	(0.000)	(0.545)
	Long-run	-0.091	-0.023	-0.097	0.069
		(0.041)	(0.902)	(0.287)	(0.764)
Vitamin E	Short-run	-0.915**	-0.139	-0.919**	-0.077
		(0.000)	(0.153)	(0.000)	(0.577)
	Long-run	-1.107**	-0.12	-1.066**	-0.143
		(0.000)	(0.335)	(0.000)	(0.384)
Pooled meta-analysis	Short-run	-0.346**	-0.081*	-0.394**	0.006
		(0.000)	(0.041)	(0.000)	(0.915)
	Long-run	-0.430**	-0.045	-0.431**	-0.005
		(0.000)	(0.371)	(0.000)	(0.946)

Notes: The number of observations for the price regressions for enzymes (organic chemicals nes) are 14362 (11469), 17139 (13036), 15408 (11305), 17359 (13256), 15697 (11894), 15588 (11785), and 17770 (13667). The number of observations for the HHI regressions for enzymes (organic chemicals nes) are 1360 (1330), 1741 (1707), 1587 (1553), 1724 (1690), 1522 (1494), 1587 (1559), 1703 (1669). The log price regressions in columns 1 and 3 include importer-exporter-product fixed effects and year effects, and are weighted by trade quantity. The HHI regressions in columns 2 and 4 include importer-product fixed effects and year effects and are weighted by total annual import quantity. In the meta-analysis: the price regressions include trade pair-product-treatment and product-year fixed effects, where treatment is a dummy equal to one for cartel products and 0 for the control product; the HHI regressions include importer-product-treatment and product-year fixed effects**.** P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table 10: Difference in difference estimates of the propensity to trade

	Enzymes		Organic Chemicals nes	
	Long-run effect	Short-run effect	Long-run effect	Short-run effect
	1a	1b	2a	2b
Citric Acid	-0.06	-0.059	-0.066	-0.067
	(0.007)	(0.013)	(0.017)	(0.020)
Methionine	0.041	0.128	0.004	0.053
	(0.195)	(0.001)	(0.908)	(0.140)
MCAA	0.016	0.099	-0.005	0.052
	(0.653)	(0.024)	(0.902)	(0.217)
Vitamin A	0.007	0.117	-0.029	0.056
	(0.796)	(0.006)	(0.371)	(0.183)
Vitamin B3	-0.003	0.056	-0.017	-0.011
	(0.946)	(0.117)	(0.694)	(0.807)
Vitamin B4	-0.032	-0.01	-0.008	-0.023
	(0.307)	(0.745)	(0.811)	(0.531)
Vitamin E	-0.026	0.117	-0.041	0.067
	(0.401)	(0.014)	(0.262)	(0.145)
Pooled meta-analysis	-0.004	0.038	-0.022	0.004
	(0.832)	(0.104)	(0.300)	(0.881)

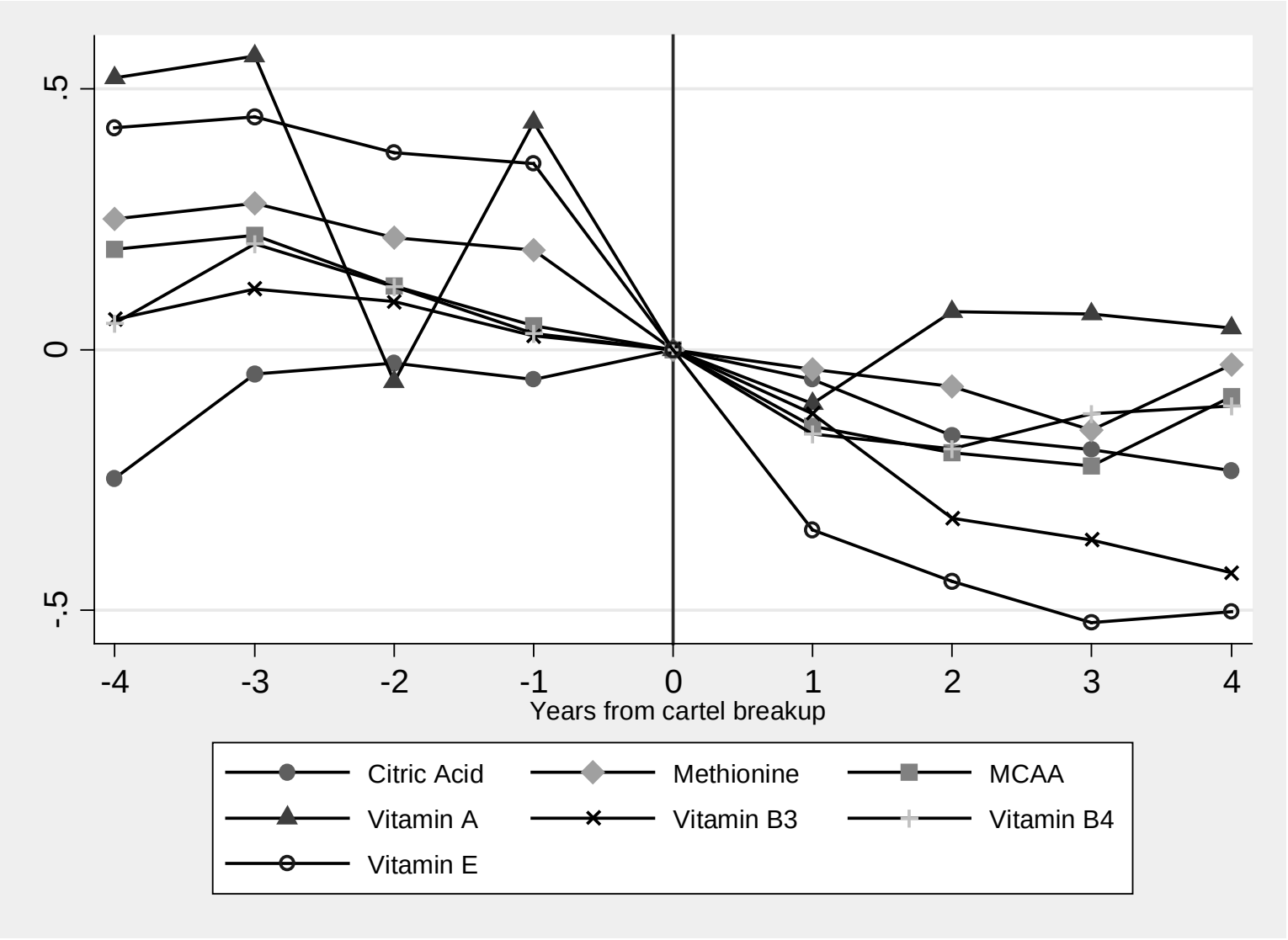
Notes: The numbers of observations for enzymes (organic chemicals nes) are 65451 (64120), 65965 (64655), 58392 (57082), 69763 (68453), 62031 (59359), 63672 (60984), and 66497 (65187). The analysis includes importer and year effects and excludes importers and exporters with fewer than 3 non-zero trade observations. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table 11: Difference in difference estimates of the distance coefficient

	HMR				PML			
	DID: Enzymes		DID: Organic Chemicals nes		DID: Enzymes		DID: Organic Chemicals nes	
	Long-run effect	Short-run effect	Long-run effect	Short-run effect	Long-run effect	Short-run effect	Long-run effect	Short-run effect
	1a	1b	2a	2b	3a	3b	4a	4b
Citric Acid	0.035	0.045	-0.04	-0.037	0.037	0.088	-0.334	-0.28
	(0.371)	(0.218)	(0.509)	(0.510)	(0.602)	(0.272)	(0.166)	(0.237)
Methionine	0.058	0.075	0.009	0.013	0.124*	0.193**	0.111	0.145
	(0.172)	(0.381)	(0.812)	(0.798)	(0.043)	(0.008)	(0.143)	(0.122)
MCAA	-0.017	0.032	-0.054	0.011	0.084	0.165*	0.072	0.129
	(0.659)	(0.621)	(0.215)	(0.840)	(0.065)	(0.021)	(0.232)	(0.190)
Vitamin A	0.03	0.063	0.004	0.019	0.102	0.183**	0.084	0.131
	(0.354)	(0.171)	(0.909)	(0.694)	(0.053)	(0.008)	(0.151)	(0.118)
Vitamin B3	0.072	0.067	0.054	0.065	0.125	0.214*	0.077	0.155
	(0.047)	(0.081)	(0.212)	(0.069)	(0.148)	(0.019)	(0.471)	(0.187)
Vitamin B4	0.001	0.006	0.085	0.129	0.128	0.153*	0.091	0.126
	(0.975)	(0.882)	(0.449)	(0.394)	(0.149)	(0.031)	(0.331)	(0.114)
Vitamin E	0.055	0.054	0.051	0.011	0.094*	0.214*	0.076	0.156
	(0.069)	(0.209)	(0.257)	(0.790)	(0.050)	(0.012)	(0.215)	(0.091)
Pooled meta-analysis	0.036	0.043	0.004	0.012	0.093**	0.162**	0.007	0.051
	(0.087)	(0.100)	(0.869)	(0.558)	(0.000)	(0.000)	(0.874)	(0.305)

Notes: The number of observations for HMR with enzymes (organic chemicals nes) are 8873 (6705), 9959 (7256), 8787 (6084), 10174 (7471), 9125 (6535), 9246 (6656), 10340 (7637); for the PML analysis, 23673 (21152), 24828 (20985), 22368 (18525), 25719 (21876), 23526 (19988), 23709(20171), and 25668 (21825). Columns 1 and 2 include exporter-product and importer-product fixed effects, year dummies interacted with distance, and correction for zero-trades based on Helpman et al (2008). Columns 3 and 4 include product-importer-exporter fixed effects and year fixed effects (interacted with distance). All specifications exclude importers and exporters with fewer than 3 non-zero trade observations. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Figure 1: Price changes following cartel breakup



Notes: The dependent variable is the log of price. This figure plots the mean log price (controlling for bilateral fixed effects, weighted by trade quantity, as in regression specification 8a) before and after the breakup of the cartels. The mean log price is normalized to 0 in the year of the breakup.

Figure 2: **Sustainable collusive equilibria**

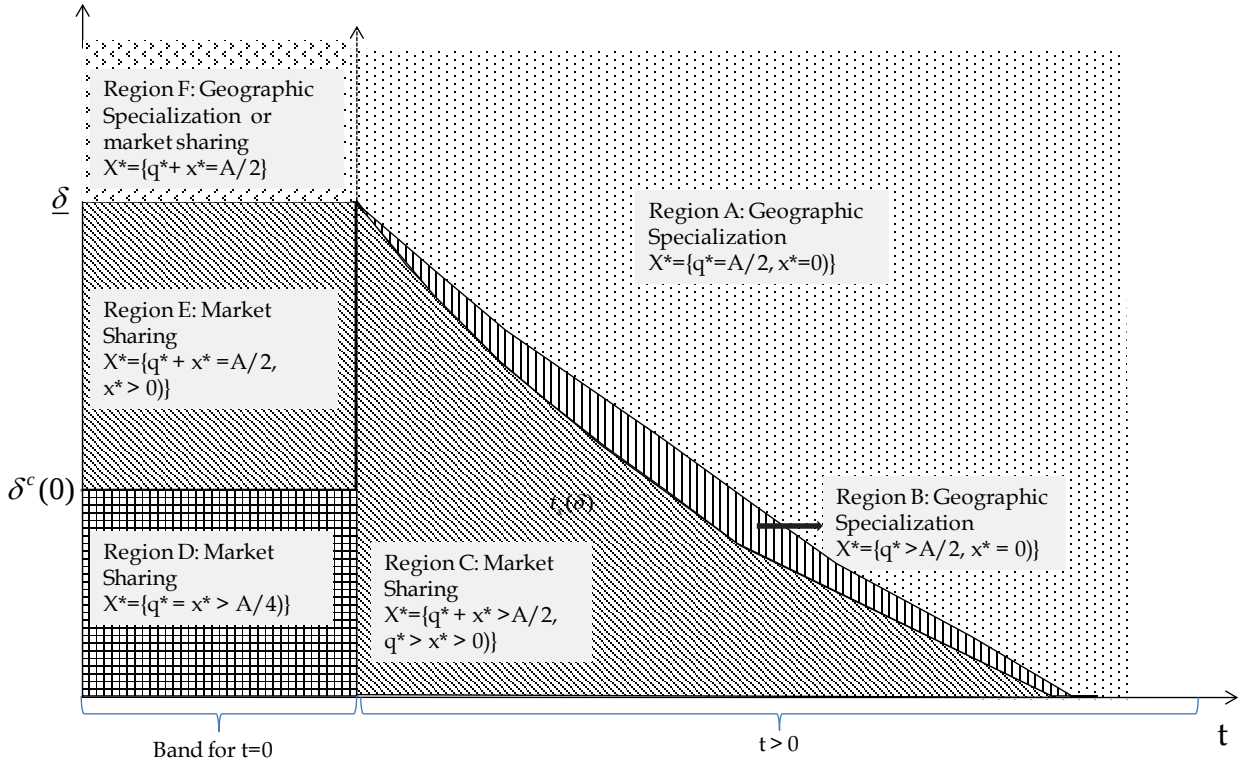
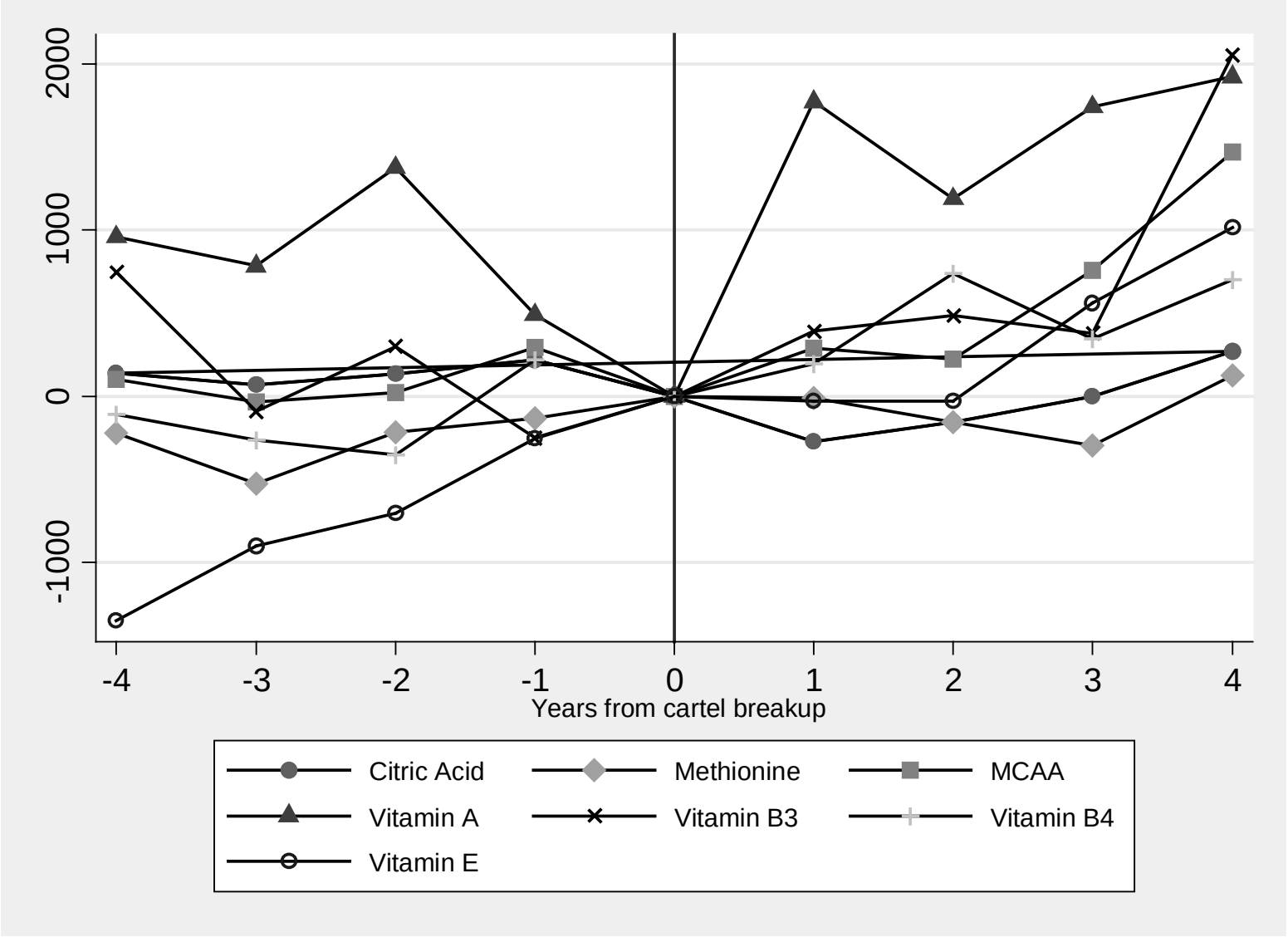


Figure 3: Average distance travelled (by unit quantity)



Note: The average distance travelled is defined as quantity weighted mean distance travelled by imports; specifically, $\bar{L_t} = \frac{\sum_{ij} q_{ijt} L_{ij}}{\sum q_{ijt}}$ where q_{ijt} is the quantity shipped between countries i and j in year t, and d_{ij} is the distance between countries i and j. This average distance is normalized to 0 in the year of the cartel breakup.

Data appendix

D1. Definitions for key variables

The key variables are all from COMTRADE, available at http://comtrade.un.org/db/default.aspx. Commodity descriptions are available from the "Harmonized Commodity Description and Coding System" (World Customs Organization) and several trade-related websites (e.g., http://www.foreign-trade.com/reference/hscode.cfm).

1. *Trade value*: total trade value in nominal US dollars.
2. *Trade quantity*: total trade quantity (in reported units).
3. *Price*: ratio of trade value to trade quantity, truncated by 2% on both tails of the distribution.[46]
4. *Distance*: Log distance between most populated cities (in km).
5. *Number of trade partners:* N_{jkt} is the number of countries exporting product k to country j in period t.
6. *Import market share:* S_{ijkt} is the market share of export country i in the total value of imports of product k entering country j in period t.
7. *Export market share:* X_{ijkt} is the share of the exports going to country j in the total value of exports of product k by exporter country i in period t.
8. *Herfindahl-Hirschman Index (HHI)*: the sum of the squares of the relative size of all importers in the country. $HHI_{jkt} = \sum_{i=1}^{N_{jkt}} (S_{ijkt})^2$

D2. Definitions for control variables used in the propensity to trade and gravity regressions:

The control variables used follow Helpman, Melitz and Rubinstein (2008). Data were obtained from multiple sources including: Centre d'Etudes Prospectives et d'Informations Internationales (CEPII), at http://www.cepii.fr/anglaisgraph/bdd/distances.htm; the World Bank's World Development Indicators 2007; Andrew Rose's website, http://faculty.haas.berkeley.edu/arose/RecRes.htm#Software.

1. *Common border*: binary variable equal to one if importer i and exporter j share a common physical boundary, and zero otherwise.
2. *Island*: binary variable equal to one if both importer i and exporter j are islands, and zero otherwise.
3. *Landlocked*: binary variable equal to one if neither exporting country j nor importing country i have a coastline or direct access to sea, and zero otherwise.
4. *Colonial ties*: binary variable equal to one if importing country i ever colonized exporting country j or vice versa, and zero otherwise.
5. *Common colony*: dummy variable indicating whether the two countries had a common colonizer post-1945.
6. *Currency union*: binary variable equal to one if importing country i and exporting country j use same currency or if the exchange rate between the pair was fixed at 1:1 for an extended period of time (see Rose (2000, 2004) and Glick and Rose (2002)), and zero otherwise.
7. *Legal system*: binary variable equal to one if importing country i and exporting country j share the same legal origin, and zero otherwise.
8. *RTA*: binary variable equal to one if exporting country j and importing country i belong to a regional trade agreement, and zero otherwise.
9. *NON-WTO*: binary variable equal to one if neither exporting country j nor importing country i belong to the GATT/WTO, and zero otherwise.[47]

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[46] As described in the data section, quantity and value are set to missing for the top and bottom 2% of the price distribution, so that all analysis involving these variables exclude these observations. Baseline results are robust to winsorizing observations by 2%, instead of truncating.

[47] For all cartels except Vitamin B4, a 1 on the non-WTO dummy perfectly predicts failure to trade and therefore this variable is dropped from the analysis.

10. *WTO*: binary variable equal to one if both countries belong to the GATT/WTO, and zero otherwise.
11. *GDP:* log of the product of GDP of importer and exporter countries measured in constant 2000 US dollars.
12. *GDPPC:* log of the product of per capita GDP of the importer and exporter countries measured in constant 2000 US dollars.
13. *Common Language:* dummy variable indicating that a single language is spoken by at least 9% of the population in both countries.
14. *Area*: log product of the areas of importer and exporter (in sq. km).

Excluded variables (i.e., included in the first stage propensity to trade regressions but excluded from the second stage gravity regressions):

15. *Entry days*: binary indicator equal to one if the sum of the number of days and procedures to form a business is above the median for both the importing country *i* and exporting country *j*.
16. *Entry costs:* binary indicator equal to one if the relative cost (as percent of GDP per capita) of forming a business is above the median in the exporting country *j* and the importing country *i*, and zero otherwise.
17. *Religion*: (% Protestants in country *i* * % Protestants in country *j*) + (% Catholics in country *i* * % Catholics in country *j*) + (% Muslims in country *i* * % Muslims in country *j*).

D3. Standardized country definitions for those that merged or divided during sample period

Region	Classified as	Comment
Belgium-Luxembourg	Belgium	Post-1998, data are from Belgium only. Since Luxembourg is small and we have no reported trade for Luxembourg post-1998, we reclassify Belgium-Luxembourg as Belgium.
Fmr Dem. Rep. of Germany Fmr Fed. Rep. of Germany	Germany	FRG and DRG are reported separately pre-1991. Post-1991 data are aggregated. We aggregate pre-1991 years for consistency.
Slovakia Czech Republic	Czechoslovakia	Pre-1992 data are reported as Czechoslovakia. We consolidate post-1992 Slovakia and Czech Republic data for consistency.
Serbia Montenegro	Serbia and Montenegro	We aggregate post-2004 data for consistency.

Appendix: Additional Robustness Results

Table A.1: Price

	Standardized Log FOB Price		Standardized Log Price Cartel Home Countries only	
	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE
	1a	1b	2a	2b
Citric Acid	0.037	-0.113**	-0.140*	-0.243**
	(0.282)	(0.005)	(0.030)	(0.000)
Methionine	-0.354**	-0.36**	-0.494**	-0.55**
	(0.000)	(0.000)	(0.000)	(0.000)
MCAA	-0.209**	-0.216**	-0.231**	-0.219**
	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin A	-0.318**	-0.333**	-0.389*	-0.313
	(0.000)	(0.000)	(0.031)	(0.066)
Vitamin B3	-0.290**	-0.447**	-0.469**	-0.844**
	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin B4	-0.209**	-0.188**	-0.221**	-0.177**
	(0.003)	(0.000)	(0.000)	(0.000)
Vitamin E	-0.775**	-0.947**	-0.966**	-1.072**
	(0.000)	(0.000)	(0.000)	(0.000)
Pooled meta-analysis	-0.282**	-0.318**	-0.42**	-0.485**
	(0.000)	(0.000)	(0.000)	(0.000)

Notes: The numbers of observations for the seven cartels in order for column 3 (4) are 5732(5822), 4274 (4307), 2549 (2576), 4490 (4527), 3847 (3876), 3731 (3767) and 4888 (4938). The dependent variable (log price) is standardized, i.e., demeaned and divided by the standard deviation. In columns 1a-b, the sample uses reported export values and quantities to define price. In columns 2a-b, only imports from cartel home countries are included in the sample. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table A.2: Concentration (HHI): Alternative sub-samples and measures

	Europe only		Balanced panel		Excluding cartel home countries		Cartel home countries only		Exports	
	Short-run effect	Long-run effect	Short-run effect	Long-run effect	Short-run effect	Long-run effect	Short-run effect	Long-run effect	Short-run effect	Long-run effect
	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Citric Acid	-0.047	0.009	-0.046	0.035	-0.037	0.041	-0.171	-0.018	-0.448**	-0.62**
	(0.463)	(0.921)	(0.491)	(0.655)	(0.686)	(0.648)	(0.162)	(0.868)	(0.000)	(0.000)
Methionine	-0.039	-0.082	-0.144	-0.124	-0.144	-0.114	-0.116	-0.14	0.405*	0.354
	(0.528)	(0.334)	(0.172)	(0.350)	(0.262)	(0.474)	(0.425)	(0.500)	(0.023)	(0.061)
MCAA	-0.016	0.100	-0.013	0.0000	-0.038	-0.052	0.058	0.038	0.106	0.599**
	(0.892)	(0.159)	(0.863)	(0.999)	(0.624)	(0.405)	(0.421)	(0.599)	(0.677)	(0.000)
Vitamin A	-0.085	-0.261	-0.143	-0.272	-0.14	-0.215	-0.206	-0.435*	-0.674	-0.94
	(0.051)	(0.270)	(0.206)	(0.046)	(0.311)	(0.102)	(0.175)	(0.032)	(0.348)	(0.160)
Vitamin B3	-0.099	-0.013	-0.140	-0.088	-0.198**	-0.124	-0.146	-0.097	0.097	-0.01
	(0.530)	(0.919)	(0.106)	(0.246)	(0.005)	(0.103)	(0.054)	(0.391)	(0.741)	(0.964)
Vitamin B4	-0.035	-0.375	-0.019	-0.06	0.023	-0.141	-0.009	-0.152	-0.41	-0.468
	(0.587)	(0.128)	(0.674)	(0.729)	(0.731)	(0.504)	(0.878)	(0.607)	(0.064)	(0.064)
Vitamin E	-0.154	-0.053	-0.173	-0.208*	-0.188	-0.242*	-0.317*	-0.340**	-0.121	0.108
	(0.050)	(0.604)	(0.050)	(0.016)	(0.082)	(0.018)	(0.015)	(0.008)	(0.441)	(0.766)
Pooled meta-analysis	-0.064	-0.075	-0.119	-0.117	-0.107	-0.110*	-0.173	-0.177	-0.168	-0.143
	(0.536)	(0.461)	(0.052)	(0.059)	(0.090)	(0.031)	(0.056)	(0.065)	(0.099)	(0.253)

Notes: The numbers of observations in order for the seven cartels in column 1 (2) are 196 (687), 242 (751), 209 (602), 239 (742), 229 (604), 220 (654), 246 (702). The numbers for columns 3 (4) are 656 (614), 742 (673), 588 (480), 725 (647), 583 (552), 633 (576), 696 (638). The numbers of observations for column 5 are 690, 766, 612, 749, 607, 672 and 728. For columns 1-4, the dependent variable is importer country HHI. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table A.3: Distance coefficient in HMR gravity estimates: Alternative sub-samples

	Europe only		Balanced panel		Cartel home countries only	
	Short-run effect	Long-run effect	Short-run effect	Long-run effect	Short-run effect	Long-run effect
	SPOST	LPOST	SPOST	LPOST	SPOST	LPOST
	1a	1b	2a	2b	3a	3b
Citric Acid	-0.235*	-0.228*	0.046	0.032	0.039	0.021
	(0.037)	(0.042)	(0.230)	(0.455)	(0.497)	(0.751)
Methionine	-0.021	0.007	0.019	-0.009	0.010	-0.247
	(0.614)	(0.874)	(0.500)	(0.769)	(0.878)	(0.028)
MCAA	-0.236*	-0.026	-0.053	-0.048	-0.155	0.291
	(0.023)	(0.841)	(0.302)	(0.674)	(0.617)	(0.004)
Vitamin A	0.040	-0.076	-0.027	-0.032	-0.093	-0.003
	(0.617)	(0.667)	(0.473)	(0.585)	(0.739)	(0.984)
Vitamin B3	-0.002	0.046	0.036	-0.009	0.088	-0.19
	(0.973)	(0.631)	(0.353)	(0.820)	(0.245)	(0.209)
Vitamin B4	-0.087	-0.024	0.05	0.043	0.130	-0.07
	(0.147)	(0.792)	(0.297)	(0.406)	(0.259)	(0.541)
Vitamin E	-0.005	0.035	0.03	-0.013	0.200	-0.033
	(0.951)	(0.560)	(0.355)	(0.666)	(0.183)	(0.710)
Pooled meta-analysis	-0.091*	-0.050	0.047	0.045	0.075*	0.097*
	(0.023)	(0.218)	(0.081)	(0.067)	(0.030)	(0.014)

Notes: The numbers of observations for the seven cartels in order for columns 1 (2) [3] are 1049 (3280) [1114], 737 (2558) [743], 461 (1394) [392], 742 (2769) [943], 675 (2132) [680], 723 (2237) [1022], 936 (2940) [1129]. The dependent variable in the gravity equation is log trade value. All specifications include exporter-product and importer-product fixed effects, year dummies interacted with distance, and correction for zero-trades based on Helpman et al (2008). Other controls are discussed in the text and data appendix. First stage Probit estimates available on request. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table A.4: Difference-in-differences estimates, price and concentration, cartel home countries

		Enzymes		Organic chemicals nes	
		Log price	HHI	Log price	HHI
		1	2	3	4
Citric Acid	Short-run	-0.061	-0.480	-0.165	0.078
		(0.575)	(0.094)	(0.236)	(0.739)
	Long-run	-0.139	-0.406	-0.331**	0.054
		(0.191)	(0.210)	(0.004)	(0.743)
Methionine	Short-run	-0.646**	-0.013	-0.574**	0.619**
		(0.000)	(0.919)	(0.003)	(0.008)
	Long-run	-0.715**	-0.243	-0.607**	0.468*
		(0.000)	(0.229)	(0.000)	(0.035)
MCAA	Short-run	-0.36**	0.044	-0.179	0.105
		(0.008)	(0.732)	(0.348)	(0.264)
	Long-run	-0.406**	-0.42	-0.147	0.170
		(0.002)	(0.043)	(0.392)	(0.234)
Vitamin A	Short-run	-0.560*	-0.021	-0.483	0.176
		(0.017)	(0.892)	(0.052)	(0.610)
	Long-run	-0.449*	0.040	-0.303	-0.394*
		(0.042)	(0.887)	(0.191)	(0.045)
Vitamin B3	Short-run	-0.534**	-0.131	-0.629**	0.075
		(0.000)	(0.591)	(0.000)	(0.606)
	Long-run	-0.917**	-0.269	-0.852**	0.164
		(0.000)	(0.364)	(0.000)	(0.227)
Vitamin B4	Short-run	-0.341**	0.16	-0.367**	0.388
		(0.002)	(0.355)	(0.003)	(0.200)
	Long-run	-0.239*	-0.355	-0.177	0.398
		(0.016)	(0.166)	(0.214)	(0.153)
Vitamin E	Short-run	-1.1**	-0.15	-1.045**	0.149
		(0.000)	(0.469)	(0.000)	(0.443)
	Long-run	-1.208**	-0.285	-1.085**	0.032
		(0.000)	(0.153)	(0.000)	(0.880)

Pooled meta-analysis	Short-run	-0.502**	-0.078	-0.477**	0.237
		(0.000)	(0.316)	(0.000)	(0.011)
	Long-run	-0.562**	-0.279**	-0.478**	0.138
		(0.000)	(0.005)	(0.000)	(0.123)

Notes: The numbers of observations in order for the seven cartels in column 1, (2), [3], and {4} are 3812, (1357), [3252], {1328}; 3389, (1717), [2944], {1674}; 2898, (1566), [2410], {1521}; 3543, (1701), [3058], {1657}; 3044, (1522), [2707], {1494}; 4299, (1587), [3615], {1559}; 4276, (1680), [3625], {1637}. The regressions are same as in Tables 9, except that the sample is restricted to include imports from cartel home countries only. The log price regressions in columns 1 and 3 include importer-exporter-product fixed effects and year effects, and are weighted by trade quantity. The HHI regressions in columns 2 and 4 include importer-product fixed effects and year effects and are weighted by total annual import quantity. In the meta-analysis: the price regressions include trade pair-product-treatment and product-year fixed effects, where treatment is a dummy equal to one for cartel products and 0 for the control product; the HHI regressions include importer-product-treatment and product-year fixed effects**.** P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.

Table A.5: Difference-in-differences estimates, distance coefficient in HMR gravity estimates, cartel home country imports

		Enzymes	Organic chemicals nes
		1	2
Citric Acid	Short-run	-0.168*	-0.213**
		(0.013)	(0.000)
	Long-run	-0.165*	-0.201**
		(0.044)	(0.007)
Methionine	Short-run	-22.54	-0.588
		(0.146)	(0.174)
	Long-run	-19.959	-0.007
		(0.147)	(0.966)
MCAA	Short-run	0.182	0.074
		(0.268)	(0.532)
	Long-run	0.157	0.230
		(0.243)	(0.097)
Vitamin A	Short-run	0.070	0.071
		(0.406)	(0.350)
	Long-run	-0.039	0.064
		(0.736)	(0.415)
Vitamin B3	Short-run	0.114	0.100
		(0.339)	(0.249)
	Long-run	0.191	0.184
		(0.102)	(0.124)
Vitamin B4	Short-run	-0.356**	-0.221**
		(0.001)	(0.000)
	Long-run	-0.106	-0.024
		(0.086)	(0.723)
Vitamin E	Short-run	0.163	0.226
		(0.149)	(0.019)
	Long-run	0.105	0.137
		(0.310)	(0.097)
Pooled meta-analysis	Short-run	0.027	0.002
		(0.424)	(0.963)

	Long-run	0.019	0.008
		(0.691)	(0.861)

Notes: The numbers of observations in order for the seven cartels in column 1 (2) are 2560 (2273), 1141 (1325), 932 (1109), 1211 (1423), 1087 (1421), 2559 (2367), 1703 (1962).The regressions are same as in Table 11, columns 1-2, except that the sample is restricted to include imports from cartel home countries only. All specifications include exporter-product and importer-product fixed effects, year dummies interacted with distance, and correction for zero-trades based on Helpman et al (2008). First stage Probit estimates available on request. P-values are in parentheses, with significance at the 95% and 99% level, indicated by * and ** respectively.