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Collapse of International Cartels**

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Abstract

How do changes in competitive intensity affect trade patterns? Models of collusive arrangements in spatially separated markets generate testable predictions of the effects of collusion on price, trade patterns and concentration. We exploit a quasi-natural experiment associated with increased anti-trust enforcement activity over the last two decades to test these predictions. In particular, we analyze detailed trade data linked to descriptive information from seven international cartels which collapsed as a consequence of increased antitrust enforcement activity. Because antitrust activity is highly unlikely to affect spatial patterns of demand and supply (other than through its effect on the competitive environment), enforcement induced changes that are ideally suited to study the effect of competition on trade patterns. We confirm significant declines in prices following the breakup of these seven cartels. Contrary to conventional wisdom, and consistent with the more recent market-sharing oligopoly trade models, 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. Neither do we find evidence of significant changes in concentration or rearrangement of market shares. These results imply that cross-hauling is not uncommon under collusion, and hence that the existence of cross-hauling by itself does not provide evidence of the existence of effective competition.

JEL Codes: F12, F23, D43, D21

Keywords: Multimarket collusion, gravity, oligopoly, anti-trust policy

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1. Introduction

We exploit a recent change in antitrust enforcement to examine the impact of competition on trade. The increased 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 such cartels in recent years.¹ In this paper, we analyze data on seven international cartels that collapsed as a result of intervention by antitrust authorities. A key challenge for empirical analysis in industrial organization is finding suitably “exogenous” changes in competitive intensity. Because antitrust action is unlikely to directly affect the patterns of production or consumption of the cartelized products, the changes triggered by antitrust activity provide the type of exogenous shifts in competition ideal for testing the predictions of oligopoly models of 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 by a foreign rival. Pinto (1986) and Fung (1991) extend this model to a repeated game environment where collusion is possible. They show that a collusive Nash equilibrium is characterized by geographic specialization, enforced by a threat of Cournot reversion to the Brander-Krugman equilibrium. In contrast, Baake and Normann (2002), and Bond and Syropoulos (2008), show that colluding firms may prefer an arrangement where both firms participate in both geographic markets (market sharing) in the collusive phase rather than specialize geographically. In this model the benefit to defection is lower, and therefore the cartel is more stable with market sharing than in the equilibrium with geographic specialization.

Following the collapse of a cartel, the Pinto/Fung models imply a significant change in trade patterns from geographic specialization to invasion of rivals’ markets. The end of a cartel will be associated with a decline in the effect of distance on trade. There will also be a significant decline in concentration as formerly forbearing cartel members enter one another’s

¹ See Evenett, Levenstein and Suslow (2001) and Levenstein and Suslow (2006) for an overview of international cartel prosecutions. Hummels, Lugovskyy and Skiba (2007) examine the effect of shipping cartels on trade; Asker (2010) studies effects of collapse of the Parcel Tanker Shipping cartel on shipping patterns.

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.

markets. On the other hand, the “market sharing” Baake-Normann/Bond-Syropoulos models imply little to no effect from cartel collapse on trade patterns or concentration as cross-hauling is observed both before and after cartel breakup. (See Table 1 for a summary of predictions of these models.)

To test the contrasting predictions of these models, we examine changes in trade patterns in products affected by seven commodity chemical cartels (listed in Table 2). In each case, the cartel includes six or fewer member firms, predominantly from the United States and Western Europe. Our selection of these cartels is based on three criteria. First, the cartel must have collapsed because of antitrust intervention. Second, there must be a close match between the product affected by collusive behavior and the trade data. Third, we must have a reliable measure of the date of cartel breakup.

In order to assure that these cartels were indeed sufficiently effective to have affected trade patterns, we first verify that they were successful in raising prices. Both market sharing and geographic specialization models imply higher prices under collusion. 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. We find significant declines in prices following the breakup of each of the cartels selected for analysis (see Figure 1).³

The primary contribution of this paper is to examine the effect of cartel breakup on estimates of the gravity equation.⁴ While we are motivated by the contrasting implications of

³ As illustrated in Figure 1, prices decline between 10.3 and 55.1 per cent (0.108 log points to 0.800 log points) within 2 years after cartel breakup, relative to one year before cartel breakup. Vitamin A’s price pattern appears to differ from the others as price begins to decline prior to cartel breakup (in 1999). This reflects intervention by FBI agents in March 1997. Connor (2007) reports “In response the cartels reduced the frequency of their meetings. The last tripartite meeting of the vitamins A and E cartel took place in Basel in November 1997. Thereafter, the conspirators would meet only bilaterally....On December 22, 1997 Rhone-Poulenc announced to the other members of the cartels that it had decided to quit the conspiracy. This announcement was a sham as the company continued to meet with Roche and BASF for another year.” (p. 286). For a more general discussion of the effect of cartels on prices, see Levenstein and Suslow (2006) and Connor & Bolotova (2006).

⁴ Other papers have examined the effect of particular factors on the distance coefficient (e.g. Freund and Weinhold (2004) on the effect of the internet). In related work, researchers have examined changes in the coefficient on distance over time (e.g. Berthelton 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.

the two sets of models for the effect of distance on trade, our focus on the gravity equation follows a rich tradition in the literature; notable examples include Rose (2000) for the effects of currency unions and Rose (2004) for the effect of WTO on trade. In our baseline specification, we use the selection and heterogeneity corrected specification recently proposed by Helpman, Melitz and Rubinstein (2008). In general, our results are consistent with market sharing models of collusion in that we find no significant change in the coefficient on distance in our gravity estimates.

We also test for changes in concentration following cartel breakup. We consider several measures of concentration, including the number of countries from which a country imports and the Herfindahl-Hirschman Index (HHI) of importers in a national market. Again, consistent with market sharing models, we find little evidence for significant changes in concentration. Thus the decline in concentration predicted by geographic specialization models is not evident in the data for these cartels.

These results survive numerous robustness tests. The estimated price declines associated with cartel breakup remain when controlling for changes in transport costs and the identity of countries in the sample. We control for other contemporaneous changes affecting other products which are not known to have cartels. In particular, we find no systematic evidence for difference-in-difference changes in the gravity distance coefficient or concentration between cartelized and non-cartelized products. The gravity equation results are robust to using bilateral trade-pair fixed effects (as advocated by Cheng and Wall 2005), to using the Poisson pseudo-maximum-likelihood (PPML) estimator proposed by Silva and Tenreyo (2006), to using measures of export and import market shares as dependent variables, and to using alternative sub-samples of the data. The concentration results are robust to using alternative measures of concentration, to using measures of market share instability (Caves and Porter 1978), and to using alternative sub-samples of the data. Finally, we examine a potential alternative explanation of our results -- the Bertrand competition model proposed by Gross and Holahan (2003). Both before and after cartels collapse, we find significant evidence for cross-hauling. We also find that levels of market concentration do not vary systematically with distance from a cartel country. This suggests that trade patterns for these products were more consistent with the Cournot models of Baake-Normann/Bond-Syropoulos than Gross and Holahan's Bertrand model.

2. Theoretical motivation

Alternative models of trade in imperfectly competitive markets differ in their predictions of the relationship between collusion and geographic specialization. Brander and Krugman (1983) show that in a one-shot static game, duopolists engage in “reciprocal dumping,” resulting in trade in identical goods (intra-industry trade).⁵ Pinto (1986) extends their model to a repeated game setting, showing that under fairly general conditions a repeated game collusive equilibrium exists in which there is no trade: each firm stays focused on its home (or nearby) markets. Fung (1991) obtains a similar “no-trade” result under collusion in the case of non-differentiated products. In Fung’s model, trade arises under collusion only in the case of differentiated goods.

These early extensions of Brander and Krugman suggest that we should observe “geographic specialization” under a collusive equilibrium and a shift to “market sharing” after cartel collapse. This has stark implications for country-level import concentration measures: markets are expected to be highly concentrated in the collusive regime. Concentration will fall as rivals invade each others’ territories in the non-collusive regime. The key intuition is that with positive transportation costs, the cartel optimizes on costs by assigning markets to firms that are geographically proximate. The negative effect of distance on trade should therefore be stronger during collusion relative to the non-collusive period.

The Pinto and Fung models imply that intra-industry trade in a homogeneous good is evidence of competition, as intra-industry trade does not occur in these models under collusion. More recently, Baake and Normann (2002) and Bond and Syropoulos (2008) have argued that there are strong incentives for firms to deviate in the “no trade” collusive equilibrium. They show that if firms are not sufficiently patient, the joint-profit maximizing “geographic specialization” equilibrium cannot be sustained. However, there exists a cooperative equilibrium with “market sharing” that yields profits higher than the static Brander-Krugman Cournot equilibrium. While collusive profits in the market-sharing equilibrium are lower than under geographic specialization, the defection profits are reduced by even more. Thus, by agreeing to share markets rather than specialize exclusively in home and nearby markets, firms reduce the incentive to deviate and can sustain collusion. A switch from a collusive equilibrium to a competitive one will not necessarily reduce concentration significantly; cartel members may

⁵ The Brander-Krugman model in turn drew upon Smithies’s (1942) model of basing-point pricing.

agree to share multiple markets and then, after the cartel breakup, compete in those same markets (i.e., in a Brander and Krugman equilibrium). The lack of geographic specialization under collusion implies that there is little effect of the breakup on the relationship between distance and trade.

In the next section we present a formal symmetric, two-country model based on Bond and Syropoulos (2008), and show how the results are likely to be applicable in more general multi-country contexts.

2.1. A repeated-game oligopoly trade model

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. Trade cost per unit exported is t (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:

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

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/j subscript for brevity.) In particular, as long as trade costs are not prohibitive (i.e., $t \leq \frac{A}{2}$), the symmetric non-collusive Nash equilibrium strategies (q, x) are $q = (A+t)/3$ and $x = (A-2t)/3$. This yields non-collusive profit, Π^N :

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

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

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

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

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

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 iff:

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

where δ is the discount factor.

Figure 2 depicts change in the collusive equilibria with variation in transport costs and the discount rate. As in Pinto/Fung, when the discount factor is above a threshold ($\delta > \underline{\delta}$, i.e., the players are sufficiently patient) firms can sustain a collusive equilibrium with maximal geographic specialization.⁶ Bond and Syropoulos (2008) show that the geographic specialization equilibrium obtains when transportation costs are above a certain threshold, corresponding to Region A in Figure 2.⁷ 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, the sustainable collusive outcome involves market sharing.⁸ An equilibrium involving cross-hauling yields the same collusive profits, but is less susceptible to deviation than one involving maximal geographic specialization. Thus, even in a range of discount factors where maximal geographic specialization 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 (2). Intuitively, 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 ($\Pi^D(A/4, A/4, 0) = 9A^2/32$) are lower than the deviation profits with maximal geographic specialization ($\Pi^D(A/2, 0, 0) = 10A^2/32$), due to the strict convexity of the deviation payoffs. Thus there is less incentive to deviate and higher collusive profits can be

⁶ See Bond and Syropoulos (2008) for proof. They also generalize the results to the case of multiple firms in a country and consider the impact on welfare of changes in tariffs and transportation costs.

⁷ 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 $x^* \in \left[0, \frac{A}{2}\right]$.

⁸ 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.

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. $t \leq \frac{A}{2}$), the symmetric non-cooperative Nash equilibrium is:

- (i) output levels: $q=(A+2t)/4$ and $x=(A-2t)/4$
- (ii) aggregate profit: $\Pi^N = \frac{3A^2 - 4At + 12t^2}{16}$

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

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

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

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

Here too we get deviation profits that 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 iff:

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

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 maximal geographic specialization 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, and therefore the key predictions of the Bond-Syroupolos and Baake-Normann models hold.⁹

⁹To extend the model to the case of N countries, assume they are located symmetrically around a circle (in a variant of Salop's (1979) model). It is then not surprising that the results extend in a fairly straightforward manner to a multi-country context. The circular model is stylized relative to the actual

To summarize, in the empirical analysis we investigate the following broad theoretical predictions: (a) an earlier generation of geographic specialization models predicts that exporters serve geographically proximate markets under collusion and invade distant markets in the non-collusive phase; and (b) a later generation of geographic specialization models predict that exporters may sell to distant markets under market sharing arrangements in the collusive phase, and therefore the shift to non-collusive competition may not result in significant changes in the extent of cross-hauling and accordingly not affect trade patterns significantly.

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). This has led to a rash of prosecutions, which we use as the basis for the data in this paper.¹⁰

We collect data on cartel membership, start and end dates, and detailed product descriptions for individual cartels, and then use the product descriptions to link cartel-specific information to import and export data. To test the hypotheses above regarding the impact of a shift from collusion to competition, we examine seven international cartels that ended as a result of antitrust intervention (Table 2). Even though the presence of a cartel is endogenous, the shift from collusion to competition was a result of a policy change driven by exogenous events. Most of the cartel members in this sample were large, multinational, multiproduct firms. In most cases, cartels included members from Europe, North America, and Asia, and

data where countries are asymmetrically located around the globe. However, one could collapse all markets close to a single cartel member country, classify them as the “home market” for that country. Locate the “home country” on a circle placing it adjacent to its closest neighboring cartel countries. While the resulting representation may not be symmetric, the key intuition in the market-sharing models continues to hold.

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), without affecting the key predictions. Again, assuming symmetry (i.e. 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 . In the empirical section, we test the robustness of our results by examining data on imports from cartel headquarters countries only.

¹⁰ See Levenstein and Suslow (2011) for detailed descriptions of the immediate events surrounding the dissolution of each of these cartels as well as analysis of the economic determinants of cartel breakup.

cartel agreements covered global markets. These agreements targeted chemicals and food additives. As relatively homogenous goods, they are appropriate for testing the models discussed above.

These seven cartels were also selected because their products are a close match to the level of aggregation in the trade data in the UN Comtrade database.¹¹ These data are bilateral (i.e., reported for country pairs), annual, and disaggregated by product. The most detailed reliable data are disaggregated at the 6-digit Harmonized System (HS) level (see Table 2 for specific HS codes). We select cartels whose product unambiguously matches the HS classification.¹² For example, the detailed description for HS 291814 is “Citric Acid,” corresponding exactly to the cartel’s targeted product. Although over one hundred international cartels have been prosecuted in the last two decades, for the vast majority 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.¹³

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 fact, 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.¹⁴

We generally observe that the number of reporting countries in the COMTRADE database increases over time. This may reflect genuine increases in trade; it may also reflect improvement in data collection, either by the UN or by reporting countries. There are also

¹¹ Available at <http://comtrade.un.org/db/default.aspx>.

¹² 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/hscodcfm>).

¹³ 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 want to focus here on competition 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. Given the endogeneity issues, they were not included in the final study.

¹⁴ 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).

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 weight as larger countries. Hence throughout the analysis, we weight observations by trade quantity.¹⁵

Finally, we select these seven cartels because the data reflect a significant change in the price of the product at the time of the cartel's demise. For each cartel, we use a nine year panel covering four years before and four years after the cartel breakup. We treat the four year period prior to breakup as "the collusive period." In some cases, the cartel formed earlier, but these four years are most comparable in all other respects to the four years after cartel breakup. We exclude the reported breakup year in most specifications because the year of the reported breakup may include both periods of collusion and non-collusion.

We define price as the ratio of trade value to trade quantity for each specific product. We calculate the average price for each product, for each year, for each bilateral trade pair.¹⁶ Table 3 shows pre and post break up summary statistics for price and concentration for each cartel. Comparing the average price from the cartel period to the average price after cartel breakup, we find a significant decline in mean log price. These declines vary from about 7.32% (0.076 log points) in the case of Citric Acid to decline of 58.02% (0.868 log points) for Vitamin E.¹⁷ As discussed above, this indicates that, for these products, there was a real change in the intensity of competition at the time of the observed cartel dissolution.¹⁸

¹⁵ When the dependent variable of interest is the price level, it is appealing to use trade quantity as the weighting variable. For example, suppose the bulk of country A's imports is 10,000 kg from country X at a value of \$30,000. Suppose for some special reason, country A imports a small quantity of 50 kg from country Y at a value of \$1000. Then the un-weighted mean price of imports into country A is $(3+20)/2 = \$11.5/\text{kg}$. The trade-weighted mean price is $(10,000*3 + 50*20)/10050 = \$3.08/\text{kg}$, and hence is a much 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 test robustness using trade value weights and find results are generally very similar.

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). That is, where the implied price lies in the tail of the distribution (2.0% on either tail), we treat the observation as missing.

¹⁷ A decline of 0.076 log points means $\log(P_{\text{post}}) - \log(P_{\text{pre}}) = -0.076$, which translates to a percentage decline in price (defined as $[(P_{\text{post}} - P_{\text{pre}})/P_{\text{pre}}]$) 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 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

We define import concentration as the *Herfindahl-Hirschman Index* (HHI) of annual import market shares of each product into a country (Table 3). This is defined as 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 . We are interested in measuring the number of competitors in each market. Our proxy is the number of trade partners, N_{jkt} (Table 3). 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.¹⁹ Mean HHI for these markets ranges from 2760 to 4290 (Table 3).²⁰ The U.S. Department of Justice’s merger guidelines set an HHI of 2500 as the threshold for “highly concentrated” markets.²¹ Not surprisingly, these are highly concentrated industries.

For each of these products, the mean number of trade partners (between nine and fifteen) is larger than the number of members of the cartel (between three and five). 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. Thus reported measures of import concentration are lower than what would be calculated based on *firm* market shares, as a single firm may export into a market from multiple countries. On the other hand, *import* concentration ignores domestic production and therefore overstates concentration. As our analysis will examine the *change* in concentration, our measure should be able to capture any impact of a change in competitive intensity on concentration.

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 trade data for these cartels are not appropriate for testing the models discussed above.

¹⁹ More detailed definitions of the variables used in the analysis are given in the Data Appendix.

²⁰ Note that HHI in Table 3 are expressed on a zero to one scale. In most policy documents, including the U.S. Department of Justice merger guidelines, HHI is expressed on a zero to 10,000 scale.

²¹ See <http://www.justice.gov/atr/public/guidelines/hmg-2010.html> for the U.S. Department of Justice merger guidelines.

4. Empirical specifications and baseline results

4.1. Price results

To begin our empirical analysis we examine the robustness of the price changes described above to controls for other determinants of trade between specific country pairs. We also distinguish the long and short run impacts of cartel breakup on price. For example, if price adjusts slowly in response to a change in competitive intensity, it may be that the immediate impact will be small, but will grow over time. It is also possible that the breakup causes intense competition in its immediate aftermath, but that, over time, tacit collusion re-emerges in these highly concentrated industries.²²

In order to estimate the short-run and long-run changes in log price following the cartel breakup (relative to the mean collusive price level), 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 (or log price), D_{SPOST} is a dummy for the short-run post-breakup period (defined as years 1 and 2 after the cartel breakup), D_{LPOST} is a dummy for the long-run post-breakup period (defined as years 3 and 4 after the cartel breakup), f_{ij} denotes importer-exporter pair fixed effects and ϵ_{ijt} denotes the error term.²³ (The subscript i denotes exporting country, j denotes importing country and t denotes year.) As discussed above, because the cartel could have broken up at any time during the year, we exclude data for the breakup year 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.

²² See Alexander (1994) for a discussion of how an episode of explicit cooperation facilitates future tacit collusion.

²³ One significant advantage of using trade panel data is that we can control for a number of country-specific and bilateral 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.

We find significant decline in price for all of these cartels, both in the short and long run (Table 4).²⁴ The short run declines in price vary from 0.045 log points (4.40%) for Citric Acid to as high as 0.797 log points (54.93%) for Vitamin E. The long run declines are generally larger, ranging from 0.142 log points (13.24%) for Citric Acid to 0.915 log points (59.95%) 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, at least for these seven cartels, had a sustained impact on market outcomes.

We also consider the possibility that a cartel had become less effective immediately prior to its breakup, and that the changes documented in Table 4 reflect a prior trend of price decline. 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 all terms are defined as above, and 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. With the inclusion of D_{SPRE} , all the coefficients capture differences in means relative to the long-run pre-breakup period (years $t-4$ and $t-3$). While in some cases there was a statistically significant decline prior to cartel breakup (column 1 of Table 5), in all cases prices fall even more after breakup (i.e., $\alpha_{SPOST} - \alpha_{SPRE}$, column 2 of Table 5, is negative). For a full set of results from specification (8b), see Appendix Table A.7; also, Figure 1 and Appendix Figure A.1 confirms that sharp declines in price occur around the time of breakup of the cartels.

4.2. Impact on trade patterns

Having established that these seven markets underwent a demonstrable change in competitive intensity, we now examine the effect of this change on trade patterns. As discussed in Section 2, the geographic specialization models predict a sharp decline in the effect of distance on trade following cartel collapse. In these models, firms focus on their home and nearby markets under collusion, but venture further into competitors' territories under the non-collusive regime.²⁵ In contrast, the market sharing models predict less rearrangement, as there can be market sharing even under the collusive regime.

²⁴ We obtain similar results using price levels rather than log prices.

²⁵ The models are framed in the context of a "home" market and a foreign "market." In the context of our trade data where we are looking at export patterns, the "home country" can be thought of as a proxy for

We first let the data speak for itself, calculating the distance travelled by each cartelized product, weighted by the relative value of imports between different countries, defined as follows:

$$\delta_{kt} = \sum_i \sum_j \frac{d_{ij} r_{ijkt}}{R_{ikt}}$$

where $R_{ikt} = \sum_j r_{ijkt}$, r_{ijkt} is the value of imports of product k into importer country i from exporter country j , and d_{ij} is the distance between country i and country j . For example, $\delta_{\text{Citric Acid}, t}$ = average number of miles traveled by one dollar's worth of citric acid imports. Figure 3 shows the variation over time in distance travelled for each product. While the graphical presentation of $\delta_{k,t}$ suggests an increase in distance travelled, there is no statistically significant break in trend around the collapse of most of the cartels (unlike the stark breaks that occurred in price).

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

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

where m_{ijt} is the log of the value of imports from country i into country j in year t , d_{ij} is the log of the bilateral distance,²⁶ D_{SPRE} , D_{SPOST} and D_{LPOST} are defined as above, X_{ijt} is a vector of bilateral controls, f_i and f_j denote importer and exporter fixed effects, f_t denotes year effects and ϵ_{ijt} is the residual error term.²⁷

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

Following HMR, we use the following selection equation:

$$P(D_{ijt} = 1 | \text{observed variables}) = \Phi(\alpha_d d_{ij} + \alpha_{SPRE} D_{SPRE} d_{ij} + \alpha_{SPOST} D_{SPOST} d_{ij} + \alpha_{LPOST} D_{LPOST} d_{ij} + \beta H_{ijt} + f_i + f_j + f_t) \quad (9b)$$

where D_{ijt} is a dummy indicating non-zero exports from exporter j to importer i in year t , $\Phi(\cdot)$ is the cdf of the unit normal distribution, and H_{ijt} is a set of control variables (see Data Appendix

“geographically proximate markets” for the first (i.e. “home”) firm, and the “foreign country” is the set of markets that are geographically proximate to the other (i.e. “foreign”) firm.

²⁶ We define bilateral distance as the log bilateral population weighted distance (in km). See Data Appendix for detailed definitions of all variables.

²⁷ Following Cheng and Wall (2005), we check the robustness of our results to using bilateral trade-pair fixed effects in Section 5.

for details).²⁸ We allow the coefficient on distance in this propensity equation to vary by competitive regime, as we are interested in any change in the impact of distance on the probability of trade. In particular, if the change in competitive intensity induces a switch from geographic specialization to reciprocal dumping, we should see a weakening in the impact of distance on the trading partner selection, i.e. the magnitude of the negative coefficient on distance should be smaller in the post-breakup regime.

The HMR methodology modifies the specification in equation (9a) to include two terms to address bias from sample selection and unobserved firm heterogeneity, respectively:

$\ln\{\exp[\delta(\hat{z}_{ijt}^* + \hat{\eta}_{ijt}^*)] - 1\} + \beta_{un\eta} \hat{\eta}_{ijt}^*$, where $\hat{\eta}_{ijt}^* = \phi(\hat{z}_{ijt}^*) / \Phi(\hat{z}_{ijt}^*)$, $\hat{z}_{ijt}^* = \Phi^{-1}(\hat{\rho}_{ijt})$, and $\rho_{ijt} = P(D_{ijt} = 1 | W_{ijt})$. To control for the first term flexibly, we follow one of the approaches suggested by HMR and include a third degree polynomial in \hat{z}_{ijt}^* . Thus we obtain the following “sample-selection and unobserved heterogeneity corrected” gravity equation:

$$m_{ijt} = \alpha_d d_{ij} + \alpha_{SPRE} D_{SPRE} d_{ij} + \alpha_{SPOST} D_{SPOST} d_{ij} + \alpha_{LPOST} D_{LPOST} d_{ij} + \beta X_{ijt} + f_i + f_j + f_t + \beta \hat{\eta}_{ijt}^* + \sum_{k=1}^3 \gamma_k (\hat{z}_{ijt}^*)^k + \epsilon_{ijt} \quad (9c)$$

Estimating the distance coefficient interactions for the propensity specification (9b), we find little or no change in the effect of distance on the probability of trade, providing support for market sharing models of collusive behavior (Table 6). Columns 1a and 2a compare the short-run post-breakup period ($t+1$ and $t+2$) to the 2-year ($t-2$ and $t-1$) and 4-year ($t-4$ to $t-1$) pre-breakup periods respectively, while columns 1b and 2b compare the long-run post-breakup period ($t+3$ and $t+4$) to the 2-year and 4-year pre-breakup periods. For most of the cartels we find no significant changes in the coefficient on distance. Thus, the probit regressions provide no support for the geographic specialization models and are largely consistent with market sharing models.

Our HMR-corrected gravity estimates are also generally consistent with market sharing models (Table 7). We find no statistically significant changes in the distance coefficient for most

²⁸ 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).

of the cartels either relative to the 4-year pre-breakup period (columns 1a and 1b) or relative to the short-run 2-year pre-breakup period (columns 2a and 2b).²⁹

These propensity and gravity specification results provide strong evidence that collusive trade patterns in these markets are more consistent with the market-sharing model than with geographic specialization. Hence these results imply that international collusion cannot be ruled out by the observation of significant intra-product trade between countries, as pointed out by Baake and Normann (2002). Our results are robust to a number of robustness checks, discussed in Section 5 below.

4.3. Concentration results

We analyze two measures of concentration: import HHI and the number of trade partners. Our descriptive statistics suggest little or no change in concentration for most of these cartels (Table 3). The number of partners generally increases; this may, however, reflect overall increases in globalization.

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 partners) as the dependent variable:³⁰

²⁹ In Column 2a of Table 7, in the short-run post breakup relative to the short-run pre-breakup period, there is a significant increase in the distance coefficient (consistent with the Pinto/Fung models) for Citric Acid and Vitamin E, but these effects are not significant in the long-run (Column 2b). We also examine year-by-year changes around the breakup year in Figures 4 and 5. The specifications are the same as in equations (9b) and (9c) respectively, except that the distance variable is interacted with period dummies. The figures confirm the results in Table 6 and 7. In particular, in Figure 5, the one cartel with a steady decline in the coefficients on distance is Citric Acid, but this appears to be the result of a pre-existing trend. For none of the cartels do we observe a sharp increase in the coefficient on distance which we would expect if there were new entry into far-off rival markets as hypothesized in the market division models. In Figure 5, consistent with the results in Table 7, we find little evidence of significant changes in the coefficient on distance. Vitamin E shows an increase one year after the breakup year, but this increase reverses in the subsequent years. For two cartels – Citric Acid and Vitamin E – we find a significant strengthening of the negative effect of distance on the propensity to trade in the short run. For Vitamin E, these effects disappear in the longer term (columns 1b and 2b). For Citric Acid, the trend analysis (Figure 4) suggests that the significant negative effects result from a pre-existing trend, rather than a structural break induced by the cartel collapse. One explanation for the increase in the negative effect of distance in these cases could be that the higher prices maintained by the cartel in the collusive regime allowed some small fringe players to operate in distant markets, which they were no longer able to do after the collapse of the cartel.

³⁰ One difference from the earlier estimates is that observations here are importer-year specific, and accordingly, the fixed effects we use are importer effects. Also, to account for differing market sizes in different countries, regressions are weighted by import quantity.

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

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

We find no statistically significant changes in HHI for most cartels (Table 8, columns 1a through 2b). Neither is there a significant change in the number of partners for most of the cartels (Table 8, columns 3a through 4b). These results are confirmed in Figure 6, which captures year-to-year changes in HHI.

Once again, these results are generally more consistent with market sharing models of collusion, than with geographic specialization models that would predict a dramatic change in concentration following cartel breakup. These markets were highly concentrated prior to breakup. The persistence of this high concentration may reflect ongoing customer relationships or other barriers to entry established under collusion. This may reflect the nature of marketing costs and customer-supplier relationships in the products we study. All the products we study here are intermediate goods, involving business-to-business marketing. In many cases, both customers and producers are global firms. Cartel market division schemes that assign customers to firms preserve the reputational capital and client relationships built up by cartel member firms before the formation of the cartel and effectively reduce the marketing and transaction costs with specific clients in particular markets.³¹ These relationships are maintained during and after collusion.

5. Robustness checks

5.1. Controlling for contemporaneous shocks using a DID approach

One potential concern with the baseline results is that the changes observed in price may be driven by contemporaneous shocks coincident with the cartel breakup. Even the stability of the distance coefficient and concentration measures could reflect countervailing influences such that changes in the competitive environment are offset by other external shocks that were common across these products.

The availability of panel data allows us to address this concern using a difference-in-differences (DID) approach, comparing changes in the cartelized product to other comparable products with no known change in competitive intensity. In particular, we examine two

³¹ Arkolakis (2009) emphasizes the role of marketing costs in trade.

related products: (i) enzymes (not including rennet, HS 350790), which includes a number of enzymes used as additives in animal feed; and (ii) organic chemicals (not elsewhere specified, HS 294200), a residual category within the broad group of organic chemicals to which all of our cartelized products belong. The comparison to enzymes and other organic chemicals allows us to control (respectively) for exogenous changes in trading patterns affecting either animal additives or organic chemicals generally. To our knowledge, neither of these product categories was cartelized (or more importantly, neither had a change in status from cartelized to non-cartelized, or vice versa), and therefore serve as valid control groups. The DID analysis confirms our results (Table 9). In particular, we find that even relative to the control products, the cartelized products in almost all cases show large (and in most cases statistically significant) declines in price. We continue to find no systematic patterns for change in concentration or in the coefficient on distance.³²

5.2. Other Robustness Checks

We check our results using a number of additional robustness tests. In each case, we find the results are consistent with those above. The price decline results are robust to alternative specifications: (i) in order to eliminate the possibility that the results are driven by changes in transportation costs, we re-estimate the equations above using FOB prices;³³ (ii) in order to confirm the price effects indeed reflect behavior of cartel members, we reran our analysis using a sample of imports from countries where cartel members are headquartered (Appendix Table A.1).

³² The price coefficients are noisier, particularly relative to organic chemicals, which is not surprising as this control group is likely to have a number of different chemicals (but could still provide a good comparison group for concentration, as well as for trade patterns affecting all organic chemicals). While there are no significant DID changes in the concentration measures, there are some significant DID results for the distance coefficient, but they do not provide any systematic evidence in favor of the geographic specialization models. Coefficients are positive and significant for two cartels relative to organic chemicals, negative in some cases and positive for couple of others relative to enzymes.

³³ If transportation (insurance and freight) costs for all of these products fell around the time of the cartel breakup, this could explain the observed fall in prices (as the reported import (c.i.f) prices we use include transportation costs). To rule out this explanation, we examine data on reported export quantities and values, which are reported F.O.B (free on board), and hence do not include insurance and freight costs. 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. The results, summarized in columns 1a and 1b of Appendix Table A.1, show significant price declines for FOB prices and confirm that the baseline results in Table 4 and 5 are not driven by declines in transportation costs.

We find the gravity equation results robust to (i) using bilateral trade-pair fixed effects (as advocated by Cheng and Wall (2005, Appendix Table A.2, columns 1a and 1b));³⁴ (ii) using the Poisson pseudo-maximum-likelihood (PPML) estimator proposed by Silva and Tenreyo (2006, Appendix Table A.2, columns 2a and 2b);³⁵ and (iii) using measures of import and export market shares as dependent variables (Appendix Table A.2, columns 3a-3b and 4a-4b, respectively).³⁶ We reproduced the results for the gravity regressions for three different subsamples: (i) restricted to Europe to abstract from markets far from most cartel headquarters (Appendix Table A.3, columns 2a and 2b); (ii) a balanced panel to assure that our results are not driven by increases in trade data coverage over time (Table A.3, columns 3a and 3b); and (iii) restricting to imports from cartel headquarter countries to abstract from effects induced by non-cartel (or other production location) exports (Appendix Table A.3, columns 4a and 4b).³⁷

Finally, we find the concentration results robust to using alternative measures of concentration (Appendix Table A.4, columns 1 and 2).³⁸ We also examine measures of market share instability (Caves and Porter 1978) and find no significant increases in this measure either

³⁴ In the baseline regressions in Section 4.2, 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.

³⁵ The PMML estimator addresses both zero-trade and bias from heteroscedasticity in the log linear model. One motivation for our use of the Silva-Tenreyo estimator is that the HMR methodology 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 PMML 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-Tenreyo estimation.

³⁶ Under the geographic specialization model, we expect exporters to have higher shares in geographically proximate markets under collusion; thus, we should observe a weaker relationship between import market share (S_{ijkt} defined as the market share of export country i in the total value of imports of product k entering country j) and bilateral distance after breakup. For the same reason, if collusion involves geographic specialization, there should be a stronger negative relationship between export market share (X_{ijkt} defined as the share of the exports going to country j in the total value of exports of product k by exporter country i) and bilateral distance under collusion. Again, overall the results suggest little change in the pattern of trade; the relationship between import and export market shares and bilateral distance is not significantly affected, either in the short run or long run for most cartels. Note that these regressions include the zero-trade observations, and therefore, following Anderson and van Wincoop (2003), we include exporter-importer fixed effects.

³⁷ 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 check.

³⁸ We use the C4 ratio, defined as the sum of market shares of the top four importers in each market, as well as the HHI measure for export shares, defined for each exporter-year as the sum of the squared share of destination markets in total exports.

close to or after the cartel breakup (Appendix Table A.4, columns 3 and 4).³⁹ We examine and find the concentration (HHI) results robust in four different subsamples (see Appendix Table A.5): (i) restricted to Europe to abstract from markets far from most cartel headquarters; (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 concentration figures here are likely disproportionately upwardly biased because of unmeasured domestic output); and (iv) restricted to imports from cartel headquarter countries to abstract from effects induced by non-cartel (or other production location) exports (Appendix Table A.3, columns 4a and 4b).⁴⁰

5.3. An alternative explanation: geographic specialization and Bertrand competition

Our results are superficially consistent with models of geographic specialization during collusion, but in which competitive reversion takes the form of Bertrand competition. In this case, there is no cross-hauling during collusion or during competition, so there is no change in trade patterns after the breakup of the cartel. For example, Gross and Holahan (2003) show that, with positive transportation costs, Bertrand competition leads to geographic specialization. In this respect, their model is observationally equivalent to the market sharing models discussed above.

In order to distinguish these two alternative interpretations of our empirical results, we look for evidence of cross-hauling. We find that cartel home countries received imports, even from other cartel member home countries, during collusion. In Table 10 (columns 1 and 2) we examine the magnitude of imports into cartel home countries. We calculate imports as a fraction of total trade (imports plus exports). Under geographic specialization, we would expect these countries to import very little relative to what they export. We find that imports are instead a considerable fraction of trade, ranging from 18.3% for MCAA to 60% for Vitamin B3, during the collusive period (column 1a). There is also evidence for significant cross-hauling in the post-breakup period (column 1b). In column 2, we examine the share of imports into

³⁹ Under the geographic specialization model, we expect to see a rearrangement of consumer-supplier relations, and hence a spike in the instability of market shares, at least in the short run after the cartel breakup. On examining the year-to-year changes in the instability measures, we did not find evidence for this.

⁴⁰ For most cartels, there are no significant concentration changes in any of the subsamples; one exception is Vitamin E, for which we find some evidence for declines in concentration in most subsamples. Also, in unreported regressions, we looked at results excluding Chinese imports, and again found results similar to the baseline.

cartel home countries that come from other cartel member countries. Our analysis finds significant cross-hauling, even from other cartel countries, both before and after the cartel breakup. We find that other cartel home countries import large quantities from other cartel countries. For example, 91% of imports of Vitamin B3 into cartel countries came from cartel countries. This is more consistent with the Baake-Normann and Bond-Syropoulos Cournot models than the Gross-Holahan Bertrand model.

As an additional test to distinguish between these two types of models, we examine geographic variation in import concentration. If the Gross-Holahan model holds, we would expect to see a significantly higher concentration in markets adjacent to cartel home countries. We distinguish two samples: (i) countries bordering exactly one cartel home country; (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 10, columns 3a-4c). In fact, for most cartels, we find lower concentration in markets adjacent to cartel home countries.⁴¹ This, again, suggests that trade patterns are more consistent with the Cournot, market-sharing models than with the Gross-Holahan Bertrand model.

6. Discussion of results and conclusions

We examine the effect of changes in competitive intensity on trade patterns using data from seven international cartels prosecuted for explicit price fixing during the 1990s. Cartel collapses triggered by increased anti-trust enforcement activity provide a quasi-natural experiment to study the effects of changes in competitive intensity on a number of interesting outcomes. Each of the products of these cartels experienced striking declines in price levels after their collapse, strongly suggesting that there were indeed substantial and meaningful changes in the competitive environment. By focusing on cartel breakups caused by a change in policy and analyzing only trade in products where the data suggest the cartel was effective

⁴¹ These results could be affected by the fact that cartel firms have production facilities in countries other than their headquarters location. This means that 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 Column 3c are also evidence against the Pinto/Fung models geographic specialization models, as these suggest no significant targeting of geographically proximate markets in the pre-cartel collapse period.

before breakup and not after, this analysis can distinguish the impact of changes in competitive intensity on trade patterns from other contemporaneous changes.

We test models of collusive behavior in homogenous good markets with starkly different implications for the effect of cartel break-up on trade patterns and market concentration. Consistent with the market sharing models proposed in Baake and Normann (2002) and Bond and Syropoulos (2008), and contrary to conventional wisdom captured in the geographic specialization models of Pinto (1986) and Fung (1991), we find no significant changes in trading patterns or import concentration following the collapse of the cartels. Our results imply that cross-hauling is not uncommon under collusion, and hence that the existence of cross-hauling by itself does not provide evidence of the existence of effective competition. To the contrary, in several recent international cartel cases, cartel members purchased from one another across international borders in order to achieve cartel market share targets.⁴²

Our finding of the lack of change in trading patterns is similar in spirit to the finding of little change in market conduct following the collapse of the parcel tanker cartel in Asker (2010). However, in the case of the cartels we examine, we do find significant declines in price, so there appears to have been an impact on conduct (in the form of pricing if not of trade patterns) consequent to these cartel breakups.

In interpreting our results, one caveat to be borne in mind relates to the nature of the products we study. All of the products we look at are chemicals with relatively low transportation costs. As stressed by Bond and Syropoulos, the collusive outcome with market sharing is likely to be a Nash equilibrium outcome only if transport costs are sufficiently low. Thus, in the case of other products that have higher transportation costs, it is possible that the collusive outcome involves geographic specialization. Accordingly, our evidence against the latter models should be viewed in the context of the nature of the products we examine.⁴³

⁴² For example, the European Commission describes the 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.

⁴³ To further explore this issue, we did attempt to examine some cartelized products that potentially have higher transportation costs. Products we examined closely included 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 was available. Our analysis of the price trends using the closest

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available matches suggested the data problems were too severe to meaningfully examine these cartel products. With better data, future researchers may be able to focus on the role played by transportation costs in determining the collusive equilibrium, as emphasized by Bond and Syropoulos (2008).

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Table 1: Summary of trade and competition models

Model	Trade Pattern during Collusion	Trade pattern during Competition	Empirical Prediction associated with Increasing Intensity of Competition	
			Concentration	Impact of distance on trade
Brander & Krugman (1983)	NA	Market sharing	NA	NA
Pinto (1986)	Geographical specialization	Market sharing	Falls	Decreases
Fung (1991) (homogenous goods case)	Geographical specialization	Market sharing	Falls	Decreases
Baake and Normann (2002)	Market sharing	Market sharing	No change (or slight decrease)	No change (or slight decrease)
Bond and Syropoulos (2008)	Market sharing	Market sharing	No change (or slight decrease)	No change (or slight decrease)

Table 2: Cartel demographics

Product	HS code	Start year	End year	Duration (years)	Number member firms	Home country of member firms
Citric Acid	291814	1991	1995	5	5	Austria, Germany, France, Switzerland, US
Methionine*	293040	1986	1999	14	3	France, Germany, Japan
Monochloro-acetic Acid (MCAA)	291540	1984	1999	16	4	Netherlands, France, Germany
Vitamin A	293621	1989	1999	11	3	Germany, Switzerland, France
Vitamin B3 (Niacin)	293624	1992	1998	7	4	Germany, US, Switzerland
Vitamin B4 (Choline Chloride)	292310	1988	1998	11	6	Canada, US, Belgium, Netherlands, Germany
Vitamin E	293628	1989	1999	11	4	Germany, Switzerland, Japan, France

*For Methionine, we used data for SITC Revision 3 (code 51544), as this had the better coverage than HS 293040.

Table 3: Summary statistics: changes in price and concentration measures

	Log Price			HHI			Number of Trade Partners		
	Pre-breakup	Post-breakup	Diff (Post-Pre)	Pre-breakup	Post-breakup	Diff (Post-Pre)	Pre-breakup	Post-breakup	Diff (Post-Pre)
Citric Acid									
N	2,029	3,793		232	458		232	458	
Mean	0.241	0.165	-0.076	0.294	0.276	-0.018	15.497	14.972	-0.524
SD (p-value)	0.224	0.224	(0.000)	0.169	0.113	(0.380)	5.201	3.988	(0.616)
Methionine									
N	1,933	2,374		338	428		338	428	
Mean	1.074	0.784	-0.290	0.411	0.352	-0.059	9.286	9.765	0.479
SD (p-value)	0.227	0.193	(0.000)	0.171	0.141	(0.009)	3.239	3.242	(0.329)
MCAA									
N	1,206	1,370		280	332		280	332	
Mean	0.097	-0.216	-0.313	0.446	0.447	0.001	9.062	9.167	0.106
SD (p-value)	0.306	0.286	(0.000)	0.215	0.207	(0.981)	3.181	3.496	(0.883)
Vitamin A									
N	1,974	2,553		327	422		327	422	
Mean	3.208	2.913	-0.295	0.417	0.371	-0.045	11.576	11.939	0.363
SD (p-value)	0.850	0.639	(0.194)	0.210	0.166	(0.334)	3.850	3.670	(0.718)
Vitamin B3									
N	1,700	2,176		271	336		271	336	
Mean	2.720	2.356	-0.364	0.415	0.364	-0.051	11.095	11.881	0.786
SD (p-value)	0.354	0.383	(0.000)	0.191	0.159	(0.307)	3.163	2.617	(0.197)
Vitamin B4									
N	1,725	2,042		296	376		296	376	
Mean	-0.070	-0.304	-0.233	0.450	0.420	-0.029	10.246	10.303	0.057
SD (p-value)	0.361	0.382	(0.000)	0.222	0.212	(0.531)	3.074	3.511	(0.916)
Vitamin E									
N	2,096	2,842		317	411		317	411	
Mean	2.834	1.966	-0.868	0.367	0.323	-0.044	12.144	14.264	2.120
SD (p-value)	0.429	0.399	(0.000)	0.152	0.129	(0.099)	3.999	3.360	(0.006)

Notes: All means are un-weighted. p-values are in parenthesis.

Table 4: Short and long run price changes relative to 4-year pre-breakup period

	Short-run effect (SPOST)	Long-run effect (LPOST)
	1	2
Citric Acid	-0.045 (0.054)	-0.142 (0.000)
Methionine	-0.288 (0.000)	-0.323 (0.000)
MCAA	-0.311 (0.000)	-0.301 (0.000)
Vitamin A	-0.331 (0.030)	-0.272 (0.056)
Vitamin B3	-0.308 (0.000)	-0.463 (0.000)
Vitamin B4	-0.278 (0.000)	-0.223 (0.000)
Vitamin E	-0.797 (0.000)	-0.915 (0.000)

Notes: For each cartel that breaks up in year t , the sample includes data on eight years: $t-4$ to $t-1$, and $t+1$ to $t+4$ (i.e. break-up year t is excluded). SPOST refers to the short-run post-breakup period (years $t+1$ and $t+2$, for breakup year t). LPOST refers to the long-run post-breakup period (years $t+3$ and $t+4$). All regressions include importer-exporter (trade-pair) fixed effects. Observations are weighted by trade quantity. Robust (clustered by importer) p -values are in parentheses.

Table 5: Short run price changes controlling for pre-breakup effects

	Pre-breakup trend	Short term post-breakup relative to short-term pre- breakup
	SPRE-LPRE	SPOST-SPRE
	1	2
Citric Acid	0.088 (0.000)	-0.075 (0.002)
Methionine	-0.064 (0.008)	-0.259 (0.000)
MCAA	-0.122 (0.000)	-0.254 (0.000)
Vitamin A	-0.364 (0.078)	-0.173 (0.448)
Vitamin B3	-0.038 (0.553)	-0.291 (0.000)
Vitamin B4	-0.054 (0.086)	-0.255 (0.000)
Vitamin E	-0.071 (0.012)	-0.766 (0.000)

Notes: For each cartel that breaks up in year t , sample includes data on eight years: $t-4$ to $t-1$, and $t+1$ to $t+4$ (i.e. break-up year t is excluded). SPOST refers to the short-run post-breakup period (years $t+1$ and $t+2$, for breakup year t). SPRE refers to the short-run pre-breakup period (years $t-2$ and $t-1$). LPRE refers to the long-run pre-breakup period (years $t-4$ and $t-3$). SPOST-SPRE indicates difference in means between periods SPOST and SPRE. All regressions include importer-exporter (trade-pair) fixed effects. Observations are weighted by trade quantity. Robust (clustered by importer) p-values are in parentheses.

Table 6: Effect of cartel breakup on the relationship between distance and the propensity to trade

	Relative to 4-year pre-breakup period		Relative to short-term pre-breakup period	
			Short-run effect	Long-run effect
	SPOST-PRE	LPOST-PRE	SPOST-SPRE	LPOST-SPRE
	1a	1b	2a	2b
Citric Acid	-0.111 (0.015)	-0.159 (0.000)	-0.096 (0.025)	-0.144 (0.000)
Methionine	0.012 (0.792)	-0.007 (0.868)	0.009 (0.850)	-0.010 (0.820)
MCAA	-0.018 (0.658)	-0.055 (0.296)	-0.030 (0.508)	-0.067 (0.250)
Vitamin A	-0.007 (0.862)	0.012 (0.811)	-0.014 (0.736)	0.005 (0.930)
Vitamin B3	-0.022 (0.573)	-0.021 (0.641)	-0.042 (0.296)	-0.041 (0.400)
Vitamin B4	-0.049 (0.152)	-0.085 (0.047)	-0.051 (0.156)	-0.088 (0.040)
Vitamin E	-0.084 (0.042)	-0.017 (0.760)	-0.097 (0.024)	-0.030 (0.600)

Notes: The dependent variable in the probit propensity estimation is a dummy = 1 if there is non-zero trade between a country pair. SPOST refers to the short-run post-breakup period (years t+1 and t+2, for breakup year t). LPOST refers to the long-run post-breakup period (years t+3 and t+4). PRE refers to the 4-year pre-breakup period (years t-4 to t-1). SPRE refers to the short-run pre-breakup period (years t-2 and t-1). SPOST-PRE indicates difference in means between periods SPOST and PRE. All specifications include importer, exporter and year effects. Other controls are discussed in the text and data appendix. Robust (clustered by importer) p-values are in parentheses.

Table 7: Effect of cartel breakup on distance coefficient gravity equations

	Relative to 4-year pre-breakup period		Relative to short-term pre-breakup period	
	SPOST_PRE	LPOST_PRE	Short-run effect	Long-run effect
	1a	1b	2a	2b
Citric Acid	0.122 (0.215)	0.110 (0.378)	0.157 (0.076)	0.166 (0.130)
Methionine	-0.007 (0.932)	-0.008 (0.920)	0.016 (0.814)	-0.014 (0.860)
MCAA	-0.079 (0.553)	-0.023 (0.938)	0.093 (0.501)	0.473 (0.020)
Vitamin A	0.024 (0.789)	-0.011 (0.905)	0.037 (0.712)	0.052 (0.560)
Vitamin B3	0.101 (0.302)	0.003 (0.974)	0.161 (0.127)	0.062 (0.580)
Vitamin B4	0.101 (0.461)	0.033 (0.875)	0.135 (0.219)	0.109 (0.380)
Vitamin E	0.163 (0.220)	0.022 (0.775)	0.221 (0.059)	0.057 (0.430)

Notes: The dependent variable in the gravity equation is log trade value. SPOST refers to the short-run post-breakup period (years t+1 and t+2, for breakup year t). LPOST refers to the long-run post-breakup period (years t+3 and t+4). PRE refers to the 4-year pre-breakup period (years t-4 to t-1). SPRE refers to the short-run pre-breakup period (years t-2 and t-1). LPRE refers to the long-run pre-breakup period (years t-4 and t-3). SPOST-PRE indicates difference in means between periods SPOST and PRE. Other column titles are similar. All regressions include importer, exporter and year effects. These specifications also include correction for zero-trades based on Helpman et al (2008). Other controls are discussed in the text and data appendix. Robust (clustered by importer) p-values are in parentheses.

Table 8: Effect of cartel breakup on concentration measures

	HHI				Number of trade partners			
	Relative to 4-year pre-breakup period		Relative to short-term pre-breakup period		Relative to 4-year pre-breakup period		Relative to short-term pre-breakup period	
			Short-run effect	Long-run effect			Short-run effect	
	SPOST_PRE	LPOST_PRE	SPOST_SPRE	LPOST_SPRE	SPOST_PRE	LPOST_PRE	SPOST_SPRE	LPOST_SPRE
1a	1b	2a	2b	3a	3b	4a	4b	
Citric Acid	-0.011 (0.491)	0.009 (0.655)	-0.019 (0.293)	0.001 (0.970)	-0.325 (0.606)	-0.060 (0.936)	-0.632 (0.330)	-0.367 (0.640)
Methionine	-0.037 (0.173)	-0.032 (0.351)	-0.039 (0.116)	-0.034 (0.320)	0.498 (0.271)	0.541 (0.411)	0.818 (0.096)	0.863 (0.170)
MCAA	-0.003 (0.863)	0.000 (0.999)	0.020 (0.224)	0.024 (0.140)	0.270 (0.631)	0.217 (0.687)	-0.160 (0.670)	-0.215 (0.680)
Vitamin A	-0.037 (0.206)	-0.070 (0.046)	-0.038 (0.258)	-0.071 (0.050)	0.768 (0.299)	1.632 (0.007)	0.762 (0.400)	1.627 (0.020)
Vitamin B3	-0.036 (0.107)	-0.022 (0.247)	-0.042 (0.047)	-0.029 (0.130)	1.725 (0.009)	0.438 (0.679)	1.639 (0.007)	0.350 (0.730)
Vitamin B4	-0.005 (0.675)	-0.017 (0.730)	-0.005 (0.731)	-0.017 (0.750)	0.601 (0.408)	0.673 (0.199)	0.555 (0.275)	0.626 (0.030)
Vitamin E	-0.045 (0.050)	-0.054 (0.016)	-0.026 (0.328)	-0.036 (0.150)	1.863 (0.002)	2.309 (0.004)	1.243 (0.073)	1.697 (0.050)

Notes: For each cartel that breaks up in year t , sample includes data on eight years: $t-4$ to $t-1$, and $t+1$ to $t+4$ (i.e. break-up year t is excluded). SPOST refers to the short-run post-breakup period (years $t+1$ and $t+2$, for breakup year t). LPOST refers to the long-run post-breakup period (years $t+3$ and $t+4$). PRE refers to the 4-year pre-breakup period (years $t-4$ to $t-1$). SPRE refers to the short-run pre-breakup period (years $t-2$ and $t-1$). LPRE refers to the long-run pre-breakup period (years $t-4$ and $t-3$). SPOST-PRE indicates difference in means between periods SPOST and PRE. Other column titles are similar. All regressions include importer fixed effects. Observations are weighted by import quantity. Robust (clustered by importer) p -values are in parentheses.

Table 9: Difference-in-differences estimates of effects on price, concentration and gravity distance coefficient

		Control: Enzymes (excluding Rennet)			Organic chemicals nes		
		Herfindahl			Herfindahl		
		Log price	Index	Gravity	Log price	Index	Gravity
		1	2	3	4	5	6
Citric Acid	Short-run	-0.002 (0.978)	-0.025 (0.490)	0.001 (0.958)	-0.215 (0.094)	0.02 (0.604)	0.033 (0.028)
	Long-run	-0.075 (0.246)	0.012 (0.642)	0.010 (0.642)	-0.384 (0.002)	0.052 (0.194)	0.063 (0.001)
Methionine	Short-run	-0.200 (0.000)	-0.028 (0.324)	0.007 (0.699)	-0.174 (0.159)	-0.01 (0.800)	0.031 (0.143)
	Long-run	-0.298 (0.000)	-0.008 (0.839)	-0.021 (0.908)	-0.217 (0.105)	-0.013 (0.796)	0.155 (0.201)
MCAA	Short-run	-0.222 (0.000)	0.006 (0.804)	0.038 (0.149)	-0.196 (0.114)	0.025 (0.525)	0.040 (0.290)
	Long-run	-0.267 (0.000)	0.024 (0.314)	0.538 (0.000)	-0.185 (0.173)	0.021 (0.629)	0.42 (0.019)
Vitamin A	Short-run	-0.245 (0.108)	-0.027 (0.406)	0.004 (0.728)	-0.244 (0.175)	-0.011 (0.777)	0.014 (0.408)
	Long-run	-0.243 (0.087)	-0.045 (0.284)	0.199 (0.000)	-0.179 (0.331)	-0.053 (0.297)	0.089 (0.244)
Vitamin B3	Short-run	-0.263 (0.000)	-0.026 (0.338)	-0.009 (0.464)	-0.416 (0.000)	-0.007 (0.849)	-0.013 (0.411)
	Long-run	-0.365 (0.000)	-0.012 (0.613)	-0.03 (0.212)	-0.334 (0.034)	0.014 (0.766)	-0.039 (0.257)
Vitamin B4	Short-run	-0.238 (0.000)	0.004 (0.829)	-0.095 (0.004)	-0.398 (0.000)	0.019 (0.546)	0.129 (0.007)
	Long-run	-0.126 (0.034)	-0.006 (0.905)	-0.184 (0.003)	-0.104 (0.501)	0.019 (0.765)	0.274 (0.006)
Vitamin E	Short-run	-0.709 (0.000)	-0.035 (0.174)	-0.028 (0.039)	-0.687 (0.000)	-0.018 (0.637)	-0.023 (0.212)
	Long-run	-0.889 (0.000)	-0.029 (0.394)	0.165 (0.009)	-0.808 (0.000)	-0.036 (0.433)	0.032 (0.783)

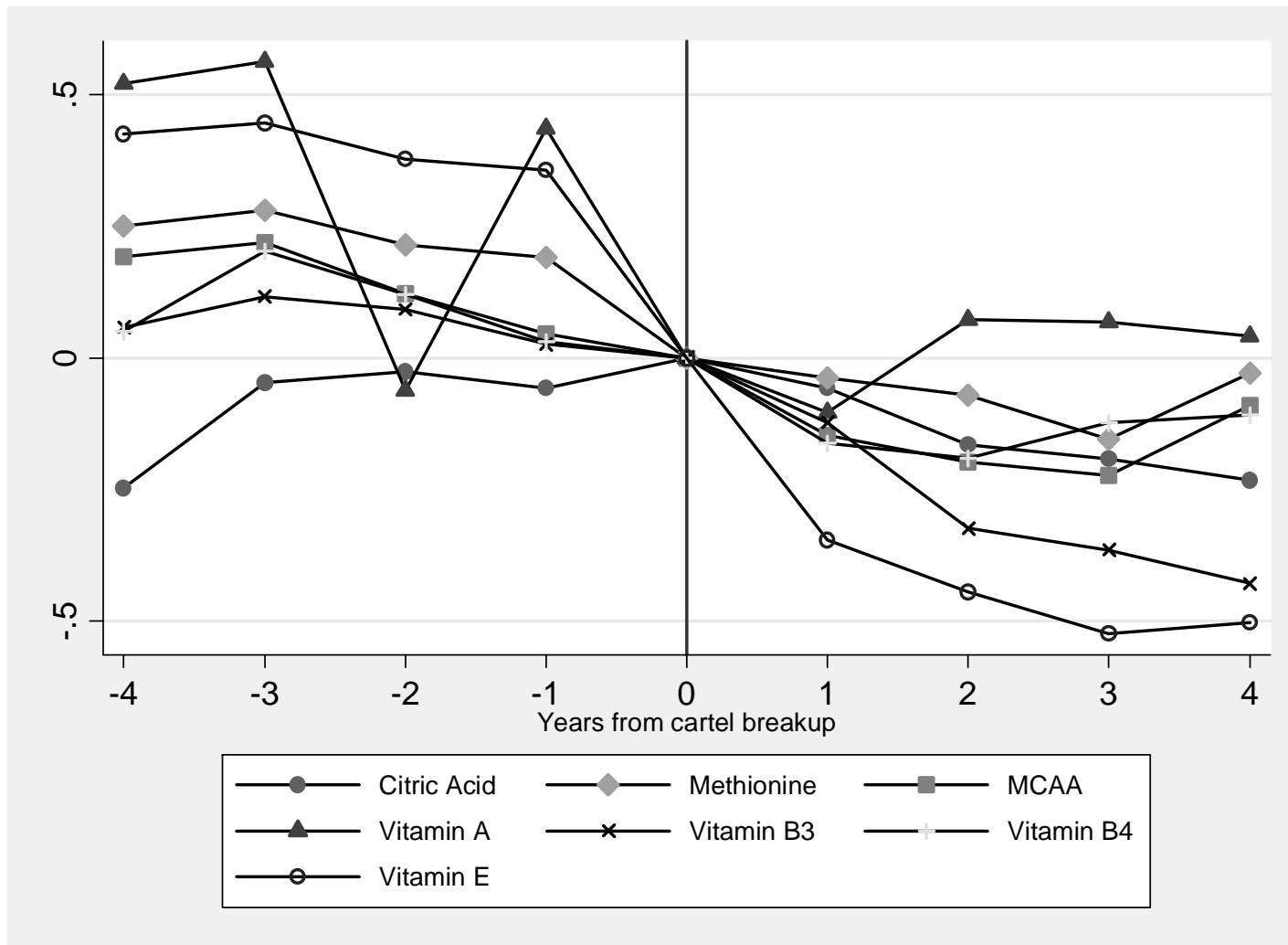
Notes: For each cartel that breaks up in year t , sample includes data on eight years: $t-4$ to $t-1$, and $t+1$ to $t+4$ (i.e. break-up year t is excluded). The corresponding years for the control product are also included. The control product Enzymes (excluding Rennet) has HS code 350790, and Organic chemicals nes has HS code 294200. The “short-run” is a dummy =1 for years $t+1$ and $t+2$ for the cartel product. Similarly, the “long-run” is a dummy =1 for years $t+3$ and $t+4$ for the cartel product. The log price regressions in Columns 1 and 4 importer-exporter-product fixed effects and year effects, and are weighted by trade quantity. The Herfindahl index regressions in Columns 2 and 5 include importer-product fixed effects and year effects and are weighted by total annual import quantity. The gravity equation regressions in Columns 3 and 6 report coefficients on the short-run and long-run dummy interacted with distance and a cartel product dummy. These specifications include exporter-product and importer-product fixed effects, as well as the year dummies interacted with distance. Robust (clustered by trade-pair in Columns 1 and 4, by importer-product in 3 and 5, and by trade-pair in Columns 3 and 6) p-values are in parentheses.

Table 10: Measures of extent of cross-hauling

	Import share of total trade for cartel home countries		Import share from other cartel member 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 (.386)	0.277	0.324	-0.047 (.341)
Methionine	25.4%	20.8%	27.2%	28.4%	0.324	0.454	-0.13 (.026)	0.303	0.366	-0.063 (.147)
MCAA	18.3%	16.4%	74.6%	72.7%	0.315	0.52	-0.205 (.030)	0.365	0.502	-0.137 (.112)
Vitamin A	22.1%	23.8%	91.0%	83.3%	0.404	0.34	0.064 (.587)	0.371	0.327	0.044 (.477)
Vitamin B3	60.0%	49.8%	22.2%	15.7%	0.551	0.359	0.192 (.098)	0.429	0.332	0.097 (.248)
Vitamin B4	38.6%	29.4%	71.1%	71.2%	0.234	0.463	-0.229 (.037)	0.256	0.424	-0.168 (.055)
Vitamin E	23.8%	29.7%	76.4%	56.5%	0.325	0.358	-0.033 (.648)	0.333	0.302	0.031 (.569)

Notes: The samples in Columns 3b and 4b exclude cartel home countries. p-values are in parentheses.

Figure 1: Price changes following cartel breakup



Notes: This figure plots the mean log price (controlling for bilateral fixed effects, weighted by trade quantity using regression specification 5c in the text) 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

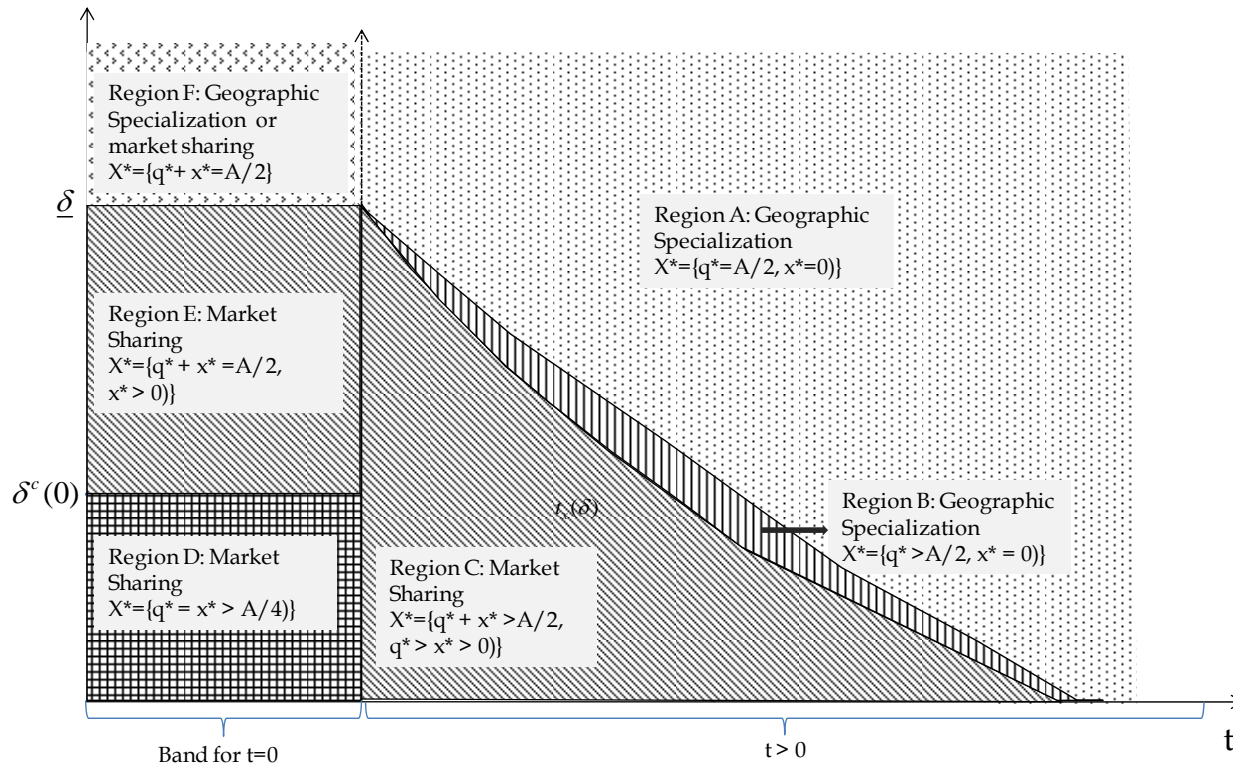


Figure 3: Average distance travelled (by unit quantity)

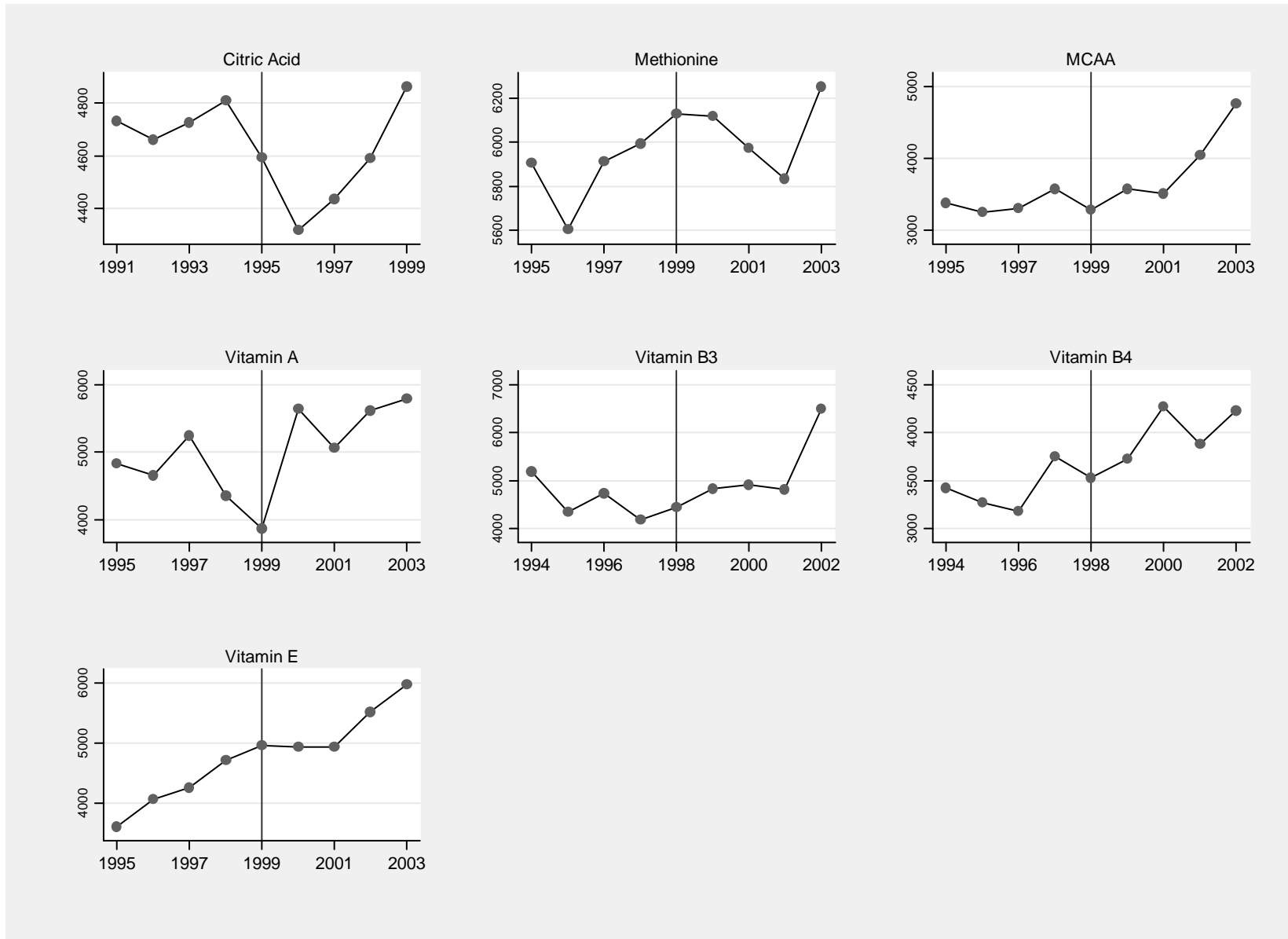
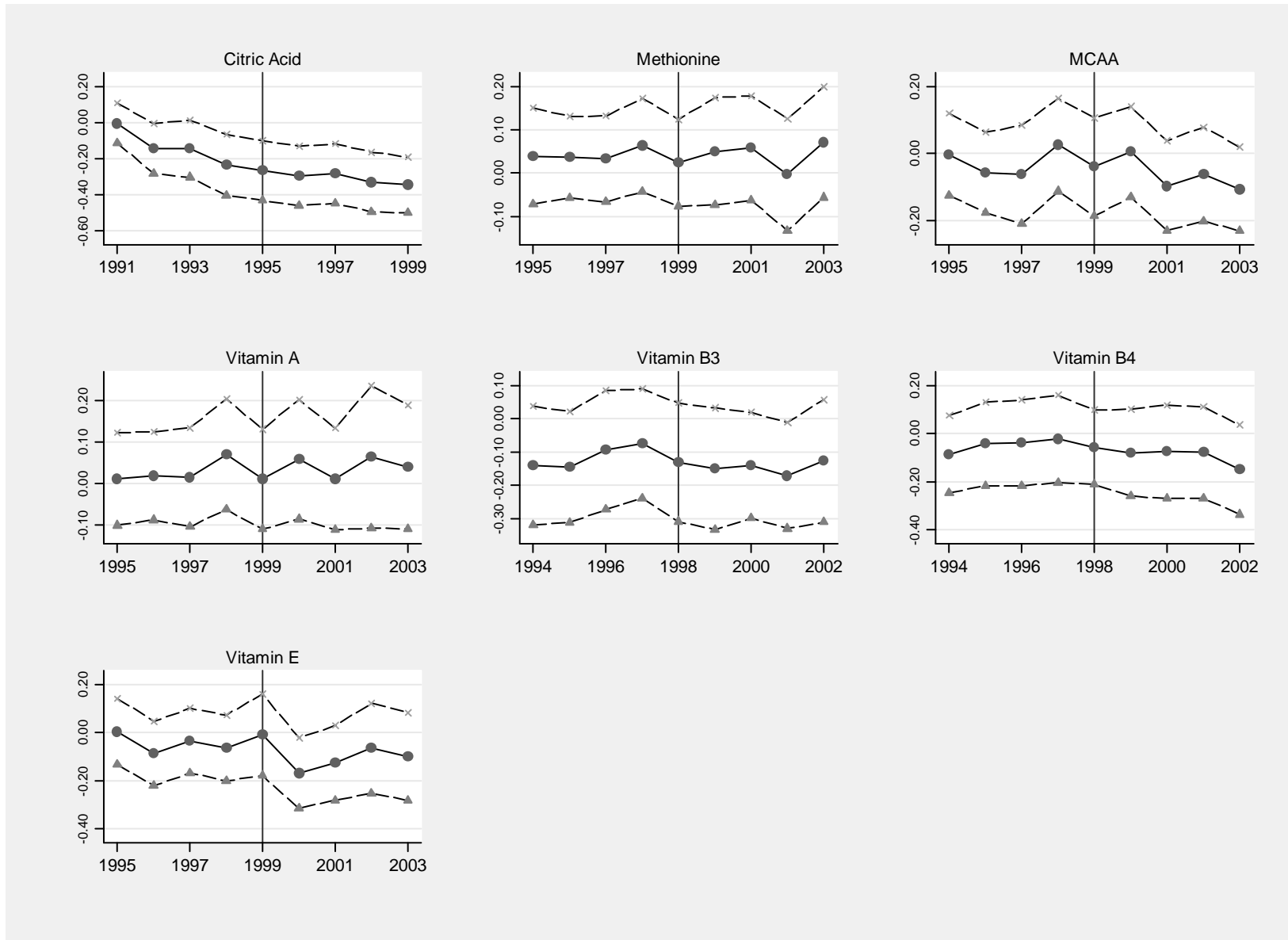
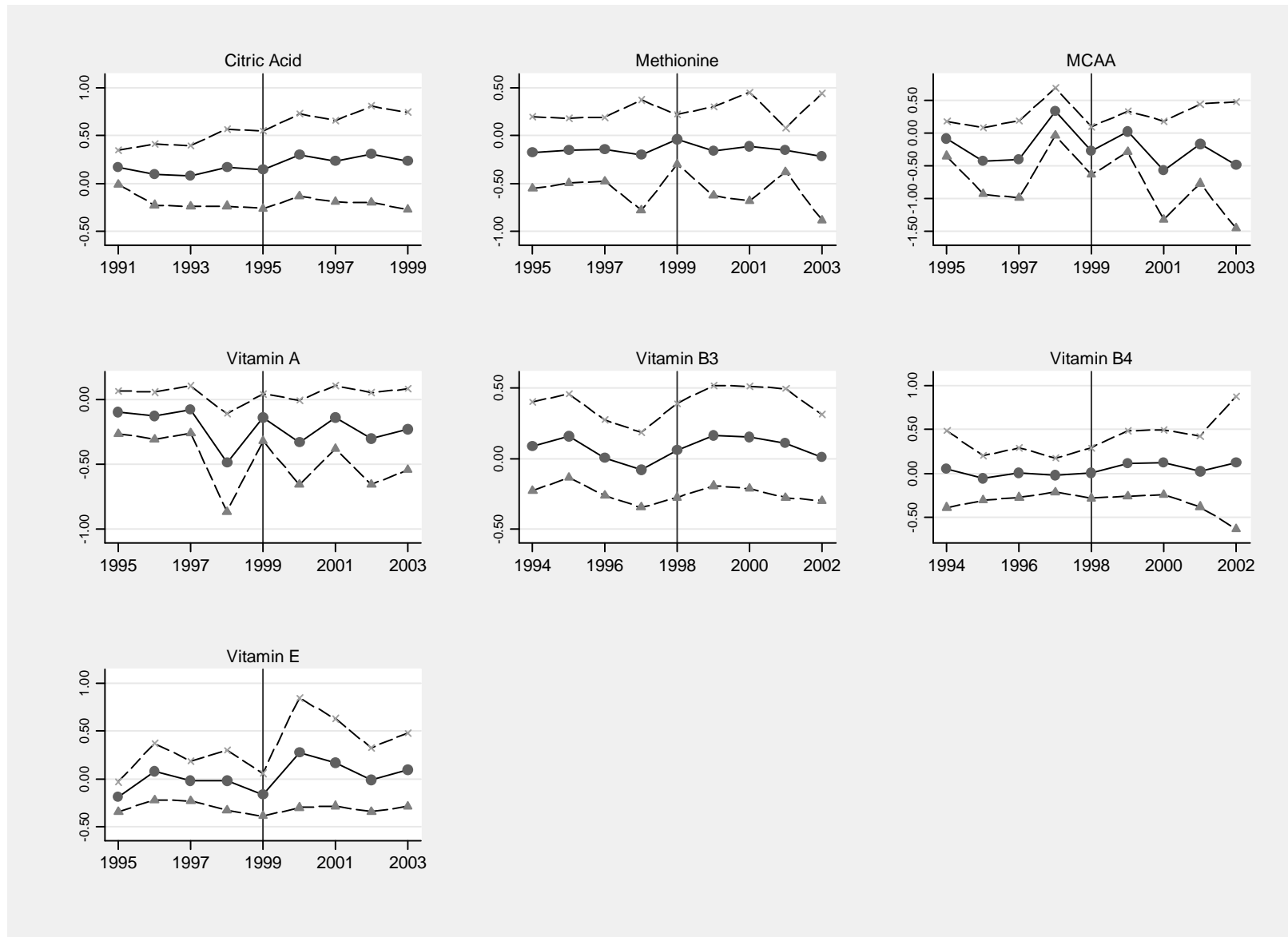


Figure 4: Change (relative to breakup year -5) in the distance coefficient in a probit (propensity to trade) equation



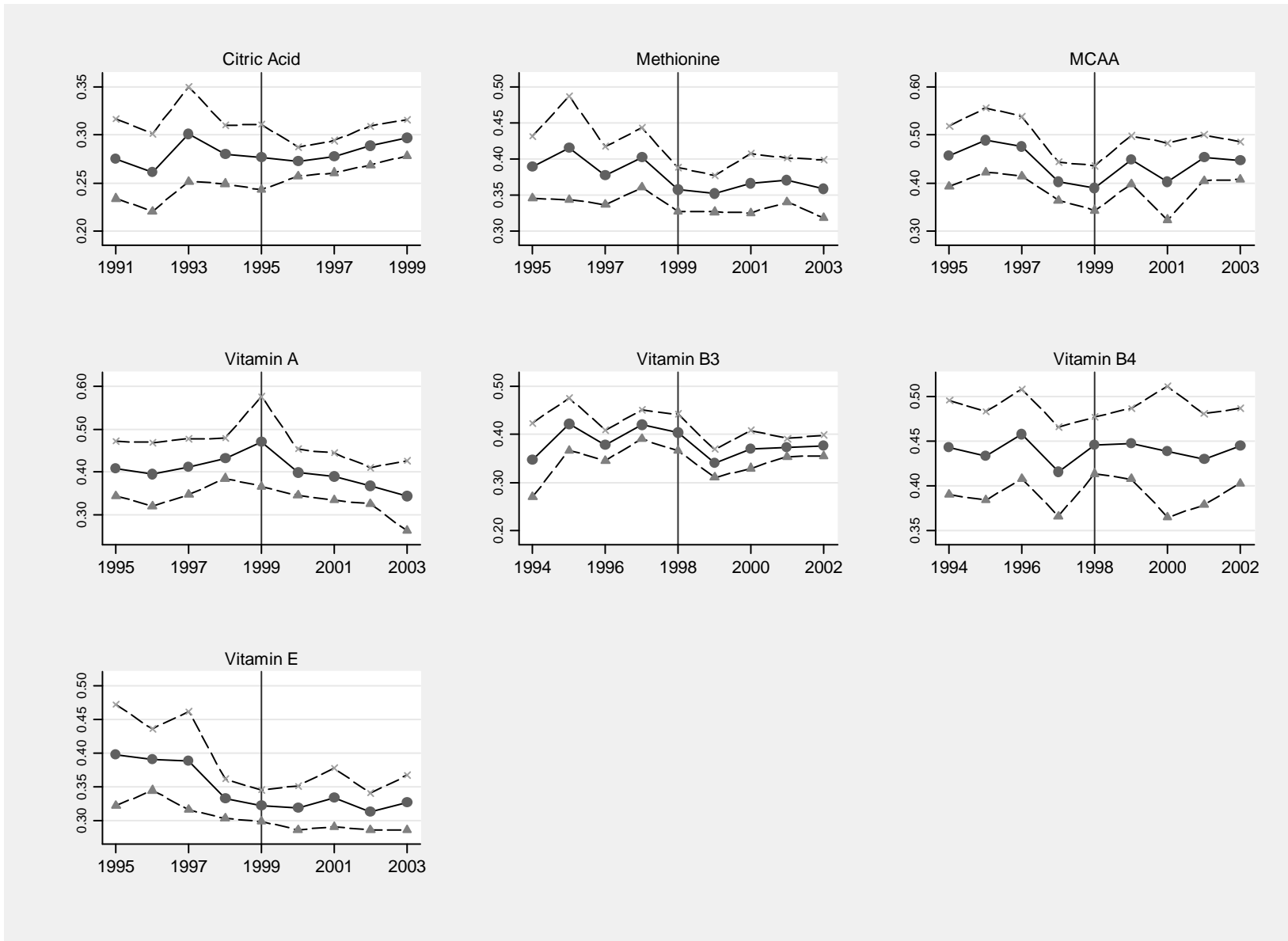
Notes: The dependent variable in the probit regression is a dummy =1 if there is non-zero trade between a country pair. All regressions include exporter, importer fixed effects and year effects. Other controls are discussed in the text and data appendix. Confidence intervals use robust (clustered by importer) standard errors.

Figure 5: Change (relative to breakup year -5) in the distance coefficient in a gravity equation



Notes: The dependent variable in the gravity equation is log trade value. All regressions include exporter, importer fixed effects and year effects, and include correction for zero-trade based on Helpman et al (2008). Other controls are discussed in the text and data appendix. Confidence intervals use robust (clustered by importer) standard errors.

Figure 6: HHI Trends



Notes: For each cartel that breaks up in year t , sample includes data on nine years: $t-4$ to $t+4$. All regressions include importer fixed effects. The importer-year observations are weighted by total import quantity. Confidence intervals use robust (clustered by importer) standard errors.

Data appendix

D1. Definitions for key variables

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.⁴⁴
4. *Distance*: Log bilateral population weighted distance (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. $HHI_{jkt} = \sum_{i=1}^{N_{jkt}} (S_{ijkt})^2$
9. *Absolute share instability*: sum of the absolute value of changes in shares between year t and year $t-1$ (with index k suppressed):⁴⁵

$$ASHVOL_{j,t} = \sum_{i=1}^{N_{j,t}} |S_{i,j,t} - S_{i,j,t-1}|$$

10. *Relative share instability*: sum of the absolute value of changes in shares between year t and year $t-1$ divided by the mean shares in period t and

$t-1$. Again suppressing product index k

$$RSHVOL_{j,t} = \sum_{i=1}^{N_{j,t}} \frac{|S_{i,j,t} - S_{i,j,t-1}|}{0.5 (S_{i,j,t} + S_{i,j,t-1})}$$

D2. Definitions for control variables used in the trade dummy probit 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.

⁴⁴ 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 subsequent analysis involving these variables exclude these observations.

⁴⁵ For both share instability measures, if an importer is present in year t or $t-1$ and absent in the other year, the share in the year it is absent is set to zero.

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.⁴⁶
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.

Excluded variables (i.e included in the 1st stage probit regressions but excluded from the 2nd 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*: $(\% \text{ Protestants in country } i * \% \text{ Protestants in country } j) + (\% \text{ Catholics in country } i * \% \text{ Catholics in country } j) + (\% \text{ Muslims in country } i * \% \text{ Muslims in country } j)$.

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.

⁴⁶ 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.

Appendix: Additional Results

Table A.1: Log price robustness checks

	Log FOB Price		Log Price (imports from Cartel HQs only)	
	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE
	1a	1b	2a	2b
Citric Acid	0.022 (0.282)	-0.068 (0.005)	-0.078 (0.030)	-0.135 (0.000)
Methionine	-0.319 (0.000)	-0.324 (0.000)	-0.292 (0.000)	-0.325 (0.000)
MCAA	-0.288 (0.000)	-0.298 (0.000)	-0.327 (0.000)	-0.309 (0.000)
Vitamin A	-0.377 (0.000)	-0.395 (0.000)	-0.353 (0.031)	-0.284 (0.066)
Vitamin B3	-0.287 (0.000)	-0.442 (0.000)	-0.303 (0.000)	-0.546 (0.000)
Vitamin B4	-0.278 (0.003)	-0.251 (0.000)	-0.299 (0.000)	-0.24 (0.000)
Vitamin E	-0.671 (0.000)	-0.821 (0.000)	-0.785 (0.000)	-0.871 (0.000)

Notes: For each cartel that breaks up in year t , sample includes data on eight years: $t-4$ to $t-1$, and $t+1$ to $t+4$ (i.e. break-up year t is excluded). All regressions include importer-exporter (trade-pair) fixed effects. Observations are weighted by trade quantity. In Columns 1a and 1b, the sample uses reported export values and quantities to define price. In columns 2a and 2b, only imports from cartel headquarter countries are included in the sample. Robust (clustered by importer) p-values are in parentheses.

Table A.2: Robustness of effect of competition on the distance coefficient in gravity equations: Alternative specifications

	OLS+ Trade-pair fixed effects		PPML (Silva-Tenreyo)		Import share (OLS + trade-pair fixed effects)		Export share (OLS + trade-pair fixed effects)	
	Long-run effect	Long-run effect	Short-run effect	Short-run effect	Long-run effect	Long-run effect	Short-run effect	Long-run effect
	SPOST_SPRE	LPOST_SPRE	SPOST_SPRE	SPOST_SPRE	LPOST_SPRE	LPOST_SPRE	SPOST_SPRE	LPOST_SPRE
	1a	1b	2a	2b	3a	3b	4a	4b
Citric Acid	-0.045 (0.396)	-0.039 (0.541)	-0.061 (0.296)	0.005 (0.941)	-0.103 (0.007)	-0.038 (0.489)	0.022 (0.880)	0.073 (0.073)
Methionine	0.141 (0.047)	0.099 (0.225)	0.106 (0.105)	0.083 (0.250)	0.039 (0.477)	0.113 (0.300)	0.133 (0.175)	0.119 (0.119)
MCAA	0.046 (0.646)	0.224 (0.073)	0.041 (0.453)	0.121 (0.158)	0.037 (0.428)	0.091 (0.199)	0.065 (0.509)	0.161 (0.161)
Vitamin A	0.106 (0.162)	0.168 (0.050)	0.042 (0.485)	0.02 (0.819)	0.149 (0.064)	0.272 (0.066)	0.156 (0.242)	0.234 (0.234)
Vitamin B3	0.061 (0.455)	0.132 (0.103)	0.161 (0.005)	0.257 (0.011)	0.05 (0.419)	0.192 (0.060)	0.251 (0.038)	0.345 (0.345)
Vitamin B4	0.095 (0.291)	0.059 (0.614)	0.284 (0.013)	0.264 (0.010)	0.09 (0.391)	0.067 (0.528)	0.264 (0.251)	0.299 (0.299)
Vitamin E	0.074 (0.326)	0.059 (0.481)	0.032 (0.552)	0.075 (0.379)	0.094 (0.085)	0.17 (0.057)	0.161 (0.069)	0.352 (0.352)

Notes: All estimated effects are relative to the 4-year pre-breakup period (t-1 to t-4). The dependent variable is log trade value in Columns 1a and 1b, trade value in Columns 2a and 2b, import share (quantity) in column 3a and 3b and export share (quantity) in columns 4a and 4b. Import and export share regressions are weighted by total annual import and export quantity respectively. All columns include importer-exporter and year effects. Other controls are discussed in the text and data appendix. Robust (clustered by importer) p-values are in parentheses.

Table A.3: Robustness of effect of competition on the distance coefficient in gravity equations: Alternative sub-samples

	Baseline		Europe only		Balanced panel		Imports from Cartel HQs only	
	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE
	1a	1b	3b	3b	3a	3b	4a	4b
Citric Acid	0.122 (0.215)	0.110 (0.378)	-0.297 (0.201)	-0.318 (0.203)	0.117 (0.224)	0.100 (0.401)	-0.034 (0.932)	-0.104 (0.920)
Methionine	-0.007 (0.932)	-0.008 (0.920)	-0.13 (0.374)	-0.065 (0.716)	-0.076 (0.565)	-0.164 (0.232)	4.892 (0.033)	1.587 (0.132)
MCAA	-0.079 (0.553)	-0.023 (0.938)	-0.361 (0.082)	0.145 (0.689)	0.008 (0.952)	0.234 (0.286)	1.874 (0.240)	1.227 (0.553)
Vitamin A	0.024 (0.789)	-0.011 (0.905)	0.135 (0.628)	0.064 (0.885)	-0.044 (0.625)	-0.112 (0.329)	1.812 (0.287)	-0.912 (0.200)
Vitamin B3	0.101 (0.302)	0.003 (0.974)	0.125 (0.454)	0.181 (0.433)	0.101 (0.301)	-0.004 (0.970)	0.154 (0.692)	1.065 (0.069)
Vitamin B4	0.101 (0.461)	0.033 (0.875)	-0.044 (0.790)	-0.059 (0.827)	0.138 (0.183)	0.147 (0.300)	-0.193 (0.702)	-0.945 (0.554)
Vitamin E	0.163 (0.220)	0.022 (0.775)	-0.075 (0.745)	0.041 (0.814)	0.124 (0.236)	-0.031 (0.701)	-1.464 (0.001)	0.176 (0.721)

Notes: The dependent variable in the gravity equation is log trade value. All effects are relative to 4-year pre-cartel breakup period. The probit and gravity regressions include importer, exporter and year effects. Gravity equations also include correction for zero-trades based on Helpman et al (2008). Other controls are discussed in the text and data appendix. Robust (clustered by importer) p-values are in parentheses.

Table A.4: Robustness of concentration results: Alternative concentration measures and changes in market share instability

	C2 ratio (imports)		HHI (exports)		Absolute share instability		Relative share instability	
	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE
	1a	1b	2a	2b	3a	3b	4a	4b
Citric Acid	-0.006 (0.169)	0.026 (0.169)	-0.066 (0.005)	-0.054 (0.108)	-0.031 (0.383)	-0.020 (0.692)	2.157 (0.375)	3.321 (0.100)
Methionine	-0.025 (0.763)	-0.009 (0.763)	-0.011 (0.503)	-0.018 (0.301)	-0.064 (0.153)	0.002 (0.979)	-0.002 (0.999)	-0.065 (0.957)
MCAA	0.015 (0.496)	0.009 (0.496)	0.000 (0.973)	-0.019 (0.186)	0.095 (0.091)	0.058 (0.156)	0.978 (0.299)	-0.276 (0.794)
Vitamin A	-0.029 (0.011)	-0.053 (0.011)	-0.026 (0.041)	-0.046 (0.000)	0.032 (0.402)	0.081 (0.150)	0.466 (0.692)	0.948 (0.413)
Vitamin B3	-0.032 (0.609)	-0.011 (0.609)	-0.012 (0.610)	-0.025 (0.361)	0.079 (0.529)	-0.040 (0.420)	2.745 (0.012)	2.772 (0.020)
Vitamin B4	-0.007 (0.798)	-0.006 (0.798)	-0.098 (0.222)	-0.117 (0.002)	0.090 (0.013)	0.112 (0.370)	2.306 (0.108)	2.210 (0.073)
Vitamin E	-0.063 (0.007)	-0.067 (0.007)	-0.02 (0.060)	0.001 (0.952)	0.058 (0.221)	0.049 (0.288)	2.393 (0.041)	0.039 (0.988)

Notes: All effects are relative to 4-year pre-cartel breakup period. For each cartel that breaks up in year t , sample includes data on eight years: $t-4$ to $t-1$, and $t+1$ to $t+4$ (i.e. break-up year t is excluded). Columns 1, 3 and 4 include importer fixed effects, and Column 2 includes exporter fixed effects. Observations are weighted by trade quantity. Robust (clustered by importer in Columns 1, 3 and 4 and exporter in Column 2) p-values are in parentheses.

Table A.5: Robustness of concentration (HHI) results: Alternative subsamples

	Europe only		Balanced panel		Excluding cartel home countries		Imports from Cartel HQs only:	
	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE
	1a	1b	2a	2b	3a	3b	4a	4b
Citric Acid	-0.012 (0.463)	0.002 (0.921)	-0.011 (0.491)	0.009 (0.655)	-0.009 (0.686)	0.010 (0.648)	-0.008 (0.646)	0.030 (0.128)
Methionine	-0.010 (0.528)	-0.021 (0.334)	-0.037 (0.172)	-0.032 (0.350)	-0.037 (0.262)	-0.029 (0.474)	-0.019 (0.486)	0.002 (0.946)
MCAA	-0.004 (0.892)	0.027 (0.159)	-0.003 (0.863)	0.000 (0.999)	-0.010 (0.624)	-0.014 (0.405)	0.034 (0.103)	0.040 (0.118)
Vitamin A	-0.022 (0.051)	-0.067 (0.270)	-0.037 (0.206)	-0.070 (0.046)	-0.036 (0.311)	-0.055 (0.102)	-0.017 (0.483)	-0.039 (0.392)
Vitamin B3	-0.025 (0.530)	-0.003 (0.919)	-0.036 (0.106)	-0.022 (0.246)	-0.051 (0.005)	-0.032 (0.103)	0.099 (0.006)	0.088 (0.032)
Vitamin B4	-0.010 (0.587)	-0.105 (0.128)	-0.005 (0.674)	-0.017 (0.729)	0.006 (0.731)	-0.039 (0.504)	-0.040 (0.098)	-0.066 (0.107)
Vitamin E	-0.040 (-0.003)	-0.014 (-0.604)	-0.045 (0.050)	-0.054 (0.016)	-0.049 (0.082)	-0.063 (0.018)	-0.010 (0.764)	-0.019 (0.603)

Notes: The dependent variable is importer country HHI. Robust (clustered by importer) p-values are in parentheses.

Table A.6: Summary statistics on trade dummy and trade values

		Non-zero trade dummy		Log trade value	
		Pre-breakup	Post-breakup	Pre-breakup	Post-breakup
Citric Acid	N	54,405	72,540	1,662	3,618
	Mean	0.031	0.050	11.149	10.735
	SD (p-value)	0.172	0.218	2.282	2.354
Methionine	N	40,572	54,096	1,432	2,333
	Mean	0.035	0.043	12.165	11.748
	SD (p-value)	0.185	0.203	2.300	2.522
MCAA	N	28,860	38,480	914	1,336
	Mean	0.032	0.035	10.612	9.922
	SD (p-value)	0.175	0.183	2.526	2.862
Vitamin A	N	46,656	62,208	1,487	2,516
	Mean	0.032	0.040	11.056	10.454
	SD (p-value)	0.176	0.197	2.412	2.588
Vitamin B3	N	28,203	37,604	1,280	2,128
	Mean	0.045	0.057	10.876	10.381
	SD (p-value)	0.208	0.231	2.319	2.485
Vitamin B4	N	39,744	52,992	1,321	1,997
	Mean	0.033	0.038	10.549	10.139
	SD (p-value)	0.179	0.190	1.915	2.143
Vitamin E	N	42,840	57,120	1,617	2,788
	Mean	0.038	0.049	11.406	10.682
	SD (p-value)	0.191	0.215	2.673	2.660

Notes: All means are un-weighted. p-values are in parenthesis.

Comparisons of price changes in different time periods:

In this appendix sub-section we discuss results from specification 8b in more detail (See Appendix Table A.7 below).

While results in Column 5 indicate some prior declining trend, comparing column 1 to Column 5 in Appendix Table A.7, in almost all cases (except Vitamin A) there appears to have been larger and more significant decline in prices following the cartel breakup (compared to the prior trend), consistent with a significant increase in competitive intensity.

One concern in the context of cartel breakups is whether prices rebound up (say because the cartel informally/tacitly start colluding again). We find greater decline in the long-run (Column 2) relative to the short run (Column 1). This is confirmed by the statistical test of the difference between the short-run and long-run post-breakup periods (i.e. $\alpha_{LPOST} - \alpha_{SPOST}$) in Column 6, where in most cases we find a statistically significant further decline. The only case with a statistically significant rebound is Vitamin B4, but the rebound is small relative to the initial decline (0.056 log points relative to -0.255 log points).

Consistent with the results on prior trends (column 5 discussed above), the declines are generally larger in magnitude when we compare post-breakup prices to the long-run pre-breakup period (years $t-4$ and $t-3$) in columns 3 and 4.

To re-confirm that there were indeed significant price declines (even relative to prior trends) for all seven cartels, we examine a richer picture of year to year variations in price effects, by plotting coefficients on period dummies from the following specification:

$$p_{ijt} = \sum_{s=-4}^{+4} \alpha_s D_s + f_{ij} + \epsilon_{ijt} \tag{8c}$$

where s is an index variable for the number of years from breakup and is defined as [year - breakup year], ranging from -4 to +4. D_s is a dummy variable corresponding to the index (e.g., $D_2=1$ if $s=2$, and 0 otherwise).

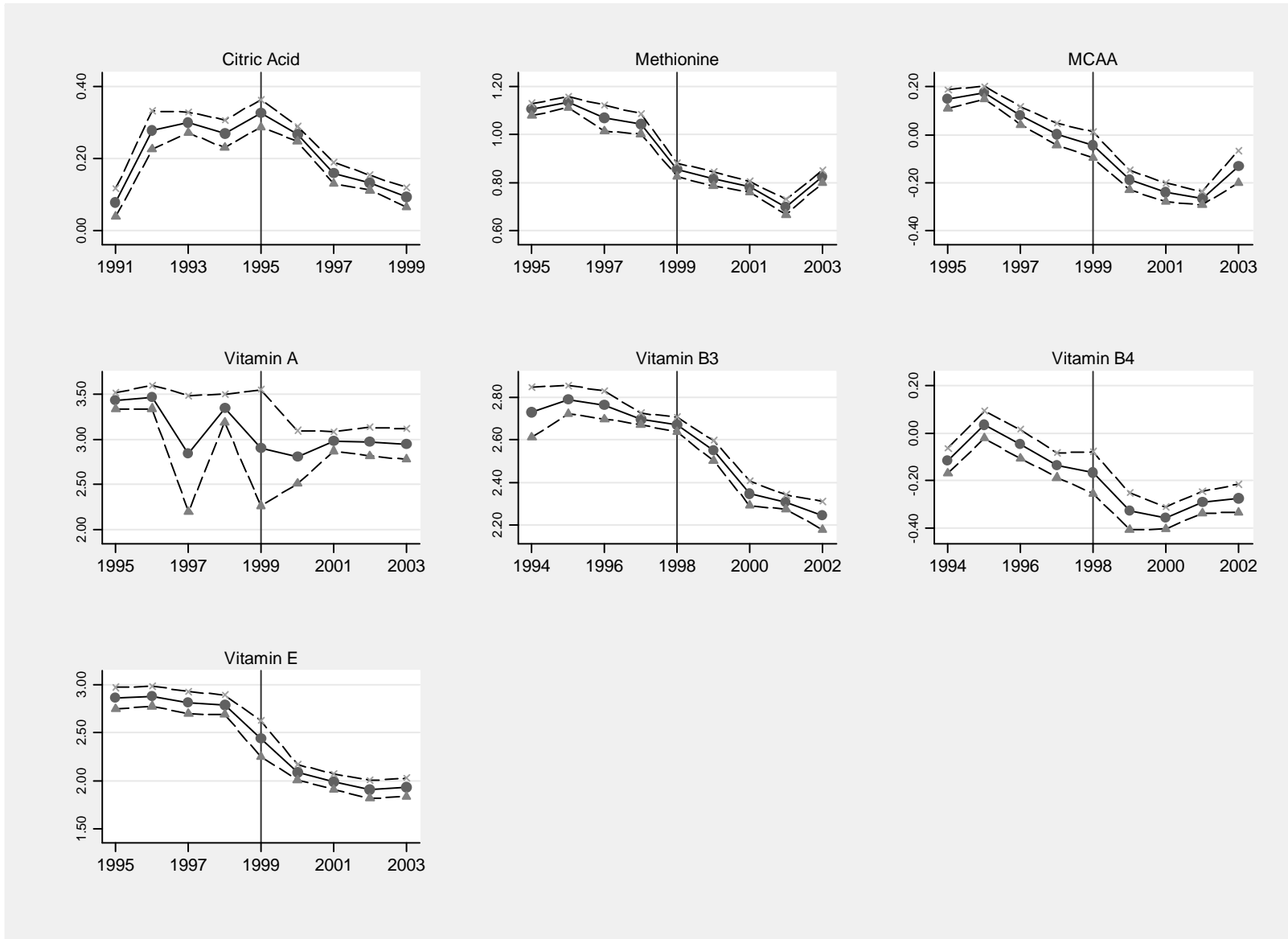
The estimated coefficients and corresponding confidence intervals are plotted in Figure 3. The figures confirm the results from Tables 4 and 5: all seven cartels show strong declines in price in the post-period relative to the pre-period. Almost all cartels show a sharp decline either in the breakup year or in the year following the breakup. Consistent with Table 4 and 5 results, Citric Acid shows a run-up in price before the breakup, and Vitamin B4 shows a significant rebound. Methionine and MCAA show some rebound too, but other cartels (except Vitamin A) show further declines.

Table A.7: Log price changes – detailed breakup of pre- and post-breakup effects (Columns 1 and 5 are in table 5 in the paper)

	Relative to short-term pre-breakup period		Relative to long-term pre-breakup period		Pre-breakup trend	Long-run rebound
	Short-run effect	Long-run effect	Short-run effect	Long-run effect		
	SPOST-SPRE	LPOST-SPRE	SPOST-LPRE	LPOST-LPRE	SPRE-LPRE	LPOST-SPOST
	1	2	3	4	5	6
Citric Acid	-0.075 (0.002)	-0.172 (0.000)	0.013 (0.641)	-0.084 (0.008)	0.088 (0.000)	-0.097 (0.000)
Methionine	-0.259 (0.000)	-0.294 (0.000)	-0.323 (0.000)	-0.358 (0.000)	-0.064 (0.008)	-0.035 (0.009)
MCAA	-0.254 (0.000)	-0.244 (0.000)	-0.376 (0.000)	-0.366 (0.000)	-0.122 (0.000)	0.010 (0.685)
Vitamin A	-0.173 (0.448)	-0.113 (0.600)	-0.537 (0.000)	-0.477 (0.000)	-0.364 (0.078)	0.060 (0.536)
Vitamin B3	-0.291 (0.000)	-0.447 (0.000)	-0.329 (0.000)	-0.485 (0.000)	-0.038 (0.553)	-0.156 (0.000)
Vitamin B4	-0.255 (0.000)	-0.199 (0.000)	-0.309 (0.000)	-0.253 (0.000)	-0.054 (0.086)	0.056 (0.029)
Vitamin E	-0.766 (0.000)	-0.884 (0.000)	-0.837 (0.000)	-0.955 (0.000)	-0.071 (0.012)	-0.118 (0.009)

Notes: For each cartel that breaks up in year t , sample includes data on eight years: $t-4$ to $t-1$, and $t+1$ to $t+4$ (i.e. break-up year t is excluded). SPOST refers to the short-run post-breakup period (years $t+1$ and $t+2$, for breakup year t). LPOST refers to the long-run post-breakup period (years $t+3$ and $t+4$). SPRE refers to the short-run pre-breakup period (years $t-2$ and $t-1$). LPRE refers to the long-run pre-breakup period (years $t-4$ and $t-3$). SPOST-SPRE indicates difference in means between periods SPOST and SPRE. Other column titles are similar. All regressions include importer-exporter (trade-pair) fixed effects. Observations are weighted by trade quantity. Robust (clustered by importer) p-values are in parentheses.

Figure A.1: Log price trends



Notes: For each cartel that breaks up in year t , sample includes data on nine years: $t-4$ to $t+4$. All regressions include importer-exporter (trade-pair) fixed effects. Observations are weighted by import quantity. Confidence intervals use robust (clustered by importer) standard error.