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

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Abstract

How do changes in competitive intensity affect trade patterns? In this paper, we exploit a quasi-natural experiment associated with increased anti-trust enforcement activity over the last two decades. A large number of international markets underwent a change in competitive intensity as they shifted from explicit collusion to oligopolistic competition. We draw on models of collusive arrangements in spatially separated markets to generate testable predictions of the effects of collusion on price, trade patterns and concentration. One set of models (Pinto 1986, Fung 1991, building on Brander and Krugman 1983) suggests that colluding firms in commodity markets are likely to specialize geographically, while competing oligopolists are more likely to invade each others' markets. More recent models (Baake and Normann 2002, Bond and Syropoulos 2008) suggest that efficient cartel arrangements may necessitate market-sharing and cross-hauling of goods, as these entail lower defection profits. We analyze detailed trade data linked to descriptive information from ten international cartels to test these predictions. Consistent with both sets of models, we confirm significant declines in prices following the breakup of each of the ten cartels. Contrary to conventional wisdom, and consistent with the more recent oligopoly trade models, we find no significant change in spatial patterns of trade; 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.

JEL Codes: F12, F23, D43, D21

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

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1. Introduction

Understanding the determinants of patterns of international trade is one of the key goals of international economics. This paper addresses the relationship between the nature of competition and trade patterns. While this has been analyzed extensively in the theoretical literature, systematic empirical investigation of this question is limited. A key challenge for empirical analysis in this area is finding suitable "exogenous" changes in competitive intensity.

This paper takes advantage of a recent change in antitrust enforcement that functions as a natural experiment to study the impact of an increase in competition on trade patterns.[1] The increased willingness of antitrust authorities, in both the United States and elsewhere, to prosecute international cartels has generated a large body of evidence on the activities of international cartels over the last twenty years.[2] Because these cartels operated across national boundaries, their breakdown is particularly suitable for studying the effects of competition on trade patterns. In this paper we analyze data on ten recently prosecuted international cartels.[3] We assembled data on cartel membership, start and end dates, and detailed product description for individual cartels; we then use the product descriptions to link cartel-specific information to import and export data. The products in these ten cases are all relatively homogeneous, making these markets an especially appropriate setting in which to examine alternative models of trade and competition in commodity goods.

Brander and Krugman's (1983) seminal work demonstrates that Cournot duopolists may engage in intra-industry trade in homogeneous goods, as each duopolist finds it in its interest to maintain prices so high that it attracts entry into its home market by its rival. Pinto (1986) and Fung (1991) extend this model to a repeated game environment and 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

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[1] Following a similar approach, in a series of papers, 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.

[2] 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.

[3] Seven of these cartels ended following intervention by antitrust authorities. Three were prosecuted only after they have ceased being effective because of a growing competitive fringe. For these three cartels, we use the year in which cartel members abandoned explicit collusion (as reported by the European Commission) as the "breakup year."

(2002), and Bond and Syropoulos (2008), show that colluding firms may prefer an arrangement where both firms participate in both geographic markets in the collusive phase rather than specialize geographically. The reason for this outcome is that the benefit to defection is lower, and therefore the cartel is more stable, relative to the case with geographic specialization.

Thus these two sets of models have contrasting implications for the effect of a shift from collusion to competition. Following the collapse of a cartel, the "geographic specialization" Pinto/Fung models imply a change from geographic specialization to invasion of rivals' markets, which in turn imply significant changes in trade patterns. In particular, these models imply that 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 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.

In order to test the contrasting predictions of these models, we examine changes in trade patterns in products affected by the ten cartels. Our selection of these ten cartels is driven largely by data quality issues. For the cartels we study, there is a close match between the description of the product that was cartelized and the six digit Hamonized Tariff System product description. For each cartel we have a reliable measure of the date of cartel breakup, allowing us to estimate precisely effects of the cartel breakup. Finally, for each there is complete trade data coverage for four years before and after the cartel collapse.

First we examine the effect on prices. All models of collusion (including both market sharing and geographic specialization models) imply higher prices under collusion. In fact, 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. In order to assure that the cartels that we are studying were sufficiently effective, we first verify that the cartels raised prices. We find significant declines in prices following the breakup of each of the ten cartels selected for further analysis (see Figure 1).[4]

[4] As illustrated in Figure 1, the price declines range from 0.108 log points (10.3 per cent) to 0.800 log points (55.1 per cent) within 2 years after cartel breakup, relative to one year before the cartel breakup. For a discussion of more general results of the effect of cartels on prices, see Levenstein and Suslow (2006) and Connor & Bolotova (2006).

Second, we examine the effect of cartel breakup on the coefficient on distance in a gravity equation.[5] 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.

Finally, we 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 importing partners 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.

We check our baseline results using a number of robustness tests. We find the price decline results robust to using FOB prices (which excludes a role for changes in transport costs), as well as to using a sample of cartel exporters only. We find the gravity equation results 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), and to using measures of export and import market shares as dependent variables. We find the concentration results robust to using alternative measures of concentration, as well as to using measures of market share instability (Caves and Porter 1978). To control for other contemporaneous changes affecting all animal feed additive chemicals or all organic chemicals, we also undertake two difference-in-differences (DID) analyses, using an (apparently non-cartelized) animal feed additive chemical (enzymes) and other unclassified organic chemicals (organic chemicals not elsewhere specified) as control groups. The DID results confirmed the conclusions from our baseline analyses. Finally, we also examine a potential alternative

[5] While we are motivated by the contrasting implications of the two sets of models for the effect of distance on trade, our approach of looking at 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. Other papers have looked at 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. Berthelon and Freund 2008). Another influential literature uses the gravity equation to examine border effects (e.g. McCallum 1995, Anderson and van Wincoop 2003). For a discussion of other work that has used the gravity equation, see Helpman, Melitz and Rubinstein (2008).

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, and find that the levels of market concentration are not significantly higher in countries bordering cartel home markets, which suggest that trade patterns for these products were more consistent with the Cournot models of Baake-Normann/Bond-Syropoulos than the Gross-Holahan's Bertrand model.

The rest of the paper is organized as follows. In Section 2, we summarize several models related to collusion in homogenous markets and discuss their implications for the effect of cartel breakups on trade and market concentration. In Section 3, we briefly describe the cartels that we study and discuss data sources. Section 4 presents the baseline empirical results. Section 5 discusses a number of robustness checks. Section 6 concludes.

2. Theoretical motivation

2.1. Summary discussion of theoretical models

In this section, we briefly discuss alternative models of multimarket collusion (see Table 1 for a summary of the models and empirical predictions). We then present a simple model that illustrates the key arguments.

In Brander and Krugman's one-shot static game, duopolists engage in "reciprocal dumping," resulting in trade in identical goods (intra-industry trade).[6] 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.

Thus these early models extending Brander and Krugman (1983) 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, and concentration will drop as rivals invade each others' territories in the non-collusive regime.

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

Further, given that there are positive transportation costs, the cartel is likely to assign markets to firms that are geographically proximate. Thus firms are likely to focus on proximate markets under the collusive regime, but enter more distant markets under the non-collusive regime. The negative effect of distance on trade (posited and documented in the literature on gravity models in 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; in these models intra-industry trade does not occur under collusion. In contrast, Baake and Normann (2002) argue that there are strong incentives for firms to deviate under 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 does exist a cooperative equilibrium with "market sharing" that yields profits higher than in 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 hence can sustain an equilibrium. Bond and Syropoulos (2008) re-affirm this result and examine its implications for the role of trade costs in sustaining collusion, showing that trade liberalization can, in some circumstances, facilitate collusion.

Thus both Baake and Normann (2002) and Bond and Syropoulos (2008) suggest that cross-hauling and market sharing may occur under collusion. A switch from a collusive equilibrium to a competitive one will not necessarily reduce concentration significantly; cartel members may agree to share multiple markets and then, after the cartel breakup, compete in those same markets (i.e., in a Brander and Krugman competitive 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 both sets of models, the collusive equilibrium does lead to higher profits for firms through higher prices. Thus a decrease in prices is an unambiguous prediction robust to the alternative models.

2.2. A repeated-game oligopoly trade model

The following model, adapted from Bond and Syropoulos (2008), illustrates the key results and clarifies the intuition behind why and when market sharing may be the preferred collusive outcome.[7] As in Brander and Krugman, consider a symmetric two-country, Cournot model of trade between symmetric duopolists.[8] We refer to the two countries as home and foreign, with (symmetric) demand in each country given by a linear demand function $p_i = A - Q_i$, where Q_i represents the total quantity sold.[9] Assume marginal cost is constant for each firm, normalized to zero without loss of generality. Trade cost per unit shipped to foreign country is t (which in the context of our application can be thought of as mainly transport costs, but in general could include tariffs). Let q_i represent the quantity sold by firms from country i in its home market and x_i represent the quantity sold in the export market. The global profit of firm i then is the sum of profit from its home market and the foreign market, and is given by:

$$\Pi_i = \left\{[A-(q_i+x_j)]q_i + [A-(q_j+x_i)-t]x_i\right\} \tag{1}$$

The setup here is identical to Brander and Krugman (1983), and hence the one-shot non-cooperative game yields the same "reciprocal dumping" equilibrium. In particular, so long as trade costs are not greater than the prohibitive levels (i.e. $t \le \frac{A}{2}$), the symmetric Nash equilibrium (with each firm maximizing global profit) involves:

(i) Output levels: $q=(A+t)/3$ and $x=(A-2t)/3$

(ii) global profit: $\Pi^N = \dfrac{2A^2 - 2At + 5t^2}{9}$

We turn to the case of a collusive equilibrium in a repeated game. The overall profit of each firm under an agreement (q, x) is given by:

$$\Pi^A = \left\{[A-(q+x)](q+x) - tx\right\} \tag{2}$$

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

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[7] See the appendix in Bond and Syropoulos (2008) for proofs.
[8] Bond and Syropoulos generalize the results to the case of n>1 firms per country. They also develop results relating welfare to changes in tariffs and transportation costs. We focus on the implications of the collusive equilibrium for trade patterns.
[9] In the context of our trade data, the "home country" can be thought of as a proxy for "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.

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

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 game in the punishment phase is the non-collusive Nash equilibrium discussed above, an agreement (*q*, *x*) is sustainable iff:

$$Z(q,x,t,\delta) = \Pi^A(q,x,t) - (1-\delta)\Pi^D(q,x,t) - \delta\Pi^N(t) \geq 0 \tag{4}$$

where δ is the discount factor.

The different types of sustainable collusive outcomes in this model are summarized in Figure 2. As in Pinto (1986) and the homogenous goods case in Fung (1991), when the discount factor is above a threshold ($\delta > \underline{\delta}$), that is if the players are patient enough, they can sustain a collusive equilibrium with maximal geographic specialization. Bond and Syropoulos (2008) show that the same equilibrium is also obtained when the transportation cost is above a certain threshold (which varies with the discount factor). That is, maximal geographic specialization is the sub-game perfect equilibrium when $t > t^G(\delta)$ or $\delta > \underline{\delta}$. This corresponds to Region A in Figure 2. Note that here 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, we enter regions where the sustainable collusive outcome involves market sharing. (An exception is region B, where there is still geographic specialization, but to meet the binding no-deviation constraint, collusive equilibrium involves output levels above the monopoly level.) The convexity of the deviation profits in Equation (2) drives the market-sharing result. For the intuition behind this, consider the region C where transport costs are zero and the discount rate is below the threshold $\underline{\delta}$. With transport costs equal to zero, assuming the cartel maintains monopoly output levels in each market (i.e., $\mathrm{q}^*+\mathrm{x}^* = A/2$), the deviation profits when the firms under collusion share output equally in each market ($\Pi^D(A/4, A/4, 0) = 9A^2/32$) is lower than the deviation profits obtained from collusion with maximal geographic specialization ($\Pi^D(A/2, 0, 0) = 10A^2/32$), due to the strict convexity of the deviation payoffs. Thus an equilibrium involving cross-hauling yields the same collusive profits, but is less susceptible to deviation than one involving maximal geographic specialization. Even in a range of discount rates where maximal geographic specialization is not sustainable in the Pinto (1986) model, a collusive equilibrium with market-sharing can be sustained. The same intuition applies in regions D and E, 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. $q^* + x^* > A/2$) in order to make the collusion sustainable.

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 2006). This has led to a rash of prosecutions, which we use as the basis for the data in this paper.[10]

To test the hypotheses outlined above (see Table 1) regarding the impact of a shift from collusion to competition, we examine ten international cartels that ended during the mid- and late-1990s. See Table 2 for a list of the products cartelized, the years of cartel activity, and home countries of cartel participants. 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 cartel agreements covered markets around the world. The products affected by these agreements were in chemicals or food additives. These are relatively homogenous goods, so they are appropriate for testing the models discussed above.

Our choice of the specific cartels examined in this study was driven primarily by data quality concerns. We use trade data from 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 focus unambiguously matches the HS classification for trade in goods.[12] For example, the detailed description for HS 291814 is "Citric Acid," corresponding exactly to the cartel's targeted product. For most of the over one hundred international cartels prosecuted in the last two decades, there is not a clean match to the trade

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[10] See Levenstein and Suslow (2011) for a more detailed description and analysis of other aspects of the dataset that we have created based on these prosecutions.
[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/hscode.cfm).

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. For each of the ten cartels in this study there is a clean match to the trade data so that we can perform the analysis proposed above.

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. Unfortunately, we find that export data are much sparser than import data.[13] For example, France reports methionine imports for most years, but reports exports for only one year. Because France is a large methionine exporter, relying on reported export data would distort the analysis. Therefore, we analyze import data and use reported imports to infer exports.[14]

For each cartel, we use a nine year panel, covering four years before and four years after the breakup. We treat the four year period prior to breakup as "the collusive period." In some cases, the cartel formed long before then, but these 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. In the Comtrade database, we generally observe that the number of reporting countries 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 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, so that larger trade flows are given appropriate weight.[15]

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[13] Also, it is likely that export data are tracked less carefully, as most countries charge duties on imports but not exports.

[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).

[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/kg. The trade-weighted mean price is (10,000*3 +50*20)/10050= $3.08/kg, and hence is a much more appropriate reflection of the price faced by consumers in country A. In regressions of log price or

We define price as the ratio of trade value to trade quantity (in the specific product). That is, we are calculating the average price for each product, for each year, for each bilateral trade pair (see Table 3 for pre and post break up summary statistics for price and concentration for each cartel). 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).[16]

We define import concentration as the *Herfindahl-Hirschman Index* (HHI) of import market shares into a country (for each product, for each year reported in 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 partners, N_{jkt} (reported in Table 3). Note that the concentration measures are defined by importer for each year, and hence the number of observations equals the number of importer-years. (More detailed definitions of the variables used in the analysis are given in the Data Appendix.)

For most of these products, the mean number of partners (between eight and fifteen, see Table 3) is larger than the number of members for any of these cartels (between three and six, see Table 2). 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

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

other hand, *import* concentration ignores domestic production and therefore overstates concentration. As our analysis will examine the *change* in concentration, and company nationality generally does not change over time, our measure should be able to capture any impact of a change in competitive intensity on concentration.

The U.S. Department of Justice's merger guidelines set an HHI of 1800 as the threshold for "highly concentrated" markets.[17] Mean HHI for these markets ranges from 2760 to 5430 (Table 3).[18] Not surprisingly, these are highly concentrated industries.

4. Empirical specifications and baseline results

4.1. Price results

We examine changes in prices using several specifications. First, we compare the average price from the cartel period to the average price after cartel breakup (four years on each side, see Table 3). In each of the ten cartels included in our sample, there is 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.[19] As discussed above, this indicates that, for these ten products, there was a real change in the intensity of competition at the time of the observed cartel dissolution.[20]

Next we consider the possibility that there may be a difference in the impact of cartel breakup in the short run versus the long run. 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

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[17] See http://www.justice.gov/atr/public/guidelines/hmg.htm for the U.S. Department of Justice merger guidelines.

[18] 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.

[19] A decline of 0.076 log points means $\log(P_{post}) - \log(P_{pre}) = -0.076$, which translates to a percentage decline in price (defined as $[(P_{post} - P_{pre})/ P_{pre})]$ equal to $e^{(-0.076)} - 1 = -7.318$ percent.

[20] 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 and Perborates. This may reflect an ineffective cartel or a misreporting of the real date of the cartel's end. In either case, this suggests that trade data for these cartels are not appropriate for testing the models discussed above.

industries.[21] Whether we observe a decline in price after the cartel breakup also depends on the price pattern prior to breakup. In particular, it would not be surprising to observe that prices had begun to fall before the reported date of cartel breakup. In several cases, we know that fringe producers had a growing market share prior to the formal breakup. A growing fringe may even underlie a member firm's decision to reveal the cartel's existence to the authorities. Thus in our analysis here, we distinguish prices during the period immediately before cartel breakup from those during the previous years of collusion.

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:

$$p_{ijt} = \alpha_0 + \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{LPOST} + f_{ij} + \epsilon_{ijt} \tag{5a}$$

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.[22] The subscript i denotes exporting country, j denotes importing country and t denotes year. 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.

We find significant declines in price for all ten of these cartels, both in the short and long run (Table 4). The short run price declines vary from 0.045 log points (4.40%) for Citric Acid to

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

[22] 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. Also, as discussed in detail in Section 3, to control for the influence of small value outlier observations, these regressions (and all analysis in this section) weight observations by the trade quantity, and prices are truncated by 2% on both tails of the distribution for each product.

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.

In order to test implications of the theoretical models for trade patterns and concentration, we want the cartel breakups to correspond to a true change in competitive intensity. There is a 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:

$$p_{ijt} = \alpha_{SPRE} D_{SPRE} + \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{LPOST} + f_{ij} + \epsilon_{ijt} \qquad (5b)$$

where all terms are defined as in equation (1a) 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.[23]

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). We find no common pattern among these cartels in pre-breakup price trends (column 5 of Table 5). In some cartels, prices were actually increasing immediately prior to breakup (e.g, Vitamin B2). Even in cases where there was a statistically significant decline prior to cartel breakup (e.g. Vitamin A), prices fall even more after breakup (i.e., $\alpha_{SPOST} - \alpha_{SPRE}$, presented in column 1 of Table 5, is negative). Thus in almost all cases there appears to have been large and significant relative declines in prices following the cartel breakup, consistent with a significant increase in competitive intensity.[24]

Table 5, columns 1 and 2, confirm large and statistically significant declines in prices even when comparing to the short-run pre-breakup period only (years *t*-2 and *t*-1). 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.

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[23] Again, we exclude data for the breakup year from the analysis.

[24] Table 5, column 6 of presents a statistical test of the difference between the short-run and long-run post-breakup periods (i.e. $\alpha_{LPOST} - \alpha_{SPOST}$). Consistent with the discussion above, in most cases there is 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 (0.56 log points relative to -0.255 log points).

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

$$p_{ijt} = \sum_{s=-4}^{+4} \alpha_s D_S + f_{ij} + \epsilon_{ijt} \quad (5c)$$

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 ten 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.[25]

4.2. Impact on trade patterns

Having established that these ten 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. In contrast, the market sharing models predict less rearrangement, as there can be market sharing even under the collusive regime.

[25] Vitamin A's price pattern shows a sharp decline in 1997 and little decline after the formal breakup of the cartel in 1999. This reflects intervention by FBI agents in March 1997 that undermined coordination. 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).

We first let the data speak for itself, reporting the weighted average distance travelled by imports of each cartelized product, 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. We then plot δ_{kt} over time in Figure 4. While overall these figures suggest an increasing trend in distance travelled, there is no significant break in trend around the collapse of most of the cartels (unlike the stark breaks we found for price).

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

$$m_{ijt} = \alpha_d d_{ij} + \alpha_{SPRE} D_{SPRE} d_{ij} + \alpha_{SPOST} D_{SPOST} d_{ij} + \alpha_{LPOST} D_{LPOST} d_{ij} + \beta X_{ijt} + f_i + f_j + f_t + \epsilon_{ijt} \qquad \text{(6a)}$$

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_{SPPRE}, 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:

$$\begin{aligned} P(D_{ijt} = 1 \mid \text{observed variables}) = \Phi(&\alpha_d d_{ij} + \alpha_{SPRE} D_{SPRE} d_{ij} + \alpha_{SPOST} D_{SPOST} d_{ij} \\ &+ \alpha_{LPOST} D_{LPOST} d_{ij} + \beta H_{ijt} + f_i + f_j + f_t) \end{aligned} \qquad \text{(6b)}$$

where D_{ijt} is a dummy indicating non-zero exports from exporter *j* to importer *i* in year *t*, $\Phi(.)$ is the cdf of the unit normal distribution, and H_{ijt} is a set of control variables (see Data Appendix, section D2 for details).[28] We allow the coefficient on distance in this propensity equation to vary

[26] There are different ways to define bilateral distance. See the data appendix for the precise definition we use.

[27] Following Cheng and Wall (2005), we check the robustness of our results to using bilateral trade-pair fixed effects in Section 5.1.

[28] Because specification (6b) 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). See Data appendix

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, then 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 (6a) to include two terms to address bias from sample selection and unobserved firm heterogeneity, respectively: $\ln\{\exp[\delta(\hat{z}^*_{ijt}+\hat{\bar{\eta}}^*_{ijt})]-1\}+\beta_{u\eta}\hat{\bar{\eta}}^*_{ijt}$, where $\hat{\bar{\eta}}^*_{ij}=\phi(\hat{z}^*_{ij})/\Phi(\hat{z}^*_{ij})$, $\hat{z}^*_{ij}=\Phi^{-1}(\hat{\rho}_{ij})$, and $\rho_{ijt}=P(D_{ijt}=1\,|\,W_{ijt})$. To control for the first term flexibly, we follow one of the approaches suggested by HMR and include a 3rd degree polynomial in $\hat{z}^*_{ij}$. Thus we obtain the following "sample-selection and unobserved heterogeneity corrected" gravity equation:

$$\begin{aligned} m_{ijt} &= \alpha_d d_{ij} + \alpha_{SPRE} D_{SPRE} d_{ij} + \alpha_{SPOST} D_{SPOST} d_{ij} + \alpha_{LPOST} D_{LPOST} d_{ij} \\ &\quad + \beta X_{ijt} + f_i + f_j + f_t + \beta\hat{\bar{\eta}}^*_{ijt} + \sum_{k=1}^{3}\gamma_k(\hat{z}^*_{ijt})^k + \epsilon_{ijt} \end{aligned} \tag{6c}$$

The results for the distance coefficient interactions for the propensity specification (6b) are reported in Table 6. Overall, 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. 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.

Similarly, our HMR-corrected gravity estimates are generally consistent with market sharing models (Table 7). We find no statistically significant changes in the distance coefficient

for a detailed list and definitions of the variables included in the gravity equation (6a) and the probit equation (6b).

for most 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]

We also examine year-by-year changes around the breakup year in Figures 5a and 5b. The specifications are the same as in equations (6b) and (6c) respectively, except that the distance variable is interacted with period dummies (similar to specification 5c). The figures confirm the results in Table 6 and 7. In particular, in Figure 5a, the two cartels with steady declines in the coefficients on distance are Citric Acid and Vitamin C, but these appear to be the result of a pre-existing trend.[30] 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 5b, 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.

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. Our results are robust to a number of robustness checks, discussed in Section 5.1 below. While these ten markets may not be representative of trade patterns in all collusive markets, they do suggest that international collusion is consistent with market sharing and cannot be ruled out by the observation of significant trade between countries.

4.3. Concentration results

We analyze two measures of concentration: import HHI and the number of partners. Our descriptive statistics suggest little or no change in concentration for most of these cartels

[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).

[30] For four cartels – Citric Acid, Vitamin B1, Vitamin C 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 B1 and Vitamin E, these effects disappear in the longer term (columns 1b and 2b). For Citric Acid and Vitamin C the trend analysis (Figure 5a) 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.

(Table 3). The number of partners generally increases, with significant increases for four cartels. This may, however, reflect overall globalization.

To isolate the impact of changes in competitive intensity, we examine regression specifications similar to those above, but with a measure of concentration (HHI or number of partners) as the dependent variable:[31]

$$CONC_{it} = \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{LPOST} + f_i + \epsilon_{it} \quad (7a)$$

$$CONC_{it} = \alpha_{SPRE} D_{SPRE} + \alpha_{SPOST} D_{SPOST} + \alpha_{LPOST} D_{LPOST} + f_i + \epsilon_{it} \quad (7b)$$

We find no statistically significant changes in the HHI measure for most cartels (Table 8, columns 1a through 2b). Neither is there a significant change in the number of partners for seven of the cartels (Table 8, columns 3a through 4b). Overall then there is no significant change in concentration for most cartels. These results are confirmed in Figure 6, which captures year-to year changes in HHI (using a specification similar to 5c). Once again, these results are more consistent with market sharing models of collusion, than with geographic specialization models that would predict a dramatic change in concentration following cartel breakup.

5. Robustness checks

5.1. Robustness checks of baseline price, distance and concentration results

We check our baseline results using a number of robustness tests. In each case, we find the results are consistent with those above. The price decline results are robust to three types of tests: (i) using FOB prices, which eliminates the possibility that are results are driven by changes in transport costs;[32] (ii) using price levels (as opposed to log prices); and (iii) using a sample of

[31] 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.

[32] 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

imports from countries where cartel members are headquartered (Appendix Table A.1). 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);[33] (ii) using the Poisson pseudo-maximum-likelihood (PPML) estimator proposed by Silva and Tenreyo (2006, Appendix Table A.2, columns 2a and 2b);[34] and (iii) using measures of import and export market shares as dependent variables (Appendix Table A.2, columns 3a-3b and 4a-4b, respectively).[35]

We reproduced the results for the gravity regressions for a subsample restricted to Europe (Appendix Table A.3, columns 2a and 2b). We also reproduced these results for 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).[36] Finally, we find the concentration results robust to using alternative measures of concentration (Appendix Table A.4, columns 1 and 2).[37] We also examined measures of market share instability (Caves and Porter 1978) and find no significant

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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.

[33] 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 not available or do not vary during the period in which we are interested.

[34] 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.

[35] 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.

[36] In unreported regressions, we also checked whether the gravity equation results are affected by the rise of Chinese exports by excluding Chinese imports -- we found results were robust.

[37] 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.

increases in this measure either close to or after the cartel breakup (Appendix Table A.4, columns 3 and 4).[38]

Finally, we undertook two sets of difference-in-differences (DID) analyses, to try to rule out effects from extraneous shocks. In particular, we used two related products as controls: (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 that all of our cartelized products belong to. 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 could serve as valid control groups. The results from the DID analysis (in Appendix Table A.5) confirm our baseline results. In particular, we find that even relative to the control products, the cartelized products in almost all cases show large difference-in-differences declines in price, but we find no systematic patterns for changes in concentration or in the coefficient on distance.[39]

5.2. An alternative explanation: geographic specialization and Bertrand competition

Our results also appear to be consistent with geographic specialization during collusion, but in which competitive reversion takes the form of Bertrand competition. With positive transportation costs, Bertrand competition also leads to geographic specialization. Such a model is proposed by Gross and Holahan (2003). Their model predicts no change in trade patterns after the breakup of a cartel: there is no cross-hauling during collusion or during competition. In this respect, it is observationally equivalent to the market sharing models discussed above.

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[38] 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.

[39] The comparison to enzymes and other organic chemicals allows us to control for exogenous changes in trading patterns affecting either animal additives or organic chemicals generally. The price coefficients are noisier, particularly relative to organic chemicals nes, 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 the geographic specialization models. (Coefficients are positive and significant for two cartels relative to organic chemicals nes, negative in some cases and positive in couple of others relative to enzymes.)

In order to distinguish these two alternative interpretations of our empirical results, we look for evidence of cross-hauling. Substantial cross-hauling would not be consistent with geographic specialization (under both collusion and competition) predicted by Gross and Holahan, but would be consistent with the market sharing models discussed in Section 2. We find that cartel home countries received imports, even from other cartel member home countries, during collusion. In Table 9 (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 (columns 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 cartel home countries that come from other cartel member countries. We find that, except in the case of Vitamin B1, other cartel countries account for a significant share of imports into other cartel countries, ranging from 22.2% (15.7%) for Vitamin B3 to 91% (83.3%) for Vitamin A in the pre-breakup (post-breakup) period. Thus our analysis finds significant cross-hauling, even from other cartel countries both before and after the cartel breakup. 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 9, columns 3a-4c). In fact, for most cartels, we find lower concentration in markets adjacent to cartel home countries.[40] This, again, suggests that trade patterns are more consistent with the Cournot, market-sharing models than with the Gross-Holahan Bertrand model.

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[40] 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

6. Discussion of results and conclusions

We examine the effect of changes in competitive intensity on trade patterns using data from ten 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.

We draw on 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.[41]

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

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some of them may be adjacent to other cartel locations), as the firms price to drive out competitors from close-by markets.

[41] 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.

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.[42]

In addition to the lower defection profits emphasized in the theoretical models, we conjecture that another reason for our results could be the nature of marketing costs and customer-supplier relationships in the products we study. All the products we study are intermediate goods, involving business-to-business marketing. In many cases, both customers and producers are global firms. Market division schemes that assign customers 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. Future models might benefit from greater attention to the role of relational capital and marketing costs.[43]

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[42] 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 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).

[43] Arkolakis (2009) is a recent paper that emphasizes the role of marketing costs in trade.

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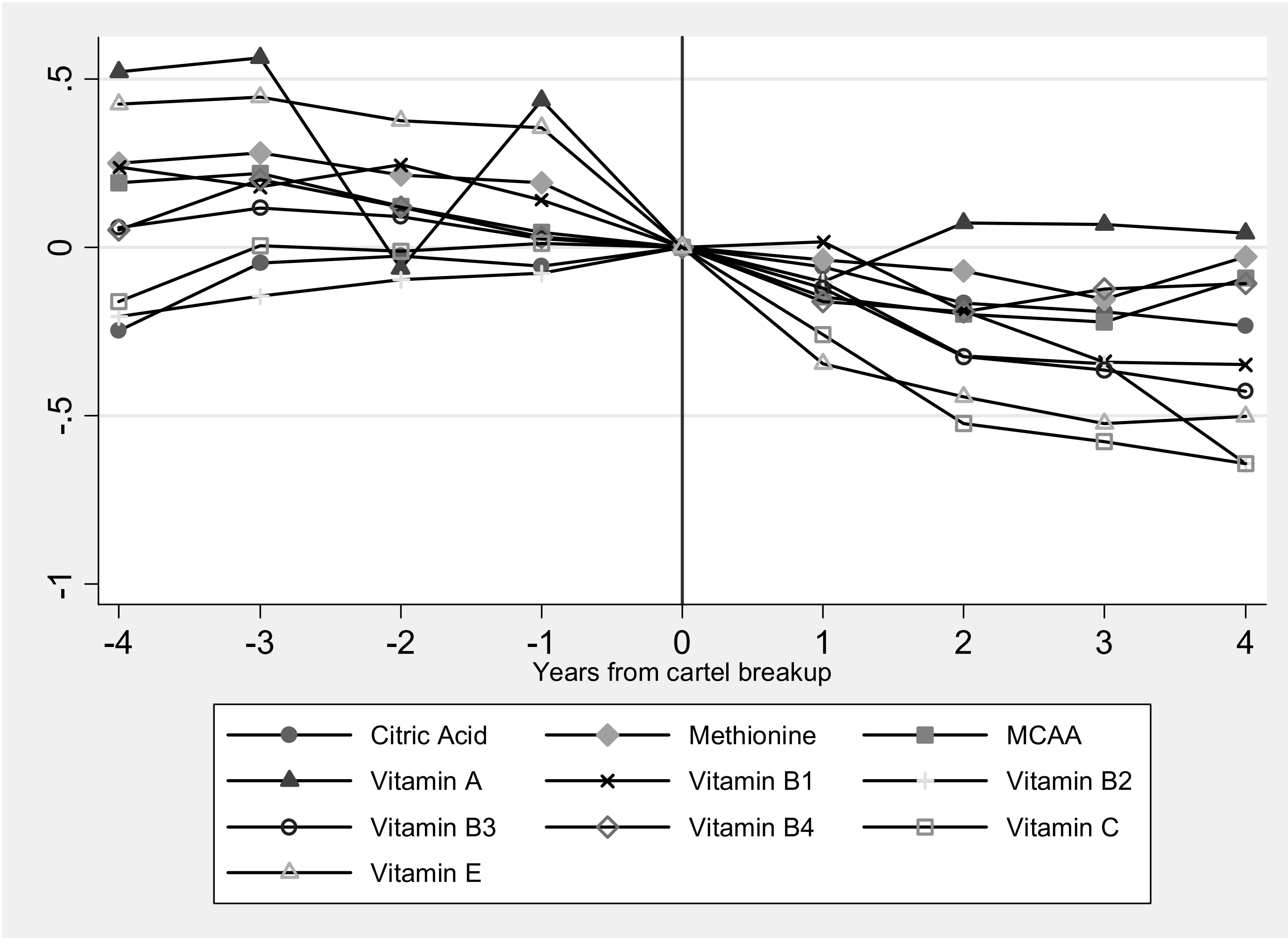
Figure 1: Price changes following cartel breakup



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.

Table 1: Summary of theoretical predictions

Model	Collusion	Competition	Empirical Prediction	
			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)

Figure 2: Sustainable collusive equilibria

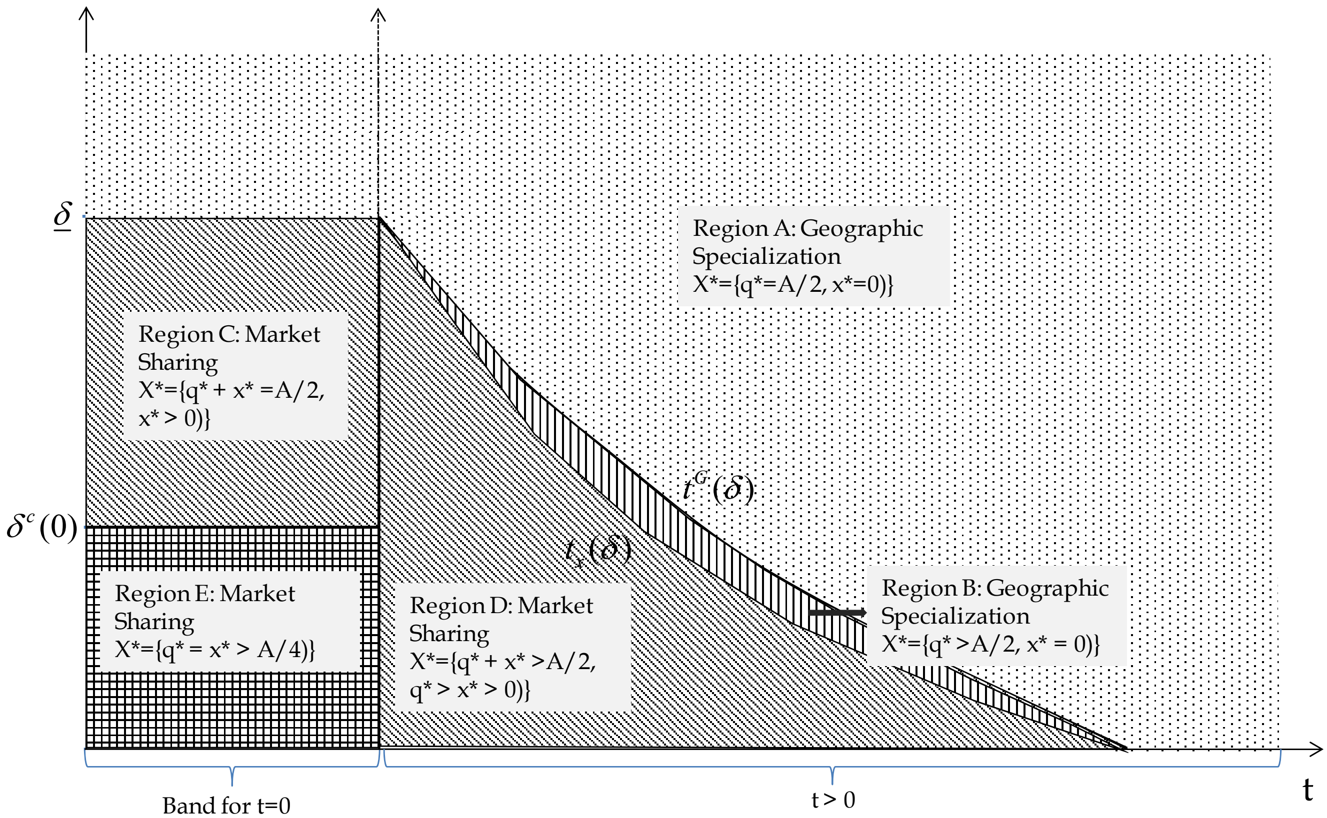


Table 2: Cartel demographics

Product	HS code	Start year	End year	Duration (years)	Number member firms	Home (headquarter) country of member firms
Citric Acid	291814	1991	1995	5	5	Austria, Germany, France, Switzerland, US
Methionine[2]	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 B1 (Thiamin)	293622	1991	1994	4	3	Switzerland, Japan
Vitamin B2 (Riboflavin)	293623	1991	1995	5	3	Germany, Switzerland, Japan
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 C (Ascorbic Acid)	293627	1991	1995	5	4	Germany, Switzerland, Japan
Vitamin E	293628	1989	1999	11	4	Germany, Switzerland, Japan, France

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

Table 3: Summary statistics, and changes in price and concentration measures (post-breakup versus pre-breakup)

	Log Price			HHI			Number of 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 B1									
N	803	1,701		137	305		137	305	
Mean	3.464	3.068	-0.396	0.428	0.543	0.115	8.370	9.751	1.381
SD (p-value)	0.345	0.466	(0.000)	0.156	0.243	(0.030)	2.497	2.455	(0.008)
Vitamin B2									
N	1,021	1,773		169	302		169	302	
Mean	3.732	3.424	-0.308	0.423	0.429	0.006	9.633	10.431	0.798
SD (p-value)	0.316	0.452	(0.000)	0.171	0.133	(0.884)	2.294	2.911	(0.152)
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)

	Log Price			HHI			Number of Partners		
	Pre-breakup	Post-breakup	Diff (Post-Pre)	Pre-breakup	Post-breakup	Diff (Post-Pre)	Pre-breakup	Post-breakup	Diff (Post-Pre)
Vitamin C									
N	1,653	3,229		193	400		193	400	
Mean	2.482	1.969	-0.513	0.289	0.306	0.016	14.414	14.331	-0.084
SD (p-value)	0.181	0.292	(0.000)	0.102	0.084	(0.332)	5.113	3.416	(0.933)
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 changes in log price relative to 4-year pre-breakup period (Specification 5a)

	Short-run effect (SPOST)	Long-run effect (LPOST)
	1	2
Citric Acid	-0.045	-0.142
	(0.054)	(0.000)
Methionine	-0.288	-0.323
	(0.000)	(0.000)
MCAA	-0.311	-0.301
	(0.000)	(0.000)
Vitamin A	-0.331	-0.272
	(0.030)	(0.056)
Vitamin B1	-0.282	-0.538
	(0.000)	(0.000)
Vitamin B2	-0.113	-0.387
	(0.084)	(0.003)
Vitamin B3	-0.308	-0.463
	(0.000)	(0.000)
Vitamin B4	-0.278	-0.223
	(0.000)	(0.000)
Vitamin C	-0.379	-0.588
	(0.000)	(0.000)
Vitamin E	-0.797	-0.915
	(0.000)	(0.000)

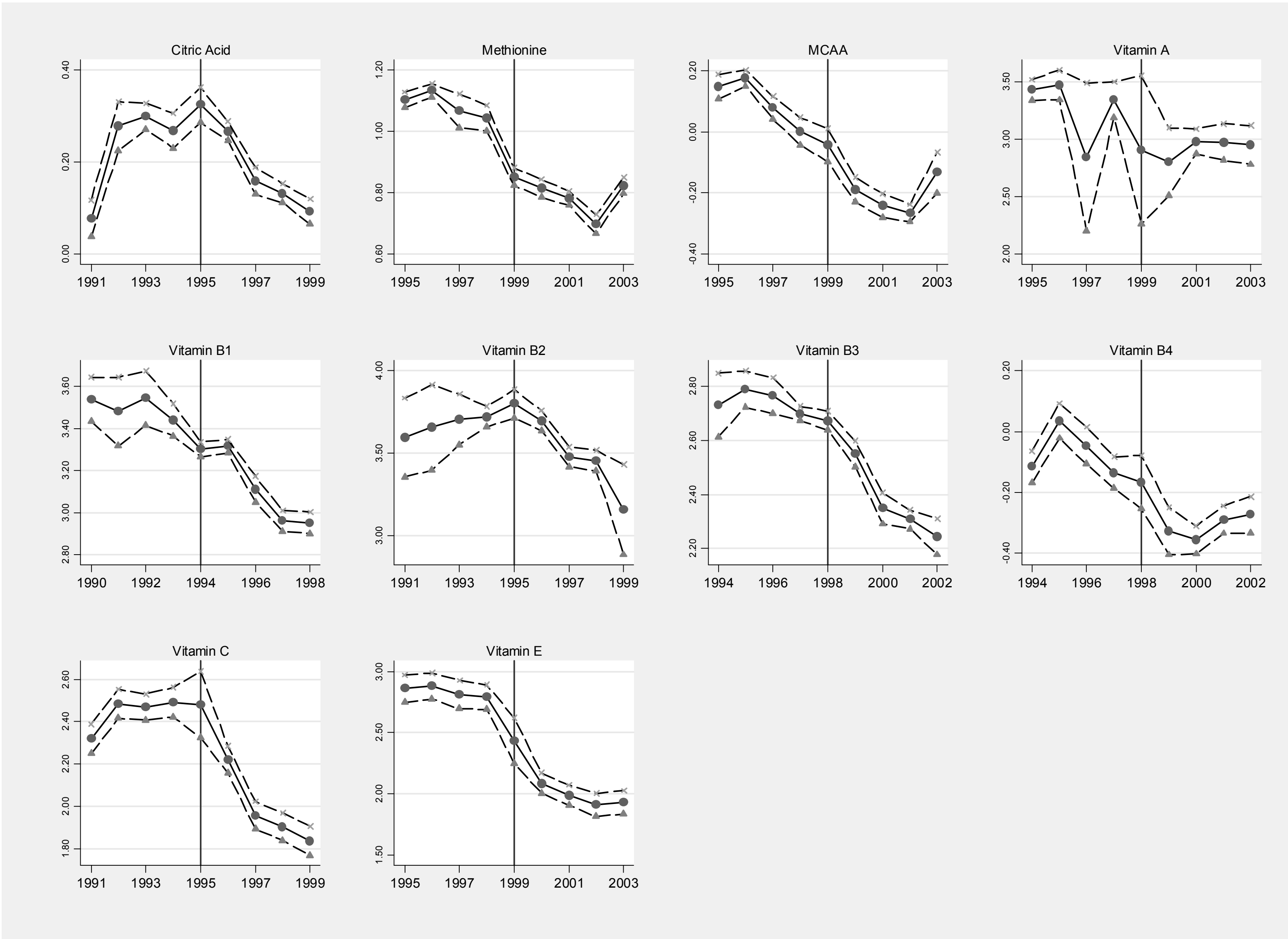
Notes: For each cartel that breaks up in year t, sample includes data on eight years: t-4 to t-1, and t+1 to t+4 (i.e. break-up year t is excluded). SPOST refers to the short-run post-breakup period (years t+1 and t+2, for breakup year t). LPOST refers to the long-run post-breakup period (years t+3 and t+4). PRE refers to the 4-year pre-breakup period (years t-4 to t-1). SPOST-PRE indicates difference in means between periods SPOST and PRE. 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.

Table 5: Log price changes – detailed breakup of pre- and post-breakup effects (Specification 5b)

	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	-0.172	0.013	-0.084	0.088	-0.097
	(0.002)	(0.000)	(0.641)	(0.008)	(0.000)	(0.000)
Methionine	-0.259	-0.294	-0.323	-0.358	-0.064	-0.035
	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.009)
MCAA	-0.254	-0.244	-0.376	-0.366	-0.122	0.010
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.685)
Vitamin A	-0.173	-0.113	-0.537	-0.477	-0.364	0.060
	(0.448)	(0.600)	(0.000)	(0.000)	(0.078)	(0.536)
Vitamin B1	-0.275	-0.530	-0.295	-0.550	-0.020	-0.255
	(0.000)	(0.000)	(0.002)	(0.000)	(0.629)	(0.000)
Vitamin B2	-0.141	-0.414	-0.049	-0.322	0.092	-0.273
	(0.002)	(0.000)	(0.710)	(0.093)	(0.403)	(0.003)
Vitamin B3	-0.291	-0.447	-0.329	-0.485	-0.038	-0.156
	(0.000)	(0.000)	(0.000)	(0.000)	(0.553)	(0.000)
Vitamin B4	-0.255	-0.199	-0.309	-0.253	-0.054	0.056
	(0.000)	(0.000)	(0.000)	(0.000)	(0.086)	(0.029)
Vitamin C	-0.401	-0.610	-0.335	-0.544	0.066	-0.209
	(0.000)	(0.000)	(0.000)	(0.000)	(0.212)	(0.000)
Vitamin E	-0.766	-0.884	-0.837	-0.955	-0.071	-0.118
	(0.000)	(0.000)	(0.000)	(0.000)	(0.012)	(0.009)

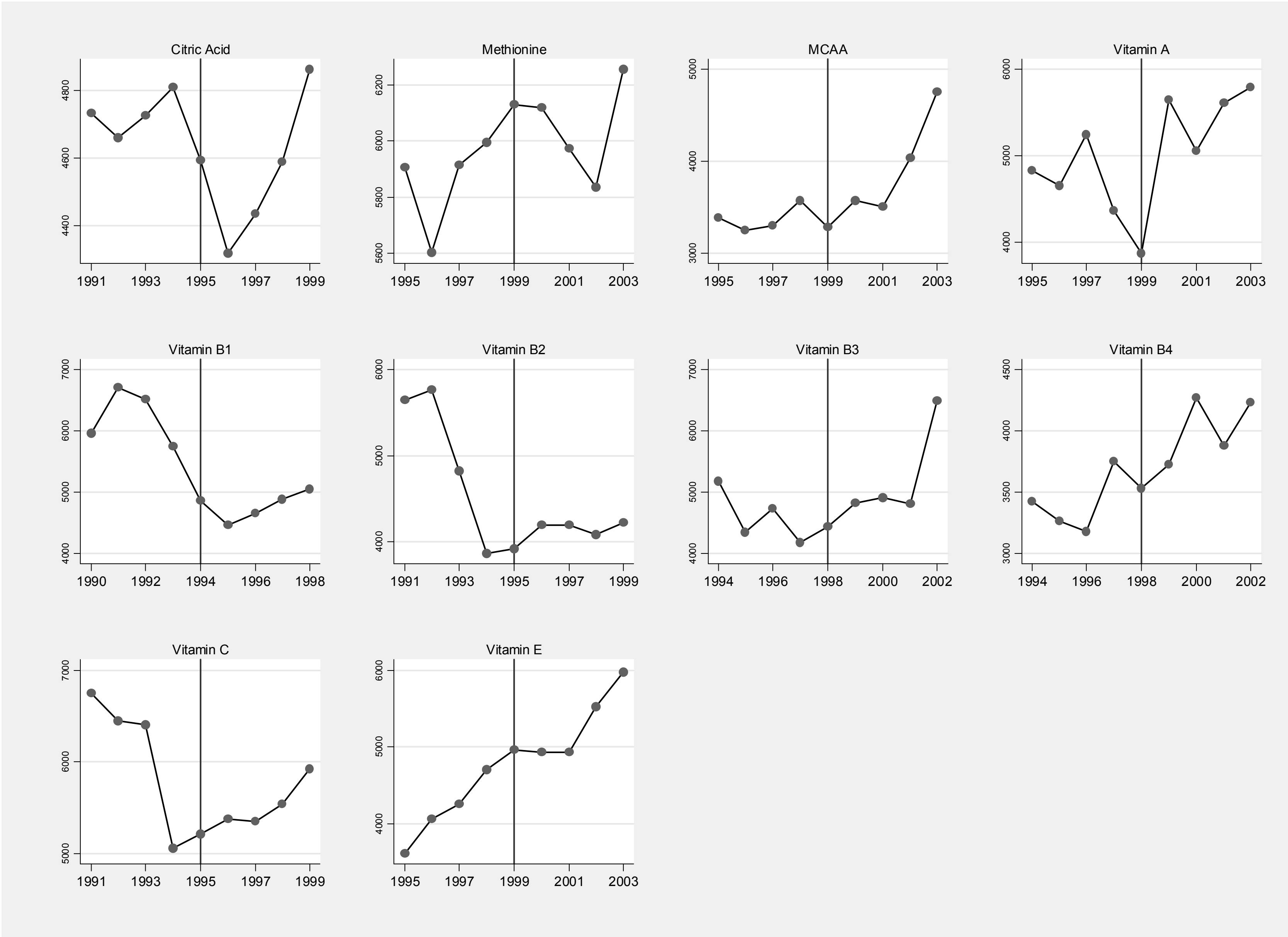
Notes: For each cartel that breaks up in year t, sample includes data on eight years: t-4 to t-1, and t+1 to t+4 (i.e. break-up year t is excluded). SPOST refers to the short-run post-breakup period (years t+1 and t+2, for breakup year t). LPOST refers to the long-run post-breakup period (years t+3 and 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 3: 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 errors. For Vitamin B1 the estimated start year is 1991, less than 4 years before the estimated breakup year.

Figure 4: Average distance travelled (by unit quantity)



Notes: The figures plot the quantity weighted average distance travelled by a unit quantity.

Table 6: Effect of cartel breakup on distance coefficient on propensity to trade

	Relative to 4-year pre-breakup period		Relative to short-term pre-breakup period: Short-run effect	Relative to short-term pre-breakup period: Long-run effect
	SPOST-PRE	LPOST-PRE	SPOST-SPRE	LPOST-SPRE
	1a	1b	2a	2b
Citric Acid	-0.111	-0.159	-0.096	-0.144
	(0.015)	(0.000)	(0.025)	(0.000)
Methionine	0.012	-0.007	0.009	-0.010
	(0.792)	(0.868)	(0.850)	(0.820)
MCAA	-0.018	-0.055	-0.030	-0.067
	(0.658)	(0.296)	(0.508)	(0.250)
Vitamin A	-0.007	0.012	-0.014	0.005
	(0.862)	(0.811)	(0.736)	(0.930)
Vitamin B1	-0.150	-0.093	-0.125	-0.068
	(0.003)	(0.102)	(0.018)	(0.230)
Vitamin B2	-0.027	-0.065	0.022	-0.022
	(0.573)	(0.256)	(0.823)	(0.834)
Vitamin B3	-0.022	-0.021	-0.042	-0.041
	(0.573)	(0.641)	(0.296)	(0.400)
Vitamin B4	-0.049	-0.085	-0.051	-0.088
	(0.152)	(0.047)	(0.156)	(0.040)
Vitamin C	-0.118	-0.163	-0.125	-0.169
	(0.018)	(0.002)	(0.009)	(0.000)
Vitamin E	-0.084	-0.017	-0.097	-0.030
	(0.042)	(0.760)	(0.024)	(0.600)

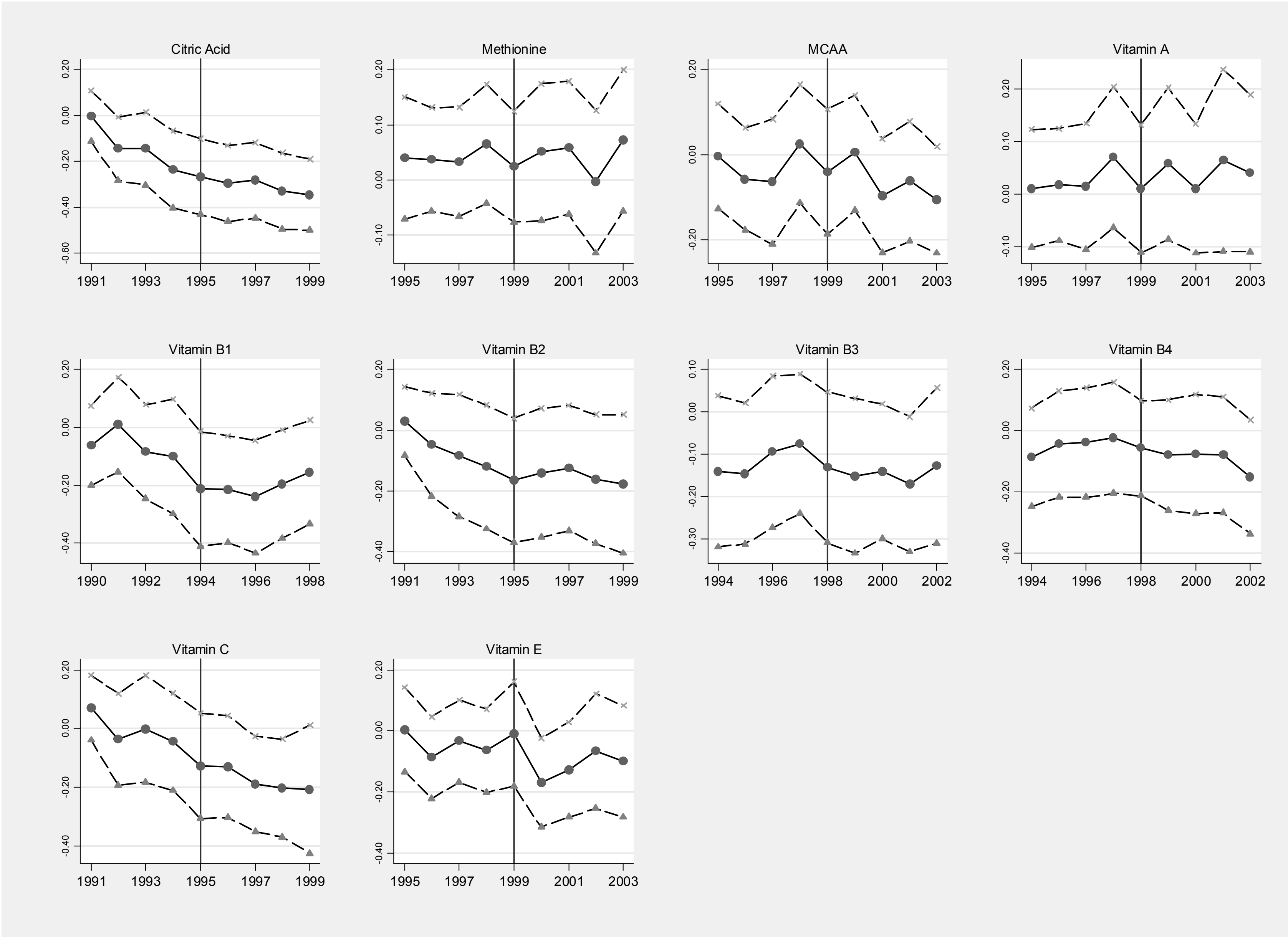
Notes: The dependent variable in the probit propensity estimation is a dummy =1 if there is non-zero trade between a country pair. SPOST refers to the short-run post-breakup period (years t+1 and t+2, for breakup year t). LPOST refers to the long-run post-breakup period (years t+3 and t+4). PRE refers 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). 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 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	
			Short-run effect	Long-run effect
	SPOST_PRE	LPOST_PRE	SPOST_SPRE	LPOST_SPRE
	1a	1b	2a	2b
Citric Acid	0.122	0.110	0.157	0.166
	(0.215)	(0.378)	(0.076)	(0.130)
Methionine	-0.007	-0.008	0.016	-0.014
	(0.932)	(0.920)	(0.814)	(0.860)
MCAA	-0.079	-0.023	0.093	0.473
	(0.553)	(0.938)	(0.501)	(0.020)
Vitamin A	0.024	-0.011	0.037	0.052
	(0.789)	(0.905)	(0.712)	(0.560)
Vitamin B1	-0.021	-0.213	-0.029	-0.222
	(0.933)	(0.244)	(0.884)	(0.130)
Vitamin B2	-0.016	-0.054	0.012	-0.036
	(0.726)	(0.310)	(0.907)	(0.740)
Vitamin B3	0.101	0.003	0.161	0.062
	(0.302)	(0.974)	(0.127)	(0.580)
Vitamin B4	0.101	0.033	0.135	0.109
	(0.461)	(0.875)	(0.219)	(0.380)
Vitamin C	0.062	0.076	0.213	0.283
	(0.805)	(0.822)	(0.257)	(0.250)
Vitamin E	0.163	0.022	0.221	0.057
	(0.220)	(0.775)	(0.059)	(0.430)

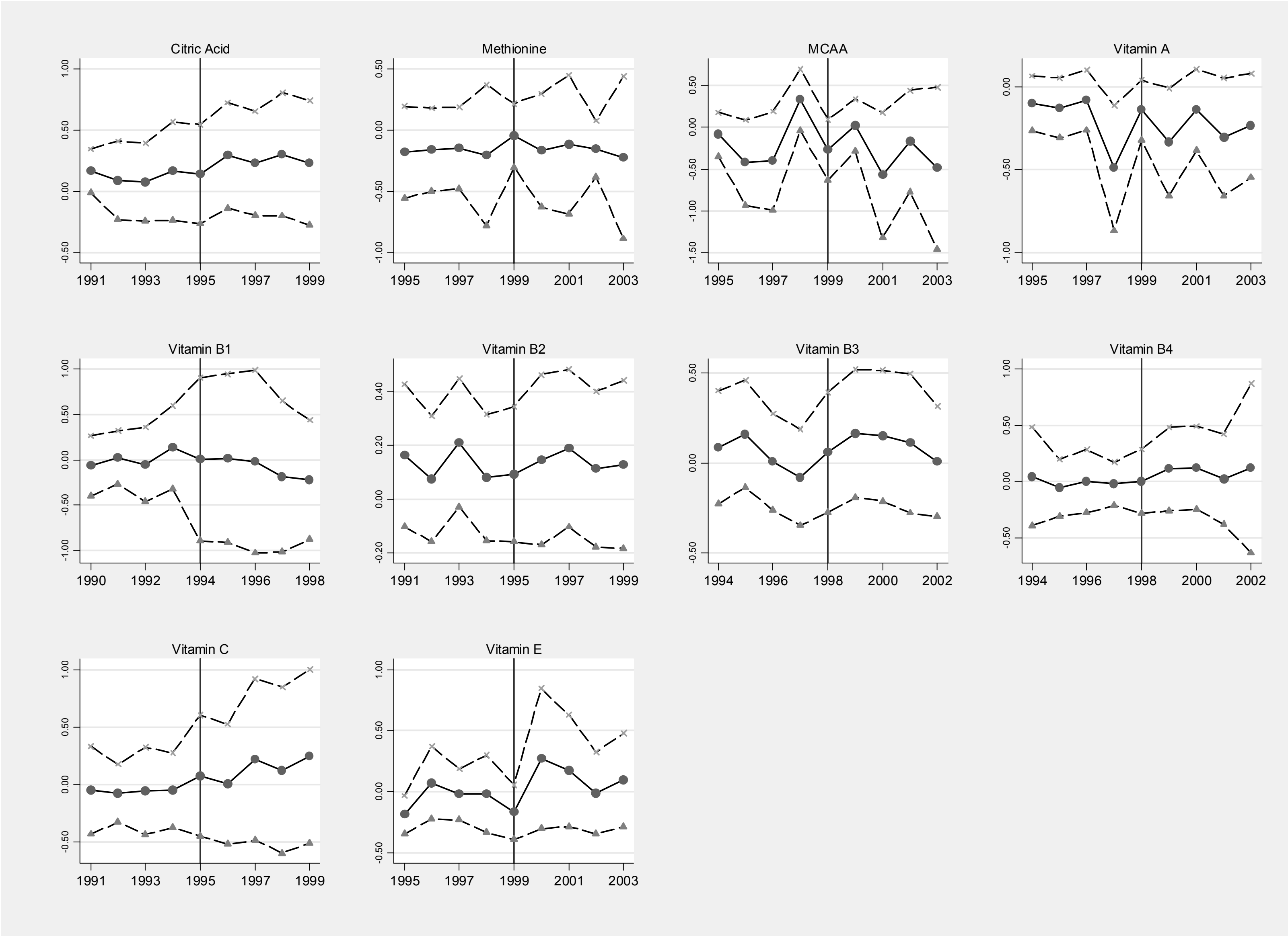
Notes: The dependent variable in the gravity equation is log trade value. SPOST refers to the short-run post-breakup period (years t+1 and t+2, for breakup year t). LPOST refers to the long-run post-breakup period (years t+3 and t+4). PRE refers to the 4-year pre-breakup period (years t-4 to t-1).SPRE 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.

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



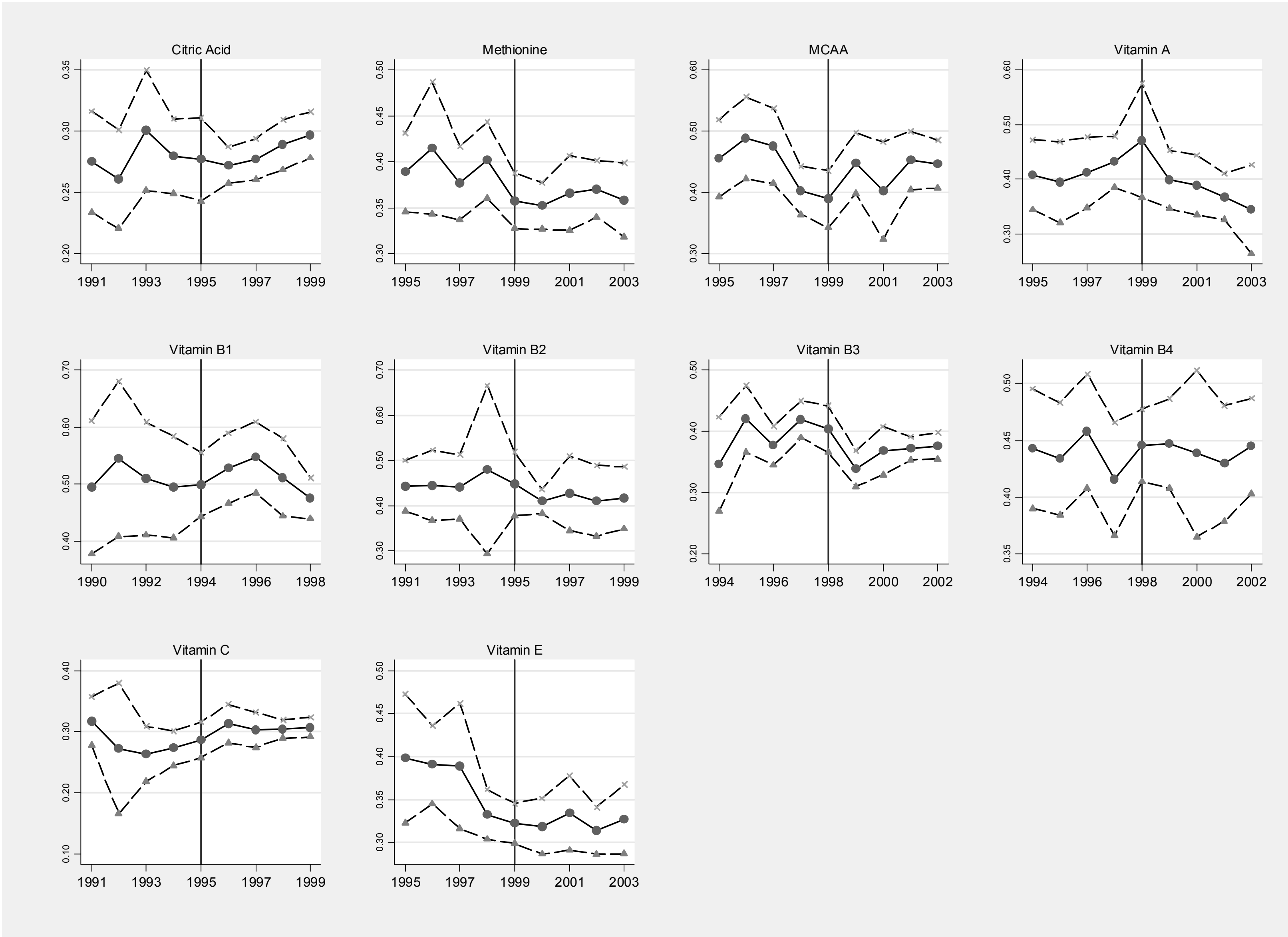
Notes: The dependent variable in the gravity equation is log trade value. All regressions include exporter, importer fixed effects and year effects, and include correction for zero-trade based on Helpman et al (2008). Other controls are discussed in the text and data appendix. Confidence intervals use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

Table 8: Changes in concentration measures

	HHI				Number of 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	0.009	-0.019	0.001	-0.325	-0.060	-0.632	-0.367
	(0.491)	(0.655)	(0.293)	(0.970)	(0.606)	(0.936)	(0.330)	(0.640)
Methionine	-0.037	-0.032	-0.039	-0.034	0.498	0.541	0.818	0.863
	(0.173)	(0.351)	(0.116)	(0.320)	(0.271)	(0.411)	(0.096)	(0.170)
MCAA	-0.003	0.000	0.020	0.024	0.270	0.217	-0.160	-0.215
	(0.863)	(0.999)	(0.224)	(0.140)	(0.631)	(0.687)	(0.670)	(0.680)
Vitamin A	-0.037	-0.070	-0.038	-0.071	0.768	1.632	0.762	1.627
	(0.206)	(0.046)	(0.258)	(0.050)	(0.299)	(0.007)	(0.400)	(0.020)
Vitamin B1	0.020	-0.023	0.019	-0.024	0.972	1.042	0.640	0.710
	(0.706)	(0.610)	(0.745)	(0.610)	(0.000)	(0.017)	(0.000)	(0.120)
Vitamin B2	-0.041	-0.032	-0.042	-0.033	1.131	1.089	0.857	0.815
	(0.379)	(0.613)	(0.456)	(0.660)	(0.348)	(0.177)	(0.437)	(0.230)
Vitamin B3	-0.036	-0.022	-0.042	-0.029	1.725	0.438	1.639	0.350
	(0.107)	(0.247)	(0.047)	(0.130)	(0.009)	(0.679)	(0.007)	(0.730)
Vitamin B4	-0.005	-0.017	-0.005	-0.017	0.601	0.673	0.555	0.626
	(0.675)	(0.730)	(0.731)	(0.750)	(0.408)	(0.199)	(0.275)	(0.030)
Vitamin C	0.027	0.024	0.034	0.031	-0.457	-0.453	-0.773	-0.769
	(0.136)	(0.319)	(0.010)	(0.110)	(0.531)	(0.478)	(0.310)	(0.220)
Vitamin E	-0.045	-0.054	-0.026	-0.036	1.863	2.309	1.243	1.697
	(0.050)	(0.016)	(0.328)	(0.150)	(0.002)	(0.004)	(0.073)	(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.

Figure 6: HHI (concentration) 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.

Table 9: Measures of extent of cross-hauling

	Imports share of total trade for cartel home countries		Imports from other cartels share of total imports		Mean HHI: Pre-breakup period			Mean HHI: Post-breakup period		
	Pre-breakup	Post-breakup	Pre-breakup	Post-breakup	Cartel border	Other	Diff	Cartel border	Other	Diff
	1a	1b	2a	2b	3a	3b	3c	4a	4b	4c
Citric Acid	55.0%	53.5%	36.5%	29.4%	0.293	0.371	-0.078	0.277	0.324	-0.047
							(.386)			(.341)
Methionine	25.4%	20.8%	27.2%	28.4%	0.324	0.454	-0.13	0.303	0.366	-0.063
							(.026)			(.147)
MCAA	18.3%	16.4%	74.6%	72.7%	0.315	0.52	-0.205	0.365	0.502	-0.137
							(.030)			(.112)
Vitamin A	22.1%	23.8%	91.0%	83.3%	0.404	0.34	0.064	0.371	0.327	0.044
							(.587)			(.477)
Vitamin B1	44.0%	20.2%	0.5%	7.1%	0.509	0.366	0.143	0.562	0.538	0.024
							(.000)			(.890)
Vitamin B2	30.0%	21.9%	41.8%	61.7%	0.610	0.354	0.256	0.490	0.320	0.17
							(.146)			(.000)
Vitamin B3	60.0%	49.8%	22.2%	15.7%	0.551	0.359	0.192	0.429	0.332	0.097
							(.098)			(.248)
Vitamin B4	38.6%	29.4%	71.1%	71.2%	0.234	0.463	-0.229	0.256	0.424	-0.168
							(.037)			(.055)
Vitamin C	39.8%	35.5%	29.1%	21.3%	0.256	0.312	-0.056	0.292	0.332	-0.04
							(.035)			(.082)
Vitamin E	23.8%	29.7%	76.4%	56.5%	0.325	0.358	-0.033	0.333	0.302	0.031
							(.648)			(.569)

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

Data appendix

D1. Definitions for key variables

1. *Importer (or reporter):* the country reporting the data (on imports).
2. *Exporter (or partner):* the country that is the source of reported imports.
3. *Trade value*: total trade value in nominal US$.
4. *Trade quantity*: total trade quantity (in reported units).
5. *Price*: the ratio of trade value to trade quantity, truncated by 2% on both tails of the distribution.[44]
6. *Herfindahl-Hirschman Index (HHI)*: the sum of the squares of the relative size of all importers in the country. $HHI_{jkt} = \sum_{i=1}^{N_{jkt}} (S_{ijkt})^2$

   where 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, and N_{jkt} is the number of countries exporting product *k* to country *j* in period *t*.
7. *Number of partners:* N_{jkt} is the number of countries exporting product *k* to country *j* in period *t*.
8. *Absolute share instability:* the sum of the absolute value of changes in shares between year t and year t-1. Defining $S_{i,j,t}$ as the market share of importer i of total value of imports entering country j in year t (for product k – this index is suppressed throughout this and the next definition), and $N_{j,t}$ as the total number of importers in country j in year t:[45] $\text{ASHVOL}_{\text{j,t}} = \sum_{i=1}^{N_{j,t}} \left| S_{i,j,t} - S_{i,j,t-1} \right|$.
9. *Relative share instability:* the 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. Defining $S_{i,j,t}$ as the market share of importer i of total value of imports entering country j in year t, and $N_{j,t}$ as the total number of importers in country j in year t: $\text{RSHVOL}_{\text{j,t}} = \sum_{i=1}^{N_{j,t}} \frac{\left| S_{i,j,t} - S_{i,j,t-1} \right|}{0.5\,(S_{i,j,t} + S_{i,j,t-1})}$.
10. *Import market share:* S_{ijkt} is as defined as in 6 above, i.e., as the market share of export country *i* in the total value of imports of product *k* entering country *j*.
11. *Export market share:* X_{ijkt} is defined as the share of the exports going to country j in the total value of exports of product *k* by exporter country *i.*

D2. Definitions for control variables used in the trade dummy probit and gravity regressions:

Most of these control variables are based on Helpman, Melitz and Rubinstein (2008) and defined identically (except for the distance variable). Data on these variables were obtained from multiple sources including the 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 CD ROM for 2007, and from data provided on Andrew Rose's webpage http://faculty.haas.berkeley.edu/arose/RecRes.htm#Software

1. *Distance*: Log bilateral population weighted distance (in km).
2. *Common border*: A binary variable that equals one if importer i and exporter j are neighbors that meet a common physical boundary, and zero otherwise.
3. *Island*: a binary variable that equals one if both importer i and exporter j are islands, and zero otherwise.

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[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.

4. *Landlocked*: a binary variable that equals one if both exporting country j and importing country i have no coastline or direct access to sea, and zero otherwise.
5. *Colonial ties*: a binary variable that equals one if importing country i ever colonized exporting country j or vice versa, and zero otherwise.
6. *Currency union*: a binary variable that equals one if importing country i and exporting country j use the same currency or if within the country pair money was interchangeable at a 1:1 exchange rate for an extended period of time (see Rose (2000, 2004) and Glick and Rose (2002)), and zero otherwise.
7. *Legal system*: a binary variable that equals one if the importing country i and exporting country j share the same legal origin, and zero otherwise.
8. *RTA*: a binary variable that equals one if exporting country j and importing country i belong to a common regional trade agreement, and zero otherwise.
9. *NON-WTO*: a binary variable equals one if both exporting country j and importing country i do not belong to the GATT/WTO, and zero otherwise.[46]
10. *WTO*: a binary variable equals one if both countries belong to the GATT/WTO, and zero otherwise.
11. *GDP:* log of the product of the GDPs of the importer and exporter measured in constant 2000 US dollars (obtained from the 2007 World Bank World Development Indicators CD ROM).
12. *GDPPC:* log of the product of the per capita GDPs of the importer and exporter measured in constant 2000 US dollars (obtained from the 2007 World Bank World Development Indicators CD ROM)
13. *Common colony*: a dummy variable indicating whether the two countries have had a common colonizer after 1945.
14. *Common Language:* a dummy variable indicating if a language is spoken by at least 9% of the population in both countries.
15. *CU*: a binary variable that equals one if exporting country j and importing country i belong to a common currency union, and zero otherwise.
16. *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):

17. *Entry days*: a binary indicator that equals 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,
18. *Entry costs:* a binary indicator that equals 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.
19. *Religion*: (% Protestants in country i * % Protestants in country j)+(% Catholics in country i * %Catholics in country j) + (% Muslims in country i * %Muslims in country j).

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

D3. Cleaning country codes

The table D1 below briefly summarizes steps taken to clean-up the certain country definitions.

Table D1: Cleaning country codes

Unusual region	**Classified as**	**ISO Code**	**Comment**
Belgium-Luxembourg	Belgium	BE	In later years (post-98), we get only data on Belgium. Since Luxembourg is likely to be small (and since we don't have any reported trade for Luxembourg in later years), we simply reclassify Belgium- Luxembourg as Belgium
Fmr Dem. Rep. of Germany Fmr Fed. Rep. of Germany	Germany	DE	FRG and DRG are reported pre-91. These are both classified as Germany and the data is aggregated to be consistent with later data on merged Germany. [a]
Slovakia Czech Republic	Czechoslovakia	CZ	Up to 1992, data is reported by Czechoslovakia. Later data is split between Slovakia and Czech Republic. We consolidate the post 1992 Slovakia and Czech Republic data into one country. [b]
Fmr Dem. Yemen Fmr Arab Rep. of Yemen	Yemen	YE	There is one reported Fmr Arab Rep. of Yemen export in 1990, and lot of exports by Yemen from 1997. We treat them as the same country "Yemen".
Fmr Ethiopia	Ethiopia	ET	We assume Fmr Ethiopia is largely consistent with Ethiopia.
Fmr Panama, excl. Canal Zone	Panama	PA	Again assume former will be similar to new definition
Neth. Antilles and Aruba	Neth. Antilles	AN	Minor consolidation of Aruba into Netherland Antilles.
Serbia Montenegro	Serbia and Montenegro	CS	Post 2004, data on Serbia and Montenegro split. We aggregate into the combined country.
CÃ´te d'Ivoire	Cote D'Ivoire	CI	In the trade data, Ivory Coast is spelt as CÃ´te d'Ivoire. To be consistent with country code data, we recode this as Cote D'Ivoire.
Rep. of Moldova	Moldova	MD	Renamed to be consistent with country code data
United Rep. of Tanzania	Tanzania	TZ	Renamed to be consistent with country code data
TFYR of Macedonia	Macedonia	MK	Renamed to be consistent with country code data

Notes: It is possible to have more than a duplication. For example if Serbia and Montenegro traded with Czech Republic and Slovakia, we could have 4 observations for a given (iso_importer iso_exporter year) combination. We do not find more than duplications in the methionine data. In any case, our code would simply aggregate the data into one unique (iso_importer iso_exporter year) observation.

Appendix: Additional Results

Table A.1: Log price robustness checks

	Log FOB Price		Price		Log Price (Cartel HQ imports only)	
	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE
	1a	1b	2a	2b	3a	3b
Citric Acid	0.022	-0.068	-0.062	-0.178	-0.078	-0.135
	(0.282)	(0.005)	(0.029)	(0.000)	(0.030)	(0.000)
Methionine	-0.319	-0.324	-0.774	-0.87	-0.292	-0.325
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
MCAA	-0.288	-0.298	-0.302	-0.296	-0.327	-0.309
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin A	-0.377	-0.395	-9.463	-7.068	-0.353	-0.284
	(0.000)	(0.000)	(0.000)	(0.008)	(0.031)	(0.066)
Vitamin B1	-0.147	-0.375	-7.802	-14.317	-0.318	-0.546
	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin B2	-0.346	-1.616	-3.609	-12.129	-0.115	-0.330
	(0.063)	(0.000)	(0.128)	(0.001)	(0.057)	(0.000)
Vitamin B3	-0.287	-0.442	-4.029	-6.306	-0.303	-0.546
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin B4	-0.278	-0.251	-0.189	-0.035	-0.299	-0.24
	(0.003)	(0.000)	(0.005)	(0.870)	(0.000)	(0.000)
Vitamin C	-0.418	-0.674	-3.604	-5.249	-0.336	-0.556
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Vitamin E	-0.671	-0.821	-9.746	-10.927	-0.785	-0.871
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(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 3a and 3b, only imports from cartel headquarter countries are included in the sample. Robust (clustered by importer) p-values are in parentheses.

Appendix: Additional Results

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	-0.039	-0.061	0.005	-0.103	-0.038	0.022	0.073
	(0.396)	(0.541)	(0.296)	(0.941)	(0.007)	(0.489)	(0.880)	(0.073)
Methionine	0.141	0.099	0.106	0.083	0.039	0.113	0.133	0.119
	(0.047)	(0.225)	(0.105)	(0.250)	(0.477)	(0.300)	(0.175)	(0.119)
MCAA	0.046	0.224	0.041	0.121	0.037	0.091	0.065	0.161
	(0.646)	(0.073)	(0.453)	(0.158)	(0.428)	(0.199)	(0.509)	(0.161)
Vitamin A	0.106	0.168	0.042	0.02	0.149	0.272	0.156	0.234
	(0.162)	(0.050)	(0.485)	(0.819)	(0.064)	(0.066)	(0.242)	(0.234)
Vitamin B1	-0.116	-0.208	-0.433	-0.393	-0.113	-0.135	-0.282	-0.202
	(0.339)	(0.145)	(0.107)	(0.143)	(0.540)	(0.558)	(0.710)	(0.202)
Vitamin B2	-0.009	-0.022	-0.084	-0.108	0.103	0.085	0.018	0.026
	(0.915)	(0.812)	(0.371)	(0.323)	(0.464)	(0.558)	(0.956)	(0.026)
Vitamin B3	0.061	0.132	0.161	0.257	0.05	0.192	0.251	0.345
	(0.455)	(0.103)	(0.005)	(0.011)	(0.419)	(0.060)	(0.038)	(0.345)
Vitamin B4	0.095	0.059	0.284	0.264	0.09	0.067	0.264	0.299
	(0.291)	(0.614)	(0.013)	(0.010)	(0.391)	(0.528)	(0.251)	(0.299)
Vitamin C	-0.056	-0.015	-0.231	-0.228	-0.031	0.069	-0.179	-0.122
	(0.505)	(0.888)	(0.004)	(0.009)	(0.432)	(0.212)	(0.402)	(0.122)
Vitamin E	0.074	0.059	0.032	0.075	0.094	0.17	0.161	0.352
	(0.326)	(0.481)	(0.552)	(0.379)	(0.085)	(0.057)	(0.069)	(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.

Appendix: Additional Results

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

	Baseline Relative to 4-year pre-breakup period		Europe only: Relative to 4-year pre-breakup period		Balanced panel: Relative to 4-year pre-breakup period	
	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE	SPOST_PRE	LPOST_PRE
	1a	1b	3b	3b	3a	3b
Citric Acid	0.122	0.110	-0.297	-0.318	0.117	0.100
	(0.215)	(0.378)	(0.201)	(0.203)	(0.224)	(0.401)
Methionine	-0.007	-0.008	-0.13	-0.065	-0.076	-0.164
	(0.932)	(0.920)	(0.374)	(0.716)	(0.565)	(0.232)
MCAA	-0.079	-0.023	-0.361	0.145	0.008	0.234
	(0.553)	(0.938)	(0.082)	(0.689)	(0.952)	(0.286)
Vitamin A	0.024	-0.011	0.135	0.064	-0.044	-0.112
	(0.789)	(0.905)	(0.628)	(0.885)	(0.625)	(0.329)
Vitamin B1	-0.021	-0.213	-0.281	-0.424	0.013	-0.240
	(0.933)	(0.244)	(0.666)	(0.431)	(0.953)	(0.109)
Vitamin B2	-0.016	-0.054	0.27	0.276	0.014	-0.028
	(0.726)	(0.310)	(0.377)	(0.425)	(0.885)	(0.793)
Vitamin B3	0.101	0.003	0.125	0.181	0.101	-0.004
	(0.302)	(0.974)	(0.454)	(0.433)	(0.301)	(0.970)
Vitamin B4	0.101	0.033	-0.044	-0.059	0.138	0.147
	(0.461)	(0.875)	(0.790)	(0.827)	(0.183)	(0.300)
Vitamin C	0.062	0.076	-0.198	-0.348	0.071	0.101
	(0.805)	(0.822)	(0.239)	(0.200)	(0.672)	(0.663)
Vitamin E	0.163	0.022	-0.075	0.041	0.124	-0.031
	(0.220)	(0.775)	(0.745)	(0.814)	(0.236)	(0.701)

Notes: The dependent variable in the gravity equation is log trade value. 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.

Appendix: Additional Results

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	
	Relative to 4-year pre-period		Relative to 4-year pre-period		Relative to 4-year pre-period		Relative to 4-year pre-period	
	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	0.026	-0.066	-0.054	-0.031	-0.020	2.157	3.321
	(0.169)	(0.169)	(0.005)	(0.108)	(0.383)	(0.692)	(0.375)	(0.100)
Methionine	-0.025	-0.009	-0.011	-0.018	-0.064	0.002	-0.002	-0.065
	(0.763)	(0.763)	(0.503)	(0.301)	(0.153)	(0.979)	(0.999)	(0.957)
MCAA	0.015	0.009	0.000	-0.019	0.095	0.058	0.978	-0.276
	(0.496)	(0.496)	(0.973)	(0.186)	(0.091)	(0.156)	(0.299)	(0.794)
Vitamin A	-0.029	-0.053	-0.026	-0.046	0.032	0.081	0.466	0.948
	(0.011)	(0.011)	(0.041)	(0.000)	(0.402)	(0.150)	(0.692)	(0.413)
Vitamin B1	-0.024	-0.044	-0.016	-0.031	0.035	0.062	1.783	2.205
	(0.401)	(0.401)	(0.681)	(0.314)	(0.356)	(0.250)	(0.082)	(0.167)
Vitamin B2	-0.052	-0.055	-0.033	-0.021	-0.054	-0.043	2.867	3.576
	(0.149)	(0.149)	(0.346)	(0.469)	(0.554)	(0.681)	(0.291)	(0.064)
Vitamin B3	-0.032	-0.011	-0.012	-0.025	0.079	-0.040	2.745	2.772
	(0.609)	(0.609)	(0.610)	(0.361)	(0.529)	(0.420)	(0.012)	(0.020)
Vitamin B4	-0.007	-0.006	-0.098	-0.117	0.090	0.112	2.306	2.210
	(0.798)	(0.798)	(0.222)	(0.002)	(0.013)	(0.370)	(0.108)	(0.073)
Vitamin C	0.017	0.002	-0.024	-0.012	-0.049	-0.093	-1.105	-0.462
	(0.925)	(0.925)	(0.296)	(0.596)	(0.492)	(0.102)	(0.719)	(0.871)
Vitamin E	-0.063	-0.067	-0.02	0.001	0.058	0.049	2.393	0.039
	(0.007)	(0.007)	(0.060)	(0.952)	(0.221)	(0.288)	(0.041)	(0.988)

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). 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: Difference-in-differences estimates of effects on price, concentration and distance coefficient (in gravity equation)

	Control:	Enzymes (excluding Rennet)			Organic chemicals nes		
		Log price	Herfindahl Index	Gravity	Log price	Hefindahl Index	Gravity
		1	2	3	4	5	6
Citric Acid	Short-run	-0.002	-0.025	0.001	-0.215	0.02	0.033
		(0.978)	(0.490)	(0.958)	(0.094)	(0.604)	(0.028)
	Long-run	-0.075	0.012	0.010	-0.384	0.052	0.063
		(0.246)	(0.642)	(0.642)	(0.002)	(0.194)	(0.001)
Methionine	Short-run	-0.200	-0.028	0.007	-0.174	-0.01	0.031
		(0.000)	(0.324)	(0.699)	(0.159)	(0.800)	(0.143)
	Long-run	-0.298	-0.008	-0.021	-0.217	-0.013	0.155
		(0.000)	(0.839)	(0.908)	(0.105)	(0.796)	(0.201)
MCAA	Short-run	-0.222	0.006	0.038	-0.196	0.025	0.040
		(0.000)	(0.804)	(0.149)	(0.114)	(0.525)	(0.290)
	Long-run	-0.267	0.024	0.538	-0.185	0.021	0.42
		(0.000)	(0.314)	(0.000)	(0.173)	(0.629)	(0.019)
Vitamin A	Short-run	-0.245	-0.027	0.004	-0.244	-0.011	0.014
		(0.108)	(0.406)	(0.728)	(0.175)	(0.777)	(0.408)
	Long-run	-0.243	-0.045	0.199	-0.179	-0.053	0.089
		(0.087)	(0.284)	(0.000)	(0.331)	(0.297)	(0.244)
Vitamin B1	Short-run	-0.266	0.015	-0.067	-0.48	0.023	0.058
		(0.006)	(0.812)	(0.001)	(0.001)	(0.707)	(0.214)
	Long-run	-0.470	-0.028	-0.068	-0.729	0.024	0.038
		(0.000)	(0.619)	(0.001)	(0.000)	(0.676)	(0.329)
Vitamin B2	Short-run	-0.073	-0.054	0.012	-0.292	-0.01	-0.003
		(0.383)	(0.298)	(0.386)	(0.044)	(0.849)	(0.854)
	Long-run	-0.324	-0.029	0.002	-0.635	0.011	-0.035
		(0.021)	(0.647)	(0.902)	(0.000)	(0.870)	(0.143)

Appendix: Additional Results

	Control:	Enzymes (excluding Rennet)			Organic chemicals nes		
		Log price	Herfindahl Index	Gravity	Log price	Hefindahl Index	Gravity
		1	2	3	4	5	6
Vitamin B3	Short-run	-0.263	-0.026	-0.009	-0.416	-0.007	-0.013
		(0.000)	(0.338)	(0.464)	(0.000)	(0.849)	(0.411)
	Long-run	-0.365	-0.012	-0.03	-0.334	0.014	-0.039
		(0.000)	(0.613)	(0.212)	(0.034)	(0.766)	(0.257)
Vitamin B4	Short-run	-0.238	0.004	-0.095	-0.398	0.019	0.129
		(0.000)	(0.829)	(0.004)	(0.000)	(0.546)	(0.007)
	Long-run	-0.126	-0.006	-0.184	-0.104	0.019	0.274
		(0.034)	(0.905)	(0.003)	(0.501)	(0.765)	(0.006)
Vitamin C	Short-run	-0.338	0.014	-0.004	-0.55	0.057	-0.011
		(0.000)	(0.732)	(0.721)	(0.000)	(0.179)	(0.501)
	Long-run	-0.524	0.027	-0.027	-0.832	0.066	-0.040
		(0.000)	(0.462)	(0.055)	(0.000)	(0.155)	(0.047)
Vitamin E	Short-run	-0.709	-0.035	-0.028	-0.687	-0.018	-0.023
		(0.000)	(0.174)	(0.039)	(0.000)	(0.637)	(0.212)
	Long-run	-0.889	-0.029	0.165	-0.808	-0.036	0.032
		(0.000)	(0.394)	(0.009)	(0.000)	(0.433)	(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.

Appendix: Additional Results

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 B1	N	21,300	28,400	668	1,675
	Mean	0.031	0.059	10.601	10.264
	SD (p-value)	0.174	0.236	2.200	2.190
Vitamin B2	N	21,420	28,560	830	1,733
	Mean	0.039	0.061	11.069	10.719
	SD (p-value)	0.193	0.239	2.195	2.304
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 C	N	44,496	59,328	1,368	3,158
	Mean	0.031	0.053	11.571	10.869
	SD (p-value)	0.173	0.224	2.399	2.368
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.