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Trade Flows in a Spatial Oligopoly: Gravity Works Well, But What Does It Explain?[*]

By

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Abstract

I begin by fitting traditional gravity equations to document that regional flows in the Brazilian cement industry exhibit gravity-like structure, with cement trade decaying sharply in distance traveled. I then show that this large distance effect owes to firms' strategic behavior over and above trade costs, with firm-level spatial supply decisions being characterized by the tacitly-collusive division (or sharing) of geographic markets. I am able to control for plant and trade costs thanks to an unusually disaggregated dataset, the simple production technology and a unique institutional setting. Thus, oligopoly can magnify the effects of distance. The paper suggests that trade theory, in its mission to explain the pattern of trade flows, should continue to advance in its modeling of strategic behavior in oligopoly. The paper also provides a rich and original example of a spatial cartel's pattern of supply. The tacit supply arrangement allows the cartel to sustain high prices, avoid large trade costs and, through the use of geography, potentially improve coordination.

1 Introduction

A consistent empirical finding in the trade literature is that bilateral trade flows exhibit gravity-like structure. Introduced to this literature by Tinbergen (1962), the gravity equation states that trade increases in market size and decreases in distance. Since then, a vast number of studies have employed gravity equations to analyze trade flows. Summing up, Feenstra, Markusen and Rose (2001) claim that "the gravity equation is one of the greater success stories in empirical economics" (p.431), while Evenett and Keller (2002) describe the equation as "one of the most important results about trade flows" (p.282). Starting with Anderson (1979), trade economists began developing theoretical foundations for gravity[1]. These theoretical developments aimed not only to explain the empirical success of the equation but also, by using theory to guide empirical specification, to improve our understanding of the determinants of trade.

Despite substantial advance in theory, data and technique, such determinants of trade are still not well understood. For example, several researchers puzzle over the large magnitude of the estimated effect of distance on trade, and why it does not appear to be falling over time (e.g. Grossman 1998). Disdier and Head (2006) carry out a meta-analysis of 1467 estimates from 103 papers, finding "a mean (negative distance) effect of about 0.9, with 90% of estimates lying between 0.28 and 1.55... Distance effects of this magnitude pose an important unsolved puzzle" (p.1-2). The implied trade costs that are typically backed out from theory-based gravity specifications to which data are fitted seem quite high. Anderson and van Wincoop (2004, Table 7) point out that actual trade flows between the US and Canada are consistent with an average trade barrier between the two countries that is equivalent to a 46% tariff, assuming an "intermediate" value of 8 for the "elasticity of substitution"[2] [3]. Recent research is revisiting the assumptions

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[1] To generate gravity, trade theorists have departed from different established general-equilibrium models of trade, such as the neoclassical Heckscher-Ohlin (HO) framework with Armington-based differentiation (e.g. Anderson 1979, Bergstrand 1985), or firm-level variety in models of monopolistic competition (e.g. Bergstrand 1989, 1990, Baier and Bergstrand 2001, Anderson and van Wincoop 2003). Gravity has also been derived when traded goods are homogeneous, such as in Deardorff's (1995) HO model with frictionless trade, or Eaton and Kortum's (2002) model of Ricardian production. Anderson and van Wincoop (2004) survey theoretical foundations for the gravity equation, as well as empirical applications. For Deardorff (1995), gravity's empirical success and the fact that it can be derived from across the spectrum of trade theories "is therefore not evidence of anything, but just a fact of life" (p.9). He explains: "All that the gravity equation says, after all, aside from its particular functional form, is that bilateral trade should be positively related to the two countries' incomes and negatively related to the distance between them. Transport costs would surely yield the latter in just about any sensible model. And the dependence on incomes would also be hard to avoid" (p.3).

[2] Such a parameter σ, typically informed by trade flow data in a manner consistent with existing trade models (e.g. monopolistic competition with CES preferences and symmetric firms), summarizes not only the substitutability between products (i.e. varieties within a sector) in the eyes of consumers (market demand) but also the competitiveness of firm-level behavior (supply), thus giving a sense of the slope of the demand curve at the individual product level (i.e. residual demand).

[3] The 46% barrier is relative to average domestic trade barriers, and is based on estimates by Anderson and van Wincoop (2003), who use aggregate trade data. Anderson and van Wincoop remark that results by Head and Ries (2001) based on sectoral data imply a "virtually the same" 47% US-Canada trade

behind existing trade models to verify the robustness of implied trade costs. Chaney (2006), for example, modifies the Krugman (1980) model of monopolistic competition to allow for heterogeneous firms and fixed costs of entry. In doing so, he finds that the implied trade costs are substantially lower[4], by virtue of an exporter selection effect.

Other researchers have taken a more empirical approach to argue that the estimated distance effect is large because distance actually proxies for mechanisms other than trade barriers. Blum and Goldfarb (2006) find large distance effects on the consumption of digital goods over the internet, where one would expect trade costs to be low, leading them to conclude that distance may proxy for consumer tastes, or cultural similarity, and "that trade costs cannot account for the entire distance effect found in previous gravity studies" (p.2). Rauch (1999) finds a smaller distance effect on the trade of homogeneous goods than on the trade of differentiated products, where one might expect higher search costs. He argues that distance proxies for search costs[5].

In this vein, the present paper argues that by inferring high distance-related trade costs from the large empirical inverse relationship between distance and trade flows, the gravity literature may be overlooking the role of firms' behavioral strategies. In some oligopolistic industries, it is conceivable that goods do not travel greater distances from their location of production *not because trade costs would make this unprofitable (in a static sense), but because firms strategically choose not to target geographic markets that are further away.* I use highly disaggregated data from a specific industry – cement in Brazil – to provide an example of a spatial oligopoly where a very high empirically-observed distance effect can be attributed to firms' strategic choices, over and above trade costs. Stated simply, firm 1 which owns a plant located in local market A (the "home" market), hardly ships to (still highly profitable) neighboring local market B (the "neighboring" market), where a plant owned by firm 2 is located, in exchange for firm 2 tacitly agreeing to stay away from market A. The unusually rich (plant-to-market) trade flow and cost data which I observe for this spatial oligopoly allows me to control for trade costs and establish a pattern of tacitly-collusive geographic market division (or market sharing)[6]. The similarity of institutions across Brazil's local cement markets allows me to assert that this pattern of trade flows does not owe to fixed costs of market entry.

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barrier, again assuming $\sigma = 8$.

[4] Regarding the 46% implied US-Canada trade barrier stated by Anderson and van Wincoop (2004), Chaney argues that this "number is unrealistically large. 46% is the punitive tariff imposed by the US on exports from Laos" (p.3).

[5] Whether his finding conflicts with or corroborates the claim that the trade costs that are estimated in the literature are "too large" obviously depends on whether one expands the definition of trade costs to include search (e.g. Anderson and van Wincoop 2004 include information costs in their definition.)

[6] Appendix A illustrates how such spatial strategies can be supported in equilibrium in simple dynamic games where firms meet in multiple markets, by pooling incentive constraints across these markets (Bernheim and Whinston 1990). Invading a rival's allotted market would invite a costly tit for tat competitive response.

Clearly, the finding that a large distance effect in a specific domestic industry is explained by firm behavior above and beyond trade costs does *not* imply that gravity-based estimates of trade costs – founded on general-equilibrium trade models and based on aggregate or sectoral bilateral trade flows – will be biased, or that any bias will be economically relevant. One can wonder whether geographic market division takes place at the supra-national level in the cement industry, let alone in other international industries[7]. But the finding does provide an example where, despite their goodness of fit, the adequacy of such trade models is limited, i.e. where the typical assumptions regarding firms' strategic behavior (e.g. monopolistic competition, with space-invariant mark-ups) that are made for the sake of tractability do come at a price[8].

In addition to the large body of general-equilibrium trade models where gravity is derived, I begin by showing in Section 2 how gravity arises in a simple partial-equilibrium spatial oligopoly model[9]. Importantly, trade flows from plants to local consumer markets exhibit gravity-like structure under different behavioral assumptions, ranging from competitive to collusive firm conduct – see Figures 1 to 3. This is a manifestation of the classic identification-of-supply problem in economics: how to empirically distinguish costs and technology from firm behavior (Bresnahan 1989). Following an introduction to the industry and data in Section 3, Section 4 then fits alternative specifications of the gravity equation to Brazilian cement flows, in the spirit of the traditional trade literature. Such gravity equations do a good job in "explaining" – in a statistical or exploratory rather than structural sense – the variation in spatial trade flows. In particular, I estimate large coefficients on distance and state-border variables, which might suggest the presence of large trade costs. For example, the (absolute value of the) estimated distance coefficient is in the order of 2 - 3 (see the log-linear specification in Figure 4). When adding controls for the number of state borders a plant's shipments must cross to reach a local market, a *first* state border lowers the corresponding firm's share in the local market by a staggering 21% (controlling for distance and other variables), while a *second* state border crossing lowers market share by a *further* 10%[10].

Following the exploratory exercise of Section 4, Section 5 adds structure to look inside

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[7] Nevertheless, in a study of the global cement industry, Ghemawat and Thomas (2004) argue that the cement "majors" do appear to engage in tit for tat strategies at the international level. Regarding European cement markets, Röller and Steen (2006) state that "competition is a multimarket game where credible threats to enter each other's markets prevent firms from entering other countries" (p.324).

[8] Trade models à la Anderson and van Wincoop (2003) – recall footnote 1 – would typically explain the large estimated distance effect on Brazilian cement flows through (i) a high elasticity of trade costs with respect to distance; and/or (ii) a high elasticity of substitution σ (equivalent to a high elasticity of trade with respect to trade costs), stemming from product homogeneity and competitive firm conduct; rather than through (iii) collusive behavior in oligopoly, characterized by the allocation of spatial markets.

[9] Despite its simplicity, the model captures features of the Brazilian cement industry, with consumers distributed along a line segment (the coastal states of Brazil), plants agglomerating at certain points (close to consumer markets but also where limestone reserves happen to be located), and spatial price discrimination.

[10] These estimates refer to the share specification of Figure 4, where $0.316 - 0.214 = 0.102$.

the supply "black box", inferring firm-level behavior controlling for observed (plant and trade) costs. I use the observed supply decisions by firms to local markets at different time periods to test the competitiveness (or collusiveness) of firm-level behavior against a standard benchmark model of oligopoly behavior – the Cournot solution[11]. I find many instances in the data where a given firm substantially undersupplies local markets as compared to the null hypothesis of Cournot behavior, in exchange for its rivals giving it the upper hand in certain local markets. As mentioned, these local markets where a given firm enjoys a large market share are typically located in the vicinity of its plants. Through such a collusive arrangement, the tacit cartel is thus able to not only sustain high prices[12] but also save on (high) transportation costs, to the extent that a competitive regime might lead to cross-hauling. Besides testing the full sample, I provide several illustrations from the data which are indicative of the pattern of geographic market division (see, for example, Maps 1 to 4).

This paper should be of interest to two main audiences. To trade economists, it documents an example where the explanatory power – in a structural sense – of typical gravity equations is poor, despite the good statistical fit. The paper offers a reminder that trade theory should continue to advance in its modeling of strategic behavior in oligopoly. Casual observation suggests that international oligopolies are an increasingly important economic phenomenon.

To industrial organization economists, the paper provides a rare and rich example of an oligopoly where shipment patterns are indicative of a spatial cartel characterized by the allocation of geographic markets. State boundaries seem to play a role in the cartel's tacit agreement. The distance between a local consumer market and a firm's existing production facilities seems to offer a natural instrument for tacit collusion. As firms' plant locations typically differ, one would expect a market sharing arrangement to exhibit a negative relationship between distance and trade flows, given the cartel's desire to save on transport costs, and protected by the difficulty of antitrust detection, since the competitive outcome also displays gravity-like structure[13].

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[11] I use the simple technology of cement production to compute a measure of plant marginal cost, while using observed freight prices for agricultural products to proxy for the plant-to-market transport costs of cement. I need to control for a complication that arises, namely the possibility that the domestic cement industry is limit-pricing in order to keep high-cost imported cement out of the domestic local markets. In other words, the delivered price of imports (the "world price plus inbound trade cost of importation") sets a price ceiling on domestic prices which may bind. Intuitively, when testing behavior, one must be careful to not interpret the competitive constraint posed by a fringe of (high-cost) imports on any given domestic firm's supply decision as a competitive constraint posed by the firm's (low-cost) domestic rivals.

[12] Further to the previous footnote, the fully collusive price is thus the landed price of (elastically-supplied high-cost) imports. I also comment on the possibility that the price ceiling set by this competitive fringe of imports acts as a focal price point for coordination, consistent with the Eastman-Stykolt (1966) hypothesis.

[13] Motta (2004) suggests that by improving coordination in a world of imperfect information, market

2 Simple spatial oligopoly models generate gravity-like structure

To provide a theoretical partial-equilibrium foundation for gravity-like structure within a simple spatial oligopolistic setting, where entry is exogenous, consider a line segment of unit length and let $l \in [0, 1]$ parameterize the location along this line segment[14]. Locate $n_0 > 1$ firms at the left extremity of the line segment (i.e. at $l = 0$) and $n_1 > 1$ firms at the right extremity (at $l = 1$)[15]. Firms have constant marginal cost c and incur constant transportation cost t (per unit of distance). Consumers are distributed along the line segment such that demand at each "point" (or infinitesimal local market) l is given by the ("spaceless") demand function $q = D_l(p(l))$, where $p(l)$ is the delivered price at market l, and $q(p; l)$ is demand per unit distance; thus market revenue in the interval $(l, l + dl)$ is given by $p(l)q(p; l)dl$.[16] (Notice that local markets can generally vary in size, as captured by the demand function $D_l(.)$.)

I now analyze the equilibrium delivered price schedules and trade flows in three benchmark models of oligopolistic behavior – Bertrand, Cournot and collusion – assuming that firms can set prices or quantities at each local market l. Notice that this spatial pricing policy is more general than in the Hotelling-Salop model, where firms are restricted to set only a "mill" (or "free-on-board") price, and prices over space are given by the sum of this mill price and the transportation cost[17].

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allocation schemes can reduce the occurrence of costly cartel-disciplining price wars à la Green and Porter (1984): "...if a shock reduces production costs or market demand, a price reduction might trigger a price war. As long as each firm does not serve segments of demand (explicitly or tacitly) allocated to rivals, prices can change without the collusive outcome being disrupted. This probably explains why such collusive schemes are often used." (p.141)

[14] Similar settings are considered by Greenhut and Greenhut (1975) and McBride (1983), who study quantity-setting (Cournot) firms, and Thisse and Vives (1988), who study price-setting (Bertrand) firms. In a similar vein to the Cournot case below, a homogeneous-good Cournot oligopoly has been studied in the "reciprocal dumping" model of international trade, which also assumes that markets are "segmented" (i.e. there is spatial price discrimination – see below), either with or without free entry, and either in a partial or a general equilibrium framework (see Brander 1981, Brander and Krugman 1983, Venables 1985, and Feenstra, Markusen and Rose 1998).

[15] To motivate this, say that limestone reserves happen to be located (and thus cement plants happen to agglomerate) at $l = 0$ and $l = 1$. Barriers to plant entry follow from the high setup costs in the cement industry and are consistent with the data, which displays no greenfield entry – see footnote 28.

[16] An alternative to this spaceless definition of demand is to consider a finite (discrete) sequence of "very narrow" but adjacent local markets along the line segment, such that each market borders another market on either side (except for the first and last market in the sequence). l then labels the local market according to the location of its center, where all that market's consumers happen to be located (i.e. there is no further spatial differentation within a local market). $q(p; l)$ then denotes the demand of local market $l \in \{0, \Delta, 2\Delta, ..., 1 - \Delta, 1\}$ where $1 + \Delta^{-1}$ is the number of local markets.

[17] I thus allow firms to "price discriminate", in the sense employed in the spatial literature that firms can offer a delivered price schedule with a slope other than t (also referred to as "pricing-to-market" in the trade literature). A slope greater than t, which is possible if consumer arbitrage is ruled out, would characterize price discrimination in favor of customers located nearby to the plants; a slope lower than t would characterize price discrimination in favor of distant buyers (also referred to as "freight absorption" or, in the trade literature, as "dumping").

I begin by considering Bertrand behavior. At each local market l, the equilibrium price is given by the lowest delivered cost, $p^B(l) = c + t\min(l, 1-l)$. Firms located at $l = 0$ serve markets located to the left of $l_0^B := \frac{1}{2}$ and firms located at $l = 1$ supply markets to the right of $l_1^B := \frac{1}{2}$ (assuming, of course, that the demand intercept is high enough such that trade flows to all markets)[18]. Assume, to illustrate, demand of the linear form $q(p;l) = a_l - p$, where the size of local market l is parameterized by a_l (and the regularity condition becomes $\frac{a_l - c}{t} > \frac{1}{2}$, $\forall l \in [0,1]$). Figure 1 depicts the delivered price schedule and aggregate trade flows over space that arise in equilibrium (drawn assuming local markets of equal size $a_l = a$; a larger market size in a single local market, say, would result in a spike in one of the trade flow schedules). The aggregate trade flow from producers at $l = 0$ to local market $l \in [0,1]$ thus exhibits gravity-like structure in equilibrium, and is given by

$$q_0^B(l) = \begin{cases} a_l - c - tl \text{ if } 0 \leq l \leq l_0^B \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

recalling that $l_0^B = \frac{1}{2}(= l_1^B)$. Similarly, the aggregate trade flow from producers located at $l = 1$ to local market l is

$$q_1^B(l) = \begin{cases} a_l - c - t\left(1 - l\right) \text{ if } l_1^B < l \leq 1 \\ 0 \text{ otherwise} \end{cases} \tag{2}$$

With Cournot firms, though price-cost margins are now positive in equilibrium, trade flows again exhibit gravity-like structure, with the aggregate quantity shipped from a producer location to a local market depending positively on the size of the market, but negatively on the distance from the producer location to the local market. In equilibrium, the supply of each local market falls generally into either one of three categories, depending *inter alia* on its location and its size: (i) case 1: local markets served only by producers located at $l = 0$; (ii) case 2: local markets served only by producers at $l = 1$; and (iii) case 3: local markets served by producers located both at $l = 0$ and $l = 1$, i.e. in case 3 there is "cross-hauling" (or "two-way trade"), in the sense that a local market is served also by the more distant set of producers. Again assuming for the purpose of illustration that demand is linear, $q(p;l) = a_l - p$, and that the same regularity condition $\frac{a_l - c}{t} > \frac{1}{2}$ holds, the equilibrium price schedule is given by

$$p^C(l) = \begin{cases} \frac{1}{n_0+1}\left(a_l + n_0\left(c + tl\right)\right) \text{ if } 0 \leq l < l_0^C(l) \text{ (case 1)} \\ \frac{1}{n_1+1}\left(a_l + n_1\left(c + t(1-l)\right)\right) \text{ if } l_1^C(l) < l \leq 1 \text{ (case 2)} \\ \frac{1}{n_0+n_1+1}\left(a_l + \left(n_0 + n_1\right)c + t\left(n_0 l + n_1\left(1 - l\right)\right)\right) \text{ otherwise (case 3)} \end{cases}$$

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[18] To reduce clutter, I further assume that only producers located at $l = 0$ serve market $l = \frac{1}{2}$.

where $l_0^C(l) := \max\left(0, \frac{n_0+1}{2n_0+1} - \frac{a_l-c}{t(2n_0+1)}\right)$ and $l_1^C(l) := \min\left(\frac{n_1}{2n_1+1} + \frac{a_l-c}{t(2n_1+1)}, 1\right)$, such that $l_0^C(l) < l_1^C(l)$.[19] The aggregate trade flow from producers at $l = 0$ to local market $l \in [0,1]$ is given by

$$q_0^C(l) = \begin{cases} \frac{n_0}{n_0+1}(a_l - c - tl) \text{ if } 0 \leq l \leq l_0^C(l) \text{ (case 1)} \\ 0 \text{ if } l_1^C(l) \leq l \leq 1 \text{ (case 2)} \\ \frac{n_0}{n_0+n_1+1}(a_l - c - t((1+2n_1)l - n_1)) \text{ otherwise (case 3)} \end{cases}$$

while the aggregate trade flow from producers at $l = 1$ to local market l is

$$q_1^C(l) = \begin{cases} 0 \text{ if } 0 \leq l \leq l_0^C(l) \text{ (case 1)} \\ \frac{n_1}{n_1+1}(a_l - c - t(1-l)) \text{ if } l_1^C(l) \leq l \leq 1 \text{ (case 2)} \\ \frac{n_1}{n_0+n_1+1}(a_l - c - t((1+2n_0)(1-l) - n_0)) \text{ otherwise (case 3)} \end{cases}$$

(To see why aggregate trade flows exhibit gravity-like structure, notice that $q_0^C(l)$ and $q_1^C(l)$ are increasing in market size a_l, and decreasing in distance traveled – i.e. $\partial q_0^C/\partial l < 0$ and $\partial q_1^C/\partial(1-l) < 0$. Clearly, the same is true regarding firm-specific trade flows: to see this, note that firm-to-market flows are simply obtained from $q_0^C(l)$ and $q_1^C(l)$ by dividing by the corresponding number of firms, respectively n_0 and n_1.) Figure 2 depicts the equilibrium delivered price schedule and trade flows, drawn for $n_0 > n_1$, and again drawn holding market size constant over space, i.e. $a_l = a$ (notice that a larger market size in a single local market, say, would result in a spike in the delivered price schedule and in *at least* one trade flow schedule)[20].

Finally, consider “fully collusive” behavior: that which maximizes total industry profit aggregated across producers located at $l = 0$ and at $l = 1$. One can motivate this by assuming, for example, that these $n_0 + n_1$ producers are actually all owned by a monopolist (i.e. $n_0 + n_1$ would then correspond to the total number of producer *establishments* rather than independent firms)[21]. The delivered price schedule is now

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[19] Notice that the argument l of $l_0^C(l)$ and $l_1^C(l)$ owes to the market size parameter a_l. It is easy to show that: (i) $(a_l - c)/t > \frac{1}{2}$ implies that $\frac{n_0+1}{2n_0+1} - \frac{a_l-c}{t(2n_0+1)} < \frac{n_1}{2n_1+1} + \frac{a_l-c}{t(2n_1+1)}$ (in fact, the two inequalities are equivalent) and thus $l_0^C < l_1^C$, such that case 3 always exists; (ii) $(a_l - c)/t < n_0 + 1$ implies that $l_0^C > 0$, i.e. case 1 exists if the transportation cost is not too low; and, similarly, (iii) $(a_l - c)/t < n_1 + 1$ implies that $l_1^C < 1$, i.e. case 2 exists if the transportation cost is not too low.

[20] Figure 2 is drawn for $n_1 + 1 > (a_l - c)/t$, such that case 2 exists ($n_0 > n_1$ then ensures that case 1 exists too). There is “reciprocal dumping” in the context of Brander and Krugman (1983), in that (delivered) price-cost margins are decreasing in a firm’s distance to market.

[21] By assuming single ownership of the n_0+n_1 producers, I abstract away from incentive compatibility in a fully collusive arrangement with n_0+n_1 independent firms – I consider multiple-firm dynamic spatial strategies that are incentive-compatible in Appendix A. Here, this will depend *inter alia* on n_1 and n_0, the distribution of market size over space, and the discount factor. My objective at present is to show how gravity structure can be generated in simple benchmark models of oligopoly. A (less desirable) alternative to ensuring that the fully collusive outcome is sustainable in equilibrium is to allow side-payments across firms in the different locations.

given by the monopoly price at each local market l:

$$p^M(l) = \arg\max_p \left(\left(p - c - t\min\left(l, 1-l\right)\right) q(p;l)\right) \tag{3}$$

where markets to the left of $l_0^M := \frac{1}{2}$ are served by plants located at $l = 0$ and markets to the right of $l_1^M := \frac{1}{2}$ are served by plants located at $l = 1$, i.e. there is no wasteful cross-hauling from the more distant set of producers. Again illustrating with linear demand, $q(p;l) = a_l - p$ (where $\frac{a_l - c}{t} > \frac{1}{2}$), such that $p^M(l) = \frac{1}{2}\left(a_l + c + t\min(l, 1-l)\right)$, the aggregate trade flows from producers (plants) located at each extremity of the line segment (left and right respectively) to local markets along the line segment are given by

$$\begin{aligned} q_0^M(l) &= \begin{cases} \frac{1}{2}\left(a_l - c - tl\right) \text{ if } 0 \leq l \leq l_0^M \\ 0 \text{ otherwise} \end{cases} \\ q_1^M(l) &= \begin{cases} \frac{1}{2}\left(a_l - c - t\left(1-l\right)\right) \text{ if } l_1^M < l \leq 1 \\ 0 \text{ otherwise} \end{cases} \end{aligned}$$

Thus trade flows again exhibit gravity-like structure in equilibrium, and are depicted in Figure 3 (drawn assuming local markets of equal size $a_l = a$), along with the delivered price schedule.

3 Industry and data[22]

Brazil ranks sixth among cement-producing countries, with output of approximately 40 mtpa (million tonnes p.a.) in the period 1998 to 2000. In 1999, 57 active plants were scattered across a geographic area slightly smaller than that of the US (see Map 1, whose content relates to Section 5). This spatial distribution is not even, however, as consumer markets and thus plants are heavily concentrated in states located along (or in proximity to) an extensive Atlantic coastline, in particular the relatively wealthy and populated states in the Southeast and South regions of the country[23]. States to the northwest of the centre of the country are sparsely populated and are largely covered with jungle. The industry also exhibits high concentration in terms of ownership. Though the 57 plants in 1999 were owned by 12 firms in total[24], the largest firm Votorantim commanded a

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[22] This section briefly covers some key features of the Brazilian cement industry and of the data. Further considerations of the industry, as well as a detailed account of the sources and treatment of the data, are provided in a separate *Supplementary Section.*

[23] The Federative Republic of Brazil is a federation of 27 states. The coastal states are those running clockwise from the north-most point of the country – the state of Amapá (AP) – to the south-most state of Rio Grande do Sul (RS). The long Atlantic coastline measures 7,491 km (4,655 miles).

[24] The 1990s saw growing consolidation of assets in the industry, particularly during some years of sharp growth in cement consumption (1995 to 1997), pulled by exogenous growth in the construction sector following the implementation of the *Real* economic stabilization plan in 1994. (After decades

nationwide shipment share of 41%, followed by Grupo João Santos (GJS), Holcim, and Lafarge, with respective shipment shares of 12%, 9% and 8%.

Given the short shelf life of cement, firms produce for immediate consumption. Shipments from producer plants to buyers in local consumer markets is primarily (i.e. 90%) carried out by road – as opposed to rail or water. In terms of *interstate* trade flows, the average producer state trades 40% of its cement production to consumer markets located in other states (over three-quarters of which are located in bordering states). In line with other developing countries, and in contrast to developed nations, around 80% of volume is shipped in bags to resellers who then sell on to small-scale consumers; only 20% is shipped in bulk by the industry directly to consumers, usually ready-mix concrete firms, large construction firms or producers of concrete products.

In terms of cement trade with other *countries*, imported cement (including the intermediate product clinker[25]) constitutes a small share of domestic consumption. In the period 1989 to 2003, this share has amounted to at most 2-3% of consumption across Brazil[26]. As I examine in Salvo (2005a), and need to control for in the structural analysis of plant-to-local-market trade flows of Section 5, the *threat* of imports plays a critical role in the Brazilian cement industry, despite the limited penetration of *actual* imports. As the price of imported cement has fluctuated over the 1990s, not least due to the wide swings in the Brazilian currency's exchange rate, the margin of adjustment has been the domestic price of cement, rather than the quantity of imported cement[27]. The elastic supply of imports has placed a ceiling on the domestic price of cement.

Data available: Plant-to-market cement flows and delivered marginal cost
The two distinguishing features of the dataset are (i) the availability of cement flows from plants to local markets (identified with states), and (ii) the observability of delivered

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of chronically high inflation, this plan successfully brought inflation under control, with the resulting reduction in "inflation tax" having a large "wealth effect" on consumption across the Brazilian economy, including housing – see Salvo 2005a.) Compared to the 12 firms that ran operations by 1999, the industry had consisted of 19 producers in 1991. (Map 1 indicates how plant ownership – and location – changed over the period 1996 to 1999.)

[25] Clinker is the main component of ordinary cement.

[26] This low level stands in striking contrast to the penetration of imports in the US. Carlsson (2001) reports that "imports represent a substantial and increasing part of the market in the United States, ranging between 10 and 17 percent of domestic consumption since 1985" (p. 7). The share of imports in some coastal US markets is actually as high as 30% (exported from regions as far away as Southeast Asia). Despite the bulkiness of cement relative to its price, the development of specialized seaborne handling and transportation equipment from the 1970s has enabled imports to make their presence felt in coastal markets. Dumez and Jeunemaître (2000) provide a historical account of the rise of international trade in cement. On the other hand, in both the US and Brazil, exports account for less than 1% of domestic production (though in Brazil the current trend is upwards).

[27] Thanks to the practice of investing in idle capacity, the domestic industry was able to keep imports at bay even during the period of sharp growth in construction activity (as well as strong appreciation of the local currency, the Real, denoted R$), in 1995 - 1997. Capacity utilization typically hovers around an average 65%.

marginal costs for every plant-market pair, *irrespective of whether firms actually choose to ship*. To be sure, it is the unusual richness of micro data for this oligopoly that will enable me to directly examine oligopolistic behavior, identifying firm conduct separately from (plant and trade) costs on the supply side.

Over the period 1991 to 1999, I observe annual cement shipments from each active plant in Brazil broken out by destination state. In other words, taking I_t to denote the total number of active plants in year t and L to denote the number of states[28], I observe nine $I_t \times L$ matrices, one for each year. A glance at these matrices indicates how local trade flows in the industry are, with the typical row (corresponding to an active plant in a given year) containing zeros in all but 4 elements, these 4 non-zero elements typically pertaining to positive shipments to the state where the plant is located and to three other states located nearby. In the traditional gravity estimates of Section 4, this steep decay of trade flows in distance will be picked up by variables that are typically interpreted in the literature to proxy for trade costs (e.g. distance traveled, number of state border crossings).

The observation of delivered marginal cost (and thus price-cost margins, given the observation of cement prices) over the same time period is brought into the picture in Section 5, where firm-level behavior generating the observed pattern of shipments is analyzed. In view of the simple fixed-coefficients technology of cement production, I use engineering estimates, observed factor prices and observed plant characteristics to directly calculate the marginal cost of each plant in serving each market. While I do not observe freight prices paid by cement producers, I approximate these by using data on freight prices for agricultural goods collected over the period 1997 to 2003 for thousands of different routes across Brazil[29]. As I explain in Salvo (2005a), I find that price-cost margins for plant-market pairs where shipments *do* take place are very high: across producers, across states and over time, the price-cost margin as a proportion of the consumer price lies in the region of 25-45% (equivalent to 40-65% as a proportion of the producer price net of sales tax)[30].

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[28] Recall that $L = 27$. As for I_t, the rates of entry and exit of plants are low in this period, with I_t starting at 56 in 1991, peaking at 60 in 1997 and falling to 57 in 1999. The only four new (fully-integrated, i.e. comprising limestone quarry, clinker-producing kiln and grinding mill) plants observed in this period were invariably set up by incumbents. Barriers to entry are notoriously high, on account of a plant's large fixed costs (not least due to growing environmental restrictions, and the fact that prospecting rights over limestone reserves typically lie in the hands of incumbents).

[29] The transportation of goods such as soybean and maize are reportedly close substitutes in the supply of cement freight (Soares and Caixeta Filho 1996). Given the importance of transportation, I report on the construction of freight cost in Appendix B. Details on the construction of other components of marginal cost, including plant cost, sales tax and the reseller's mark-up, are provided in the *Supplementary Section*. In addition to location and ownership (over time), observed plant characteristics include capacity, number and age of kilns, type of fuel usage, and the proportion of shipments in bags as opposed to bulk. Observed (local) factor prices include fuel oil, coal, electricity and wages.

[30] Two robustness tests of the calculated marginal costs and the resulting price-cost margins are

4 Traditional gravity estimates: High trade costs?

Having theoretically motivated gravity in a spatial oligopoly setting in Section 2, I now estimate equations that have a gravity flavor to statistically analyze the observed flow of cement between plants (owned by the different multiplant firms and located in states across the country) and markets (identified with states). To emphasize, the exercise should be interpreted in a statistical rather than a structural sense, in that this section makes no attempt to identify the nature of the strategic interaction among the oligopolistic firms that is generating the trade flows. I find the fit of gravity to be good, estimating large coefficients on distance and state border variables. I note, however, that the magnitude of the fitted coefficients on such variables that the trade literature normally takes to proxy for trade costs, as well as closer examination of the fitted residuals, suggests that the estimated model is misspecified. In Section 5, guided by theory, I will show that the observed spatial pattern of shipments can be explained (now in a structural sense) by tacitly collusive oligopolistic behavior that is characterized by the *division of geographic markets*, rather than by trade costs. Contrasting the statistical (or so-called "traditional") gravity estimates with structural estimates of a single industry that benefit from the use of rich institutional information suggests a more general point: that the large distance and border effects typically inferred in the trade literature from bilateral trade flows may be proxying for oligopolistic behavior.

4.1 Plant (firm) to market flows

Given that for many firm-market-year triples shipments are zero[31], I estimate the following tobit model:

$$q_{flt} = \max(q^*_{flt}, 0) \quad \text{where} \quad q^*_{flt} = \gamma_1 + \gamma_2 d_{flt} + \gamma_3 Y_{lt} + \gamma_4 B_{flt} + \epsilon_{flt} \tag{4}$$

where q_{flt} denotes the logarithm of cement shipments from firm f's plants to market (i.e. state) l in year t, d_{flt} is the log of some measure of the physical distance from firm f's plants to market l in year t, Y_{lt} is the log of some measure of the exogenous demand for cement in market l in year t, and B_{flt} is an indicator variable indicating whether firm f owns a plant located in market l (i.e. within state l's borders) in year t. A log-linear specification seems a natural starting point given "the near universal use

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conducted in the *Supplementary Section.* The first one is based on unusually-detailed accounting data reported by country of operation (and by line of business) by the multinational firm Cimpor. The second test is based on accounting data sampled among establishments in the cement industry by the Brazilian Institute for Geography and Statistics (IBGE) as part of their Annual Industry Survey (PIA) series. To the extent that there is any systematic bias in my data (stemming from measurement error), this would conservatively *overstate* the true marginal cost, reinforcing the findings of Section 5.

[31] In 1999, for example, the mean number of firms shipping to each state was 5.7 (of a total of 12 active firms in that year).

of the gravity equation which estimates a units-free elasticity" (Disdier and Head 2006, p.5). The base measure for d_{flt} is the average distance traveled (by road[32]) from firm f's plants to market l, weighted by that firm's observed shipments from its plants to that market each year (or, if zero shipments are observed, then it is the distance from the market of firm f's closest plant)[33]. The base measure for Y_{lt} is construction activity. The inclusion of B_{flt} attempts to capture state border effects, since the variable takes on the value 1 when a firm can serve a market from a plant located within that market, thus not having to cross any state border (recall that markets are identified with states)[34]. I later verify the robustness of estimates to each of these specification choices.

Figure 4 presents estimates. Column (1) includes only distance d_{flt} and market size Y_{lt}. (2) adds the firm-located-in-market dummy B_{flt}. All estimated coefficients have the expected sign, and are significantly different from zero. (Heteroskedasticity-robust standard errors, unless otherwise noted, are displayed in parentheses. The log likelihood for each tobit regression is also shown, along with an R^2 for its OLS counterpart, for comparison with some studies in the literature.) Of note, the elasticity of shipments with respect to distance is very high: a 1% increase in a firm's plants' average distance to a market is associated with a 2.7 to 3.7% reduction in shipments. For comparison, recall that estimates of the elasticity of bilateral trade flows with respect to distance in the international trade literature typically fall in the -0.3 to -1.6 range (Disdier and Head 2006). By regression (2), border effects are significant: controlling for distance, having a plant located within the market (state), raises shipments by 6%. As regressions (3) to (6) show, the magnitude of the distance effect is robust to the addition of year effects, market effects and firm effects, while the magnitude of the border effect is robust to the addition of year effects but not to the addition of market effects and firm effects. Compared to (2), specification (3) adds year effects, (4) adds market effects, (5) adds firm effects, and (6) adds the three kinds of fixed effects. In specification (6), I obtain that (i) a 1% increase in distance is associated with a (statistically significant) 2.6% reduction in shipments, (ii) a 1% increase in the size of a market is associated with a 0.7% increase in shipments to that market (though this is statistically insignificant due

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[32] In 1999, for example, 91% of cement shipments from plants to markets was carried out by road, as opposed to rail or water.

[33] The distance from a plant to a given market (state) is taken to be the distance from the plant to the corresponding state's capital city – each state in Brazil has a state capital, which almost invariably is its most populous city. According to IBGE, 83% of Brazil's households in 2000 were located in urban areas and, of these, 50% were located in the metropolitan areas of the 27 state capitals. While this is an approximation to the true distance to market – a plant most certainly ships to municipalities within a state other than the state capital, possibly located closer to it – this avoids the need to arbitrarily pick the distribution of a plant's shipments across municipalities *within* a state, which I do not observe. This approximation is typical in gravity studies: when only trade flows at the country level are available, the distance between nations' capitals is usually adopted. Unlike these conventional gravity studies, however, I need not assume "great-circle" distances but can fortunately rely on *actual* road distances.

[34] In 1999, for example, in aggregate 61% of shipments from plants to customers did not cross state borders.

to the inclusion of market effects), and (iii) owning a plant located within a market is associated with a (statistically significant) 1.4% increase in shipments to that market[35].

Robustness In columns (7) to (9) of Figure 4, I verify the robustness of estimates to the choice of measures of distance, market size and border effects. Regression (7) replaces the shipment-weighted average distance by the distance between market l and firm f's *closest* plant in year t, regardless of how much that plant actually ships[36]. Regression (8) replaces a market's construction activity in year t by its population in that year. Gravity estimates are robust to these alternative specifications; in particular, the elasticity of shipments to distance remains in the -2 to -3 range[37]. In regression (9), I replace the firm-located-in-market dummy by three variables also intended to capture state border effects: (i) a dummy which takes on the value 1 when the market is adjacent to a state in which the firm's closest plant is located, (ii) a dummy which takes on the value 1 when the firm has to cross exactly two state borders to reach the market from among the plants it owns, and (iii) a variable which captures the effect of *each* state border crossing when three or more borders need to be crossed. One may expect such variables to correlate highly with distance and thus impact the distance coefficient. Indeed, the distance elasticity drops to -1.0. This richer specification of borders is picking up some of the variation in shipments that was previously accounted for by distance. Controlling for distance, and compared to serving a market from a plant located within that market, I find that serving a market from a plant located: (i) in an adjacent state is associated with a 2.7% reduction in shipments to that market, (ii) two state borders away is associated with a 10.4% reduction in shipments, and (iii) three or more state borders away is associated with a 5.6% reduction in shipments *per border crossing* (i.e. three borders crossings correspond to a shipment reduction of $3 \times 5.6 = 16.8\%$). The log likelihood improves considerably. The combination of distance and border-related variables considerably explain (at least in a statistical sense) cement trade flows from plants to markets.

I then reestimate specification (9) using variables q_{flt}, d_{flt} and Y_{lt} linearly rather than their logarithmic transformations – estimates are depicted in column (10). A 100

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[35] Figure 4 also displays "clustered" standard errors for regression (6), allowing for a same firm's shipments to a same market to be correlated over time. While the distance coefficient remains significantly different from zero, the border effect is no longer significant.

[36] Formally, $\tilde{d}_{flt} := \min_{i \in \mathcal{O}_{ft}}(d_{il})$, where $\mathcal{O}_{ft}$ is the set of plants owned by firm f in year t, and d_{il} is the distance between plant i and market l. This compares to the baseline measure $d_{flt} = \sum_{i \in \mathcal{O}_{ft}} q_{ilt} d_{il}$ if $q_{flt} > 0$ (and $d_{flt} = \tilde{d}_{flt}$ otherwise).

[37] Given the large variation in population density across the country's different "regions" (North, Northeast, Southeast, South and Centerwest), regression (6) was also modified allowing the coefficient on the distance variable to vary across regions. Equality of estimated distance elasticities across regions cannot be rejected in all but one pairwise test. Specification (6) was also estimated year by year, rather than using data pooled over the nine years, and results are similar.

km increase in distance is on average associated with a 15.3 kt (153.3 t/km × 100 km) reduction in a firm's shipments to a market, controlling for the number of state border crossings. Crossing one (resp. two) state border(s) entails a 383 kt (resp. 619 kt) reduction in shipments; crossing three or more borders is associated with a 242 kt shipment reduction *per border*.

Finally, a similar statistical exercise to equation (4) can be performed by fitting the alternative equation:

$$s_{flt} = \max(s^*_{flt}, 0) \quad \text{where} \quad s^*_{flt} = \gamma_1 + \gamma_2 d_{flt} + \gamma_3 B_{flt} + \epsilon_{flt} \tag{5}$$

where $s_{flt} := \frac{q_{flt}}{\sum_f q_{flt}}$ is firm f's share of shipments to market l in year t. The market size variable Y_{lt} is dropped in this shipment-share version (5) as compared to equation (4). In regression (11) of Figure 4, year effects, market effects and firm effects are again included, and the richer set of state border variables of specification (9) is used. A 100 km increase in the distance to a market, controlling for border crossings, is associated with a 1.8% reduction in the shipment share. A firm that ships across one (resp. two) state border(s) to reach a market has a 21.4% (resp. 31.6%) lower share of the market as compared to a firm shipping from within that market! Each border crossing when three or more borders need to be crossed translates into a reduction in shipment share of 13.3% per crossing! This state border effect is surprisingly large in that one might expect the nature of institutions in the Brazilian cement industry to be similar across states and any trade frictions at state borders to be small. The magnitude of these estimates suggests that the distance and border-related variables may be picking up more than trade costs in explaining firms' spatial supply decisions.

Analysis of outliers: Residuals also suggest that the model is misspecified While fitted coefficients provide information on "average" correlations in the data, thus "explaining" (in a statistical sense) cement flows conditional on plant ownership and location, closer examination of residuals reveals interesting patterns in the data that do not conform to this average pattern. The non-randomness of fitted residuals over firms and markets suggests that the estimated equations may be misspecified; in other words, their ability to structurally explain shipment decisions appears to be limited.

I briefly illustrate this point by reference to observed shipments to the two largest markets – the states of São Paulo (*SP*) and Minas Gerais (*MG*) – by three among the four largest firms nationwide – Votorantim, Holcim and Lafarge[38]. (I return to these

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[38] Salvo (2005b, p.158-165) extends this analysis of fitted residuals to shipments to the six largest markets by the eight largest firms, flagging some odd situations in the data beyond the one that I describe next. Similarly, he compares actual against predicted trade flows to markets located in the Northeast region. The idea is to let the data pinpoint the firm-market pairs that do not conform to an "average" pattern of supply (cost and behavior) which is captured by the explanatory variables.

"gravity outliers" in Section 5.) The two markets, located in the Southeast region of the country, are adjacent, and (in 1999) each of the three firms owns plants located in each of these markets[39] (in addition to owning plants located in neighboring markets such as Rio de Janeiro – RJ – which may also serve these two markets SP and MG). I use the linear version of gravity-like equation (4) to predict these three firms' shipment decisions to buyers in these two markets, on the basis of the *average* distance and border effects informed by the data (i.e. column (10) of Figure 4), including fixed effects and conditional on plant location and market size. Figure 5 compares these gravity-fitted shipments (along with 95% confidence intervals) against actual shipments. While Votorantim's actual shipments to SP dwarf predicted shipments, its actual shipments to MG pale in comparison to predicted shipments (and each of these comparisons are statistically significant). In contrast, actual shipments by Holcim and Lafarge to MG exceed predicted shipments (significantly so), while these firms' actual shipments to SP fall short of predicted shipments (significantly so in the case of Lafarge)[40].

Thus, on closer examination of fitted residuals, the specified gravity equation does not seem to satisfactorily explain shipment variation on the basis of plant location and ownership and market size.

4.2 Source-state to host-state flows

More in line with the conventional trade literature, in which only (geographic) market-level sourcing data rather than (establishment- or) plant-level data are typically available, I now aggregate cement flows originating from plants located within the same state at every period of time. Clearly, doing so discards information in that the observed trade flows q_{ilt} for each sourcing plant i, host-state l, year t combination are aggregated up to the *source-state* level k, i.e. $q_{klt} := \sum_{i \in \mathcal{L}_k} q_{ilt}$, where $\mathcal{L}_k$ is the set of plants located in source-state k. Again, this exercise should be interpreted in an exploratory, not struc-

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[39] Votorantim operates three plants in SP and one in MG, Holcim operates one plant in SP and two in MG, and Lafarge operates one plant in SP and four in MG.

[40] Votorantim's plant in MG ships 1183 kt across the state border to SP, while shipping only 340 kt within the state of MG. As I later state, Votorantim commands a 50% share in SP while enjoying only an 8% share in the neighboring MG market. In contrast, Holcim and Lafarge enjoy market shares of 24% and 25% respectively in MG, but only 9% and 5% respectively in SP.

tural, sense. I thus use the bilateral trade flows q_{klt} to estimate the gravity equation[41]

$$q_{klt} = \max(q^*_{klt}, 0) \quad \text{where} \quad q^*_{klt} = \gamma_1 + \gamma_2 d_{klt} + \gamma_3 Y_{kt} + \gamma_4 Y_{lt} + \gamma_5 B_{klt} + \epsilon_{klt} \tag{6}$$

where d_{klt} is the road distance between the capital cities of source-state k and host-state l in year t, Y_{kt} and Y_{lt} are the market sizes (activity in the construction sector) in source-state k and host-state l in year t, and B_{klt} are indicator variables that attempt to pick up border effects (see below).

Estimates are shown in Figure 6. Regressions (1) through (4) use shipment, distance and market size data in logs. In column (1), the elasticity of inter-state cement trade with respect to the distance between states is -3.7 (and highly significant), controlling only for market sizes in the source-state and in the host-state. Higher market sizes in the source-state or in the host-state correlate positively with inter-state shipments (again in a statistically significant sense). Regression (2) introduces a control that indicates the (minimum) number of state borders that need to be crossed in order to reach the host-state from the source-state[42]. Controlling for distance and market sizes, every state border that is crossed is associated with a 5.7% reduction in shipments. As in the regressions based on plant to market data, the inclusion of state border controls lowers the estimated distance coefficient (due to the covariation between the regressors) and the log likelihood improves considerably. Column (3) additionally controls for year fixed effects, source-market fixed effects, and host-market fixed effects[43]. The border effect is robust, remaining in the order of a 6 - 7% trade volume reduction per border crossing. On the other hand, the negative coefficient on source-market size suggests some misspecification – this negative coefficient is being estimated from the within-unit (i.e. time) variation, given the inclusion of fixed effects. Regression (4) adds controls for (the log of) average cement prices in the source-market and in the host-market. Prices

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[41] Contrast the source-state aggregation q_{klt} employed here to the firm-level aggregation used in estimating (4) or (5), where $q_{flt} = \sum_{i \in \mathcal{O}_{ft}} q_{ilt}$. Equation (6) is consistent with the form which "almost all" empirical implementations of gravity take (Disdier and Head 2006, p.5; see their equation (1)). In the present paper's partial-equilibrium framework, where market size is treated as exogenous (recall Section 2), it is not clear why I should include a source-market income covariate – again, one should view this simply as a statistical control. (See Feenstra, Markusen and Rose 2001 for a discussion of source-region and host-region income coefficients in different general-equilibrium trade models.)

[42] This covariate extends the concept of "adjacency" that is controlled for in typical gravity studies (where country pairs that do not share a common border are often linked by sea). In the present setting, transportation is overwhelmingly by road across possibly multiple (state) borders. I choose a linear functional form because it displays good fit.

[43] Standard errors for source-market and host-market clusters are also shown. A discussion of source-market and host-market fixed effects in the estimation of gravity equations that are derived in general equilibrium is provided by Feenstra (2004) and Anderson and van Wincoop (2004). In partial equilibrium, one may view the fixed effects as potentially controlling (again in a statistical sense) for unobserved year-specific and market-specific shocks. Though I do not allow source-market effects and host-market effects to vary by year in regression (3), reestimating (3) year by year rather than using pooled data return similar estimates for distance and border effects.

are potentially endogenous but I do not attempt to instrument for them – a structural approach that is founded on oligopoly theory is the subject of the following section[44], and my present objective is to demonstrate the good fit of traditional gravity equations used extensively in the trade literature. Trade flows correlate negatively with prices in the source state and correlate positively with prices in the host state.

Finally, columns (5) to (8) depict estimates for the linear counterparts of regressions (1) to (4) (except for the addition of an indicator variable which controls for within-state shipments – i.e. it takes on the value 1 when the source-state and the host-state are the same). In column (7), for example, a 100 km increase in distance is associated with a 25.7 kt (257.4 t/km × 100 km) reduction in a firm's shipments to a market, controlling for the number of state border crossings (and fixed effects). Crossing the first state border entails a large $577 + 285 = 862$ kt reduction in shipments; thereafter each additional border is associated with a further 285 kt shipment reduction.

5 A structural approach: Using cost data to look inside the supply "black box"

5.1 A "road map"

Having shown that (i) gravity-like structure is consistent with alternative spatial oligopoly theories of firm behavior, ranging from competitive to collusive conduct (Section 2), and (ii) trade flows in the Brazilian cement industry (Section 3) exhibit gravity-like structure, with large estimated distance and state-border effects (Section 4), this section will show that such spatial shipment patterns in the Brazilian cement industry owe to (collusive) oligopoly behavior – tacit *market division* – above and beyond (large) trade costs. In other words, oligopoly can magnify the effects of distance.

I use the observed delivered marginal costs and supply choices for every firm-market pair over time to empirically disentangle firm-level behavior from costs on the supply side. Naturally, one might think that the availability of such rich data would allow the immediate testing of oligopoly behavior. In the present institutional setting, however, there is a complication which needs to be controlled for: the existence of a competitive fringe of potential foreign suppliers. As Salvo (2005a) details, and I summarize in Section 5.2, the Brazilian cement industry is constrained in its ability to set prices by the threat of imports. Intuitively, one must be careful to not interpret the competitive constraint

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[44] In Section 5, in fact, I argue that cement prices are *exogenous* to the extent that market outcomes are constrained by the threat of imports.

posed by this fringe of (high-cost) foreign entrants on any given domestic firm's supply decision as a competitive constraint posed by the firm's (low-cost) domestic rivals.

Section 5.2 begins by defining the notion of a "constrained market outcome" and laying out the evidence supporting my claim that the domestic oligopoly is constrained by the threat of foreign entry. The very low price elasticities of demand in equilibrium across the many local markets, coupled with the very high price-cost margins, indicate that the domestic industry is constrained by the threat of imports – this explains why the domestic industry, setting high prices but still facing inelastic market demand, does not raise prices even further[45]. Section 5.3 then proposes a test of firm behavior that controls for the possibility of market outcomes being constrained. Mechanically, the test endogenously selects firm-level supply decisions in (geographic and time) markets which can only be explained by behavior that is more collusive than the Cournot benchmark solution. I show that trade flows in Brazilian cement are characterized by tacit market division, with a given firm holding back supply to certain local markets (relative to the Cournot solution) in exchange for its rivals giving it the upper hand in other local markets. Prior to employing the full sample, I illustrate the test by reference to the supply decisions of some specific firms in some specific markets which are reflective of the broader trend in the data.

5.2 Domestic oligopoly constrained by the threat of (high-cost) imports

Consider a local market l served by a domestic monopolist with constant delivered marginal cost c_l.[46] The monopolist faces a competitive fringe of high-cost imports, with perfectly-elastic supply at marginal cost (or "world price plus inbound trade cost of importation") $P^W + T > c_l$. In general, the equilibrium is given by either of two situations (see Figure 7). If the marginal cost (delivered price) of imports $P^W + T$ is lower than the domestic monopoly price in the absence of imports, denoted $p^M(l)$, the price will be equal to $P^W + T$, the monopolist will supply the entire local market, yet the foreign fringe exerts downward pressure on price, arbitraging away any price premium on top of $P^W + T$. Alternatively, if $P^W + T > p^M(l)$, imports have no "bite" and the

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[45] An alternative interpretation that domestic prices are constrained by regulatory threat, while less plausible in view of the present institutional setting, would be equivalent in terms of its implications for what follows. Yet another equivalent interpretation is that the landed cost of imports provides a *focal price point* for the domestic cartel, in the spirit of Harris (1984). Harris considers the Eastman-Stykolt (1966) hypothesis, whereby providing a domestic industry with a focal point equal to the world price plus tariff, protection may facilitate oligopolistic coordination of the protected firms. Relatedly, Knittel and Stango (2003) document the role of regulatory price ceilings in facilitating collusion in credit cards.

[46] I formally introduce the notion of a constrained equilibrium by reference to the supply decision of a *monopolist* for the sake of illustration only. The concept extends intuitively to other models of oligopoly behavior, as Section 5.3 shows with regard to the hypothesis of domestic incumbents behaving à la Cournot.

equilibrium price will be $p^M(l)$, with the monopolist again supplying the entire local market though in an unconstrained manner[47]. Formally, the equilibrium price in local market l is given by

$$p(l) = \begin{cases} P^W + T & \text{if} \quad p^M(l) \geq P^W + T \\ p^M(l) & \text{otherwise} \end{cases}$$

where $p^M(l) = \arg\max_p \left((p - c_l)\, q(p; l) \right)$. (Recall expression (3).)

Notice that at a constrained equilibrium, where $p^M(l) \geq P^W + T$, while the price elasticity of (residual) demand faced by the domestic oligopoly is infinitely high in absolute value, the market price elasticity of demand, $\eta(p; l) := \frac{\partial \ln q(p;l)}{\partial \ln p}$, is finite (and possibly inelastic, as illustrated in the figure, drawn for a linear demand example[48]). It is clear that around this constrained equilibrium, fluctuations in the delivered price of imports $P^W + T$, say due to fluctuations in the exchange rate, allow one to trace out the market demand curve, since the kinked equilibrium moves up and down along the demand curve.

5.2.1 The evidence (Salvo 2005a)

Salvo (2005a) estimates the demand for cement in each of 17 states (identified with local markets) of the Brazilian federation[49]. He estimates the following (parametric) demand function at the local market (state) level:

$$q_{lt} = D(p_{lt}, Y_{lt}, \alpha_l, \epsilon_{lt}^d) \tag{7}$$

where p_{lt} is the price of cement to the consumer (in market l and time period t), Y_{lt} are exogenous variables moving demand (e.g. output in the construction and building sector, seasonal dummies), α_l are market-specific parameters to be estimated, and ϵ_{lt}^d is an econometric error term. The choice of instruments (prices are potentially endogenous)

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[47] Were the supply of imports less than perfectly elastic, imports would occur in equilibrium. However, I assume flat marginal cost for imports on account of (i) imports hardly occur in Brazil, and (ii) the limited size of Brazil, let alone each local market, relative to the global cement industry. Further, I assume constant marginal cost for the domestic industry only to simplify exposition. Were domestic marginal cost to increase in output, the perfectly-elastic supply of imports at price $P^W + T$ would still ensure that imports not occur in equilibrium as long as $P^W + T$ exceed the domestic competitive price, i.e. the price at which increasing domestic marginal cost were to cross the market demand curve.

[48] As drawn, demand in the local market is given by $q = 160 - 10p$, and $c_l = 4$. Notice that Figure 7 also graphs the market price elasticity of demand as a function of q, given by $\eta(q) = 1 - 160q^{-1}$.

[49] A remaining 10 states, accounting for 60% of Brazil's land mass but only 11% of its cement consumption (in 1999), are dropped from the demand estimation due to measurement error − located northwest of the center of the country, they are sparsely populated and are largely covered in jungle. As a point of comparison, the global market research firm ACNielsen, that has long been established in Brazil, does not audit these "outlier" states owing to their unusual geo-demographic characteristics. Note, however, that in analyzing supply decisions to the 17 consumer markets, I do consider sourcing from plants located in *all* 27 states.

depends on whether the imports arbitrage constraint binds or not – recall the right and left panels of Figure 7. Around constrained market outcomes, as mentioned above, fluctuations in the delivered price of imports allow one to trace out the demand curve (assuming that $P^W + T$ does not rise to the extent that imports no longer have bite). Observed factors which move $P^W + T$, such as the exchange rate, world fuel prices (used in the production of clinker abroad and in the international transport of cement), and domestic freight to the consumer (the latter being highly correlated with the domestic price of diesel oil), can then be used as instruments for prices in the estimation of (7) (under the identifying assumption that these factors are not correlated with the unobserved market-specific demand shocks ϵ_{lt}^d). When imports do not restrain domestic prices (left panel of Figure 7), identification of demand hinges on traditional supply-shifters. These include factor prices (i.e. prices of kiln fuel such as fuel oil and coal, electricity prices which determine the cost of grinding, the price of diesel oil which drives the cost of freight, and wages, the latter also impacting freight in addition to the cost of production) and other cost-shifters such as plant capacity, to the extent that changes to scale shift marginal cost[50].

Salvo (2005a) obtains very low market price elasticities of demand, of the order of -0.5. (Appendix B summarizes some results.) Such low market elasticities are systematically estimated across each local market, including markets where the one-firm concentration ratio is as high as 80% (e.g. the state of Santa Catarina, *SC*). Two main possibilities arise to rationalize why an industry facing such inelastic demand does not cut output to raise prices to a point where demand is more elastic[51]: (i) strategic behavior among incumbent firms is such that there is weak pricing power[52], or (ii) prices are constrained by the potential behavior of agents other than consumers (market demand) and incumbents, such as entrants or regulators. By the first alternative, an industry seeing such inelastic demand would not be able to restrict output to raise prices because competition among incumbent producers drives prices down toward marginal cost. However, one can reject competition on the basis of the large observed price-cost margins, amounting to around 50% of producer prices (recall Section 3). The second explanation is the accepted hypothesis. While market demand in equilibrium is inelastic, the residual demand which the domestic industry faces at the price ceiling posed by high-cost imports is highly elas-

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[50] Salvo (2005a) estimates demand in each local market from 156 monthly observations for the period January 1991 to December 2003. He shows that results are robust to the choice of alternative functional forms and performs all manner of specification tests.

[51] A third possibility hinges on a very special class of models of spatial competition, à la Hotelling-Salop, where firms cannot price discriminate (recall comment in Section 2). The restrictive nature of pricing then ensures that a low *market* price elasticity of demand does not translate into a low price elasticity of demand faced by the *firm*. See Salvo (2005b).

[52] For example, behavior is competitive, or low concentration ensures that any firm internalizes only a small fraction of the aggregate benefit (of the large price rise) that would result from a (small) reduction in output (thus in equilibrium the price remains at a level consistent with aggregate demand being inelastic).

tic[53]. Attempts by the domestic industry, already enjoying a large price-cost margin, to raise prices above this price ceiling would only invite foreign entry[54].

As Salvo (2005a) argues, this imports-constraining (or trade arbitrage) story is further supported by a wealth of anecdotal and interview-based evidence. Other consistency checks are conducted. For one, while the (fluctuating) price ceiling $P^W + T$ is not observed, in part because the international cement market is less developed than (say) the international oil market[55], Salvo (2005a) reports that domestic cement prices in local currency are highly correlated with the exchange rate, as one might expect. Also consistent with the imports-constraining story, in the cross-section of local markets cement prices are increasing in the market's distance from the coast[56].

Finally, one might worry that the estimated demand elasticities are too low in absolute value (due to, say, attenuation bias). Despite the extensive specification tests conducted in Salvo (2005a) suggesting otherwise, higher absolute (more negative) elasticities would only reinforce the finding of tacit market division among incumbent oligopolists, as I turn to next.

5.3 Testing Cournot against "more collusive" conduct: Inferring oligopoly behavior in a constrained equilibrium

In a constrained equilibrium, it may be possible to empirically distinguish between alternative models of conduct which, owing to the binding imports-arbitrage constraint, give rise to the same aggregate outcomes. I propose a measure that uses each firm's supply decision toward each local market to test the hypothesis of (constrained) Cournot conduct against the alternative of "more collusive" behavior[57]. While the test requires the

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[53] That market demand is inelastic in equilibrium owes to demand, costs and firm conduct (i.e. the structural parameters of the data generating process) being such that this upper limit to prices binds, and demand happens to be inelastic at this limit, as in the constrained monopoly of Figure 7.

[54] Other studies of cement have found low market price elasticities in equilibrium. For example, Röller and Steen (2006) find an average fitted elasticity of -0.46 for Norway, while Jans and Rosenbaum (1996) report an average -0.81 across 25 regional US markets. It is conceivable that in these markets imports also restrain the prices set by the domestic oligopolies. The explanation commonly advanced behind such inelastic demand is that cement accounts for a low share of construction budgets and that it has few substitutes (except in highway construction, where asphalt is a substitute). Yet while helping to explain the steepness of the inverse demand curve, this does not explain the steepness *at the equilibrium*. One must still explain why an industry, facing such inelastic demand at the market price, does not cut output in an attempt to raise prices and thus move up along the demand curve to a point where demand is more elastic.

[55] For example, unlike oil, cement is not yet listed on any organized exchange.

[56] I take neither of these consistency checks, however, as *prima facie* evidence that potential imports restrain prices. Such features of the data can also be explained by alternative stories, such as factor prices (i.e. oil) being set in hard currency on the world market, and producers incurring higher transport costs to distribute cement in less densely populated areas (recall that less dense markets are those further removed from the coast).

[57] "More collusive" behavior is employed in the sense that, were the constraint not to bind, aggregate output supported by such behavior would be lower than the Cournot oligopoly solution.

observation of (domestic) cost and is only sufficient to reject the hypothesis of Cournot, its value resides in uncovering firm-level behavior in a constrained setting.

5.3.1 In search of a benchmark: Cournot[58]

Figure 8 establishes the Cournot benchmark (in any given local market l[59]). In the left panel, the steep line depicts firm f's reaction function in the absence of imports; write this as $q_f = R_f(q_{-f})$, where $q_{-f} := \sum_{j \neq f} q_j$ is the joint output of firm f's (domestic) rivals. The line with slope -1 represents the constraint on firm f's output posed by the threat of foreign arbitrage, given by $q_f + q_{-f} \geq q(P^W + T)$. (To see this, note that the price ceiling set by the perfectly-elastic supply of imports is equivalent to an output floor.) Thus, firm f's best response to the output of its rivals and to the threat of imports corresponds to the outer envelope to its reaction function in the absence of imports and the boundary to the imports constraint; denote this "constrained" reaction function as

$$q_f = \tilde{R}_f(q_{-f}; P^W + T) := \max(R_f(q_{-f}), q(P^W + T) - q_{-f})$$

Drawn as a thick curve in the left panel, for $R_f(0) < q(P^W + T)$ such that $q_f = R_f(q_{-f})$ crosses $q_f + q_{-f} = q(P^W + T)$, the constrained reaction function consists of two segments. For high enough q_{-f} such that $\tilde{R}_f(q_{-f}; P^W + T) + q_{-f} \geq q(P^W + T)$, imports have no bite and the standard Cournot pricing equation holds:

$$D^{-1}(q) + \frac{D^{-1}(q)}{\eta(q)} \frac{q_f}{q} = c_f \tag{8}$$

where $q = q_f + q_{-f}$, $D^{-1}(.) = q^{-1}(.)$ denotes the inverse demand function and, as in Figure 7, the market price elasticity of demand η is written as a function of q. Now, for lower q_{-f} such that $\tilde{R}_f(q_{-f}; P^W + T) + q_{-f} = q(P^W + T)$, the imports constraint binds and firm f's optimal reply *exceeds* the quantity that it would set in the absence of imports. Here, firm f's (perceived) marginal revenue falls short of marginal cost:

$$D^{-1}(q) + \frac{D^{-1}(q)}{\eta(q)} \frac{q_f}{q} < c_f \tag{9}$$

Conditions (8) and (9) combine to prove the following proposition:

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[58] For a model with a similar flavor where a Cournot oligopoly may deter entry by producing the limit output, see Gilbert and Vives (1986) (I thank Xavier Vives for pointing this out). As in the empirical literature on firm behavior, the Cournot assumption serves as a benchmark.

[59] In order to simplify notation, in this section I omit references to local market l.

Proposition 1 *("Constrained" Cournot first-order condition) In the presence of imports, if firm f behaves as a Cournot player, it will be the case that*

$$D^{-1}(q) + \frac{D^{-1}(q)}{\eta(q)}\frac{q_f}{q} \leq c_f \tag{10}$$

This condition holds as a strict inequality when the "imports (arbitrage) constraint" $q_f + q_{-f} \geq q(P^W + T)$ binds, in which case price is equal to the delivered price of imports $P^W + T$.[60]

The rival firms' constrained joint reaction function, $q_{-f} = \tilde{R}_{-f}(q_f; P^W + T)$, is similarly derived. The set of equilibrium outcomes is then the intersection of $q_f = \tilde{R}_f(q_{-f}; P^W + T)$ and $q_{-f} = \tilde{R}_{-f}(q_f; P^W + T)$. For a low enough price of imports (i.e. an imports boundary sufficiently far from the origin), there are multiple equilibria and imports restrain domestic prices at the Cournot equilibrium[61].

In a constrained setting, how can one then use – via FOC (10) – a domestic firm's observed marginal cost and level of supply (to a local market) to test Cournot against the alternative of "more collusive" behavior (toward that local market)? The left panel of Figure 9, depicting domestic duopolists f and g, shows that this may not always be possible. Notice that the set of constrained collusive equilibrium outcomes is collinear with the boundary to the imports constraint and is a superset of the set of constrained Cournot equilibrium outcomes. Suppose that one observes the constrained outcome marked with a "+". Because such an outcome is consistent with both Cournot and more collusive behavior, for either duopolist, it is not possible to tell whether the firms behave in Cournot fashion (in which case aggregate equilibrium output in the absence of imports would equal $q^C := q^C_f + q^C_g$) or whether firm behavior is more collusive than the Cournot benchmark (in which case the aggregate equilibrium output in the absence of imports would be lower than q^C). However, it may be possible to observationally distinguish collusion from Cournot if firm-level supply levels are "sufficiently" asymmetric[62]. This is illustrated in the right panel of Figure 9. From the observed equilibrium outcome, marked with a "•", firm g's behavior is still consistent with both Cournot and more collusive conduct. Under the Cournot hypothesis, firm g does not cut output in an attempt to raise price above $P^W + T$, as an unconstrained Cournot firm would do, since this would only open the door to imports. In contrast, firm f's behavior is *not* consistent with Cournot. Firm f is restricting output as compared to the supply decision of a

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[60] Condition (10) also holds as an inequality in the case of a corner solution (i.e. $D^{-1}(q_{-f}) < c_f$ such that $q_f = R_f(q_{-f}) = 0$), but this is standard so is omitted from the proposition.

[61] In the absence of imports, the unique Cournot equilibrium outcome (q^C_f, q^C_{-f}) is defined implicitly by $q^C_f = R_f(R_{-f}(q^C_f))$ and $q^C_{-f} = R_{-f}(R_f(q^C_{-f}))$. Formally, imports have bite under Cournot conduct if $D^{-1}(q^C) \geq P^W + T$, where $q^C := q^C_f + q^C_{-f}$, or equivalently when $q^C \leq q(P^W + T)$.

[62] I examine the equilibrium support of this type of spatial supply arrangement in Appendix A.

constrained Cournot firm. The point is to recognize that for a Cournot firm, the general (i.e. allowing for potential imports arbitrage) pricing condition (10) of Proposition 1 has to hold. That is, for no Cournot firm can (perceived) marginal revenue *exceed* marginal cost, otherwise the firm would optimally expand supply, and this holds irrespective of whether the imports constraint binds or not (since the latter places a *lower* bound on aggregate domestic supply). This translates into the following test. Rewrite (10) as an equality:

$$D^{-1}(q) + \frac{D^{-1}(q)}{\eta(q)} \frac{q_f}{q} = \varphi_f + c_f \tag{11}$$

Proposition 2 *(Sufficient statistic to reject Cournot behavior) Under the null of Cournot behavior,* $\varphi_f \leq 0$. *When the imports constraint binds,* $\varphi_f < 0$ *is consistent with Cournot behavior. The finding that* $\varphi_f > 0$ *allows one to reject the hypothesis that firm* f *is behaving in Cournot fashion, in favor of more collusive behavior, regardless of whether the imports constraint binds or not.*

5.3.2 The evidence

Prior to testing the supply decisions of firms in geographic space and over time, conditional on plant location, for the entire sample, I consider some specific examples extracted from the data. These are reflective of a broader trend, where in many instances firms in the Brazilian cement industry undersupply local markets as benchmarked against the supply behavior of a Cournot firm.

Illustration 1: The supply of 2 firms to 2 northeastern markets in 1996 Consider the two adjacent states of Alagoas (*AL*) and Sergipe (*SE*), located in the northeast of Brazil (see Map 1, which I return to below). These states are equally small both in terms of market size and geography. Up until 1996 each was home to only one plant: the firm Brennand operated the plant located in *AL* (respectively firm 1 and market A) and its rival Votorantim operated the plant located in *SE* (respectively firm 2 and market B)[63]. Consider the year 1996. While firm 1 commands an 83% share in market A, it chooses not to supply to neighboring market B, right next door to its plant located in market A, despite the large price-cost margin it would enjoy were it to do so. Equally striking, firm 2 commands an 89% share in market B, while attaining only a 7% share in the neighboring market A, next door to its plant in market B. Average consumer prices in markets A and B are almost identical, respectively R$ 9.46 (per bag)

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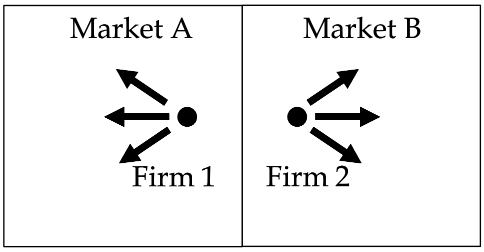
[63] In late 1996 a third firm, GJS, set up a plant close to Votorantim's plant in *SE*. However, I abstract away from this in this illustration, by considering the year 1996. Both Brennand and Votorantim owned other plants located in nearby states.

and R$ 9.44. I calculate firm 1's marginal cost (including sales taxes and the reseller's mark-up) in supplying markets A and B to be respectively R$ 5.20 and R$ 5.47. As for firm 2, I calculate its cost in supplying markets A and B to be respectively R$ 5.30 and R$ 5.16.[64] This is illustrated in the following picture and table, where I take the price elasticities of demand in equilibrium to be their point estimates (in 1996) from Salvo (2005a): -0.84 for market AL and -0.18 for market *SE*.



E.g. Market A: *AL* Market B: *SE*
Firm 1: Brennand Firm 2: Votorantim

(Year $t = 1996$)	Price	Share	Marginal Revenue Cournot	MC	Reject Cournot?[65]
	p_{lt}	$\frac{q_{flt}}{q_{lt}}$	Point estimate $p_{lt}+\frac{p_{lt}}{\hat{\eta}_{lt}}\frac{q_{flt}}{q_{lt}}$	c_{flt}	TS $= \hat{\varphi}_{flt,2.5\%} > 0$
Local market $l = A$ (AL)					
Firm $f = 1$ (Brennand)	9.46	0.83	$9.46 - \frac{9.46}{0.84}0.83 = 0.13$	5.20	No
Firm $f = 2$ (Votoran)	9.46	0.07	$9.46 - \frac{9.46}{0.84}0.07 = 8.72$	5.30	**Yes**
Local market $l = B$ (SE)					
Firm $f = 1$ (Brennand)	9.44	0	$9.44 - \frac{9.44}{0.18}0 = 9.44$	5.47	**Yes**
Firm $f = 2$ (Votoran)	9.44	0.89	$9.44 - \frac{9.44}{0.18}0.89 = -36.38$	5.16	No

I thus reject the hypothesis of firm 2 behaving in Cournot fashion towards market A in 1996, since (perceived) marginal revenue (point estimate of 8.72) significantly exceeds marginal cost (5.30), with the 95% confidence interval (C.I.) for $\varphi_{2A,1996}$ (the test statistic from Proposition 2) being $(2.56, 3.69)$ (and where a point estimate of $8.72 - 5.30 = 3.42$ amounts to $3.42/9.46 = 36\%$ of consumer price). Likewise, I reject Cournot behavior for firm 1 towards market B in 1996 (a point estimate of $\hat{\varphi}_{1B,1996} = 9.44 - 5.47 = 3.97$ amounts to 42% of consumer price!). Notice that firm 2's (resp. firm 1's) supply decision toward market A (resp. market B) corresponds to that of firm f in the right panel of Figure 9. A story where Votorantim tacitly agrees to give Brennand the upper hand in AL in exchange for the latter staying away from SE is consistent with observed

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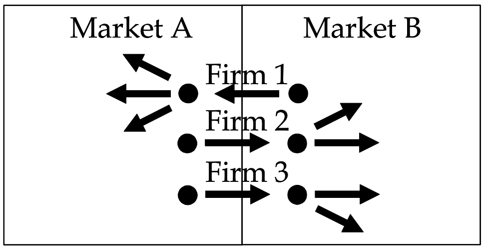
[64] Note that the state-capital cities of AL (market A) and SE (market B) are located less than 300 km apart. Nevertheless, the difference in Votorantim's (say) cost of supplying AL and SE seems low: only R$ 0.14. The reason is that Brazil has an awkward sales tax system which may work against within-state shipments, as happens here, i.e. shipments from Votorantim's plant in SE to resellers in SE are penalized compared to its shipments across the state border to resellers in AL. This mitigates the difference in average freight costs from Votorantim's plant in SE: R$ 0.32 to resellers in SE and R$ 0.77 to resellers in AL.

[65] When testing the null hypothesis of Cournot behavior, I take the upper bound to the 95% confidence interval for the demand elasticity (which corresponds to the lower bound to the 95% confidence interval for the test statistic φ, since the randomness in $\hat{\varphi}$ stems from the randomness of the estimated demand elasticity $\hat{\eta}$), or truncate this upper bound at -0.3. I return to this below.

shipments. Interestingly, Brennand ships from its plant in *AL* to the states of *PB*, *PE* and *BA*, located at further distances than *SE* and where prices are similar to those in *SE*.

Illustration 2: The supply of 3 firms to 2 southeastern markets in 1999 I return to the supply decisions of Votorantim, Holcim and Lafarge, three among the four largest firms nationwide, to the two largest markets, the southeastern (and adjacent) states of São Paulo (*SP*) and Minas Gerais (*MG*), in 1999. Recall from Section 4 that the three firms own plants located in each of the two markets (in addition to owning plants in the also adjacent state of Rio de Janeiro, *RJ*). While Votorantim's share of the *SP* market amounts to 50% (respectively firm 1 and market A), its share in the *MG* market (market B) barely reaches 8%, despite having a plant located in the latter market[66]. This pattern of shipments is inverted when it comes to Holcim and Lafarge (respectively firms 2 and 3). Holcim and Lafarge command single-digit shares of 9% and 5% (respectively) in the *SP* market, while enjoying shares of 24% and 25% (respectively) in the *MG* market.



E.g. Market A: *SP* Market B: *MG*
Firm 1: Votorantim; Firm 2: Holcim; Firm 3: Lafarge

(Year $t = 1999$)	Price	Share	Marginal Revenue Cournot	MC[67]	Reject Cournot?
	p_{lt}	$\frac{q_{flt}}{q_{lt}}$	Point estimate $p_{lt}+\frac{p_{lt}}{\hat{\eta}_{lt}}\frac{q_{flt}}{q_{lt}}$	c_{flt}	TS $= \hat{\varphi}_{flt,2.5\%} > 0$
Local market $l = A$ (*SP*)					
Firm $f = 1$ (Votoran)	8.67	0.50	$8.67-\frac{8.67}{0.37}0.50 = -3.10$	5.19	No
Firm $f = 2$ (Holcim)	8.67	0.09	$8.67-\frac{8.67}{0.37}0.09 = 6.51$	5.35	**Yes**
Firm $f = 3$ (Lafarge)	8.67	0.05	$8.67-\frac{8.67}{0.37}0.05 = 7.55$	5.85	**Yes**
Local market $l = B$ (*MG*)					
Firm $f = 1$ (Votoran)	7.57	0.08	$7.57-\frac{7.57}{0.63}0.08 = 6.62$	5.28	**Yes**
Firm $f = 2$ (Holcim)	7.57	0.24	$7.57-\frac{7.57}{0.63}0.24 = 4.63$	4.67	No
Firm $f = 3$ (Lafarge)	7.57	0.25	$7.57-\frac{7.57}{0.63}0.25 = 4.57$	4.67	No

As the table above indicates, I reject the hypothesis that firms 2 and 3 are behaving à la Cournot with respect to market A in 1999, in favor of the alternative of more collusive

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[66] Recall that Votorantim's plant in *MG* ships 3.5 times more to the *SP* market than within the state of *MG*.

[67] As I explain below, I take as marginal cost c_{flt} the minimum marginal cost of serving market l across all the plants owned by firm f at time t.

behavior. (Notice that the supply decisions of firms 2 and 3 towards market B are consistent with both Cournot and more collusive conduct, since the imports constraint may be binding.) Similarly, on the basis of the 95% C.I. for $\varphi_{1B,1999}$ lying entirely on the positive domain, I reject the hypothesis that firm 1 is behaving in Cournot fashion toward market B, accepting the alternative of more collusive behavior. Again, a story where Votorantim tacitly agrees to give Holcim and Lafarge the upper hand in *MG* (and, for that matter, also in *RJ*, the country's third largest market) in exchange for Holcim and Lafarge staying away from *SP* explains the observed supply pattern.

Illustration 3: The supply of the top 4 firms to all 17 markets in 1996 and in 1999 I now consider the supply behavior by the top 4 nationwide firms (Votorantim, GJS, Holcim and Lafarge) with respect to all 17 markets at 2 periods in time, the years 1996 and 1999. The results of these 4 × 17 × 2 tests are summarized in Maps 1 to 4 (a figure corresponding to each firm). Firm-market-year triples depicted with straight [red] lines correspond to supply decisions that can only be explained by supply behavior that is more collusive than Cournot[68]: were firms acting à la Cournot towards such markets, they would expand supply vis-à-vis their observed shipment shares (which may or may not be as low as zero). An example is provided by Votorantim's supply behavior towards *AL* in 1996 – see Map 1[69]. Firm-market-year triples depicted with dotted [blue] lines correspond to supply decisions where Cournot behavior cannot be rejected and where prices in the local market exceed the firm's delivered marginal cost[70]. An example is provided by Lafarge's supply behavior towards *MG* in both years – see Map 4. Firm-market-year triples which are unmarked on the maps (apart from those corresponding to the 10 markets which were dropped in the demand estimation, as explained in footnote 49) correspond to supply decisions where prices in the local market fall short of the firm's delivered marginal cost, i.e. the firm's nearest plant is too far from the market. An example is provided by Holcim's decision to (not) supply several northeastern markets in 1999 (e.g. the state of Maranhão, *MA*) – see Map 3. The reason why these markets are unmarked in 1999 yet marked with straight [red] lines in 1996 is that low cement prices in 1999 (R$ 8.13) fall short of marginal cost (R$ 9.44); in contrast, in 1996, Holcim's decision to not ship to these markets despite the high cement prices of that year leads

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[68] Rejection of the null hypothesis of Cournot behavior is again based on the lower bound to the 95% C.I. of φ being greater than 0 – see below.

[69] Notice that, in contrast to 1996, in 1999 I cannot reject the hypothesis of Votorantim behaving à la Cournot with regard to *AL* because cement prices in that market in 1999 (R$ 6.66 per bag) were considerably lower than in 1996 (R$ 9.46). Also, Votorantim's share of the *AL* market more than tripled from 7% in 1996 to 23% in 1999, possibly as a result of GJS setting up a plant in the neighboring state of *SE* in late 1996 (see footnote 63), and/or due to Brennand (the market leader in *AL*) being up for sale by 1999 (Brennand was to be acquired by Cimpor in late 1999). Such events may have led to the reallocation of market shares, with the unraveling of any previous tacitly collusive arrangement.

[70] Notice from (11) that $\varphi_f < 0$ and $p = D^{-1}(q) > c_f$ jointly imply that $q_f > 0$, i.e. such supply decisions are ones where the firm's share in the market is strictly positive.

to the rejection of Cournot (a price of R$ 9.40 against a marginal cost of R$ 9.08).

The figures indicate that there are plenty of local markets to which the four leading firms are holding back supply relative to the Cournot benchmark. The local markets where Cournot behavior cannot be rejected in favor of more collusive behavior are those which are either (i) too far away such that the marginal cost to serve the market exceeds the consumer price; or, most importantly, (ii) local markets which under a tacit collusive arrangement, as I argue, may correspond to a firm's "own home turf": these are typically local markets where the firm owns plants (i.e. Votorantim in many states, GJS in northeastern states, Holcim and Lafarge in MG and RJ).

Testing the full sample Having illustrated why the data broadly rejects Cournot behavior, pointing to a pattern of market division, I now present the results for the full sample. From the Cournot pricing condition (11), I compute the test statistic

$$\hat{\varphi}_{flt} = p_{lt} + \frac{p_{lt}}{\hat{\eta}_{lt}} \frac{q_{flt}}{q_{lt}} - c_{flt} \tag{12}$$

for each active-firm-market-year combination (f, l, t), where $\hat{\eta}_{lt}$ is based on the estimation of demand (Salvo 2005a), and p, q and c are observed. Recall that $\hat{\varphi}_{flt} > 0$ is sufficient to reject the null hypothesis that firm f is behaving in Cournot fashion towards market l in year t, in favor of more collusive behavior; importantly, this statistic allows for the constraining effect of imports.

A few comments are in order. A firm is active in a given year if it owns at least one plant (indexed by i) which is active in that year; that is, firm f is active iff $\sum_l \sum_{i \in \mathcal{O}_{ft}} q_{ilt} > 0$, where $\mathcal{O}_{ft}$ is the set of plants owned by firm f in year t. For every year t in which a firm f is active in the nine-year period 1991 to 1999 for which plant-to-market shipments are available, there are 17 (f, l, t) combinations, one for each of the 17 local markets, irrespective of the markets to which firm f *actually* ships in year t. There are 2431 active-firm-market-year combinations corresponding, therefore, to an average of $2431/17/9 \approx 16$ active firms in the sample in any given year[71]. For every

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[71] Of these 2431 observations, 1471 correspond to supply decisions where shipments (shares) are zero. Of these 1471 observations where shipments are zero, a surprisingly low 207 of them correspond to supply decisions where the firm's delivered marginal cost exceeds the consumer price, say because the firm's nearest plant is too far from the market. (I again interpret this as evidence that firms are serving their own home turf, restricting supply to other markets, despite this being profitable in a static sense.) The remaining 1264 zero-shipment decisions where price exceeds marginal cost (a mean price of R$ 11.34 against a mean marginal cost of R$ 8.99, or a mean 21% price-cost margin) are indicative of behavior that is more collusive than Cournot. Robustness checks (see the *Supplementary Section*) reassure me that delivered marginal costs are not understated: quite to the contrary, recall that costs may be overstated (though any systematic bias is small) and that this reinforces my findings. Of note, there are only 5 observations where shipments are positive and marginal cost exceeds price: these seem to be one-off shipments, of minimal volume (across these 5 observations, the mean share of the market is less than 1%, and the mean price-cost margin is only -4%).

year t, I take firm f's marginal cost in serving market l, c_{flt}, as the minimum among the marginal costs in serving market l from the plants that it owns, i.e. $c_{flt} := \min_{i \in \mathcal{O}_{ft}} c_{ilt}$; this cost typically corresponds to that of the closest plant (though costs do vary across plants conditional on location on account of other characteristics such as kiln size, kiln age and factor prices). Given the idle capacity that is pervasive in the industry, this reflects firm f's cost of increasing supply to market l on the margin. Recall that, with a view to testing conduct, the marginal costs I construct are conservative, i.e. they may err on the high side. Inspection of (12) makes it clear that this understates the test statistic $\hat{\varphi}$, working against the rejection of Cournot conduct. Finally, in view of Proposition 2, I reject the null hypothesis of Cournot behavior in favor of the alternative of more collusive behavior when the 95% C.I. for the test statistic $\hat{\varphi}$ falls entirely on the positive domain, i.e. when the lower bound to the C.I. is greater than zero. Now, since the randomness in the test statistic $\hat{\varphi}$ stems from the randomness of the estimated demand elasticity $\hat{\eta}$ – see (12) – I map the 95% C.I. (lower bound) for $\hat{\varphi}$ from the 95% C.I. (upper bound[72]) of $\hat{\eta}$. But there is an empirical issue I must overcome: of the $17 \times 9 = 153$ market-year pairs, 57 market-pairs have 95% C.I. for the demand elasticity that cross over to the positive domain, suggesting (for η at the upper extreme of the interval[73]) that the demand curve slopes upward! I deal with this in two alternative ways. One way is to drop supply decisions that pertain to these market-year pairs[74]. The alternative is to truncate the 95% C.I. for the demand elasticity from above at -0.3.[75]

Total number of active-firm-market-year combinations, (f, l, t)	2431	
Combinations for which the upper limit to the 95% C.I. for η_{lt} is negative...	1475	100%
and $\hat{\varphi}_{flt}$ is greater than zero...	1125	
and $\hat{\varphi}_{flt}$ is significantly greater than zero at the 5% level	**1015**	69%
and $\hat{\varphi}_{flt}$ is positive and exceeds 10% of consumer price	935	
and $\hat{\varphi}_{flt}$ is positive and exceeds 20% of consumer price	**602**	41%

The table above summarizes the results. Of the 1475 active-firm-market-year supply decisions for which the C.I. for the price elasticity of demand falls within the interval $(-\infty, 0)$, I find that the null hypothesis of Cournot behavior that allows for the constraining effect of imports, $\varphi_{flt} \leq 0$, can be *rejected at the 5% level of significance in 1015 instances*. In other words, under the Cournot conjecture, one would expect firms to expand their supply to local markets in $1015/1475 \simeq 69\%$ of supply decisions vis-à-vis

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[72] To see this, notice from (12) that increasing (a negative) $\hat{\eta}$ toward zero lowers $\hat{\varphi}$.

[73] In terms of *point estimates*, only 9 of the 153 market-year pairs have positive elasticities of demand.

[74] This entails dropping 956 out of the 2431 supply decisions, with 1475 observations remaining – see the table below.

[75] For example, the estimated 95% C.I. for $\hat{\eta}_{MA,1993}$ is $(-0.517, 0.121)$. I thus compute the lower bound to the test statistic corresponding to every active firm's supply decision to the *MA* market in 1993 using an upper bound to $\hat{\eta}_{MA,1993}$ of -0.3, rather than dropping these supply decisions.

observed shares – these firms are choosing output to the left of their Cournot reaction functions[76]. As in the above illustrations, the test statistics $\hat{\varphi}_{flt}$ are not only positive but sizeable: the point estimate for $\hat{\varphi}_{flt}$ exceeds 20% of consumer price in 602 supply decisions! Alternatively, if I truncate the 95% C.I. for the demand elasticity from above at -0.3, of the 2431 active-firm-market-year supply decisions, I can reject the hypothesis of Cournot behavior in 1856 decisions, or $1856/2431 \simeq 76\%$ of instances[77].

6 Concluding remarks

This paper has provided an example of a spatial industry in which trade flows exhibit gravity-like structure yet where the sharp decay of flows with respect to distance owes to firms' behavioral strategies. Hummels (2001) writes that "we have remarkably little concrete evidence as to the nature, size, and shape of (trade) barriers" (p.2). My paper suggests that in some international oligopolies, some barriers may not be barriers at all, but simply reflect the outcome of firms' behavioral decisions. The finding suggests that trade theory should continue to advance in its modeling of supply behavior[78]. The desire to avoid cross-hauling in the presence of trade costs, coupled with improved coordination in a world of imperfect information, may lead an oligopoly to tacitly divide geographic markets, allocating large shares in local markets to those firms with nearby facilities. In this sense, strategic behavior can magnify distance effects.

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[76] Notice that if I consider only the 1344 active-firm-market-year supply decisions for which the C.I. for the price elasticity of demand falls within the interval $(-\infty, 0)$ *and* where prices exceed delivered marginal cost, I then reject Cournot behavior in favor of the alternative of greater collusion in as many as $1015/1344 \simeq 76\%$ of supply decisions.

[77] Notice from (12) that lowering the truncation threshold (i.e. increasing the absolute value of the elasticity, say, to -0.5) reinforces this result.

[78] Note that the paper concerns supply behavior in the product market *conditional on firms' spatial entry decisions.* Hummels (2001) makes the related point that trade theory should continue to advance in its modeling of supply with regard to *entry.* Hummels argues that because of an "endogenous production response", "(t)ransport costs operate indirectly by placing the production of specific varieties proximate to locations where these varieties are strongly preferred." (p.23) Not controlling for the migration of production in response to trade barriers then "magnifies the effects of barriers on trade volumes and may explain the large estimates from aggregate (trade) models" (p.3)

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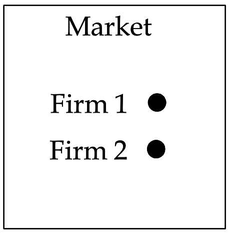
A Appendix: Supporting market division in equilibrium

For the sake of illustration, I provide some simple collusive arrangements which support market division (or market sharing) in equilibrium. Set in a context where firms meet in different (geographic) markets, such examples are inspired by the different local market structures observed in the Brazilian cement industry. These simple dynamic games give rise to the pattern of market division identified in Section 5.3 as equilibrium phenomena. Following Bernheim and Whinston (1990), by pooling incentive constraints across the different markets, a firm's share in those markets where it enjoys a low cost (e.g. those local markets in proximity to its plants, in a spatial model with multiplant firms) may be increased at the expense of its share in markets where it has a high cost (e.g. markets further away from its plants, but closer to the plants of rival firms).

Illustration 1: two firms with plants located in a single local market (*A local market which comes to mind here is Rio Grande do Sul (*RS*), where two firms, Votorantim and Cimpor, operate plants, located very close to one another.*)

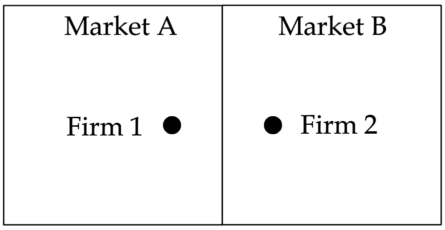


Consider two firms, 1 and 2, with symmetric marginal costs c facing a competitive fringe of imports with elastic supply at price $P^W + T$ such that $c < P^W + T < p^M$, where p^M is the monopoly price as in the theoretical framework of Section 5. Recall that in such a setup the most collusive price, which maximizes aggregate (domestic) industry profit, is $p = P^W + T$, where the aggregate industry profit (per period) is $\Pi := (P^W + T - c)q(P^W + T)$ and $q(p)$ denotes the demand function in the local market. As is standard in the literature on supergames, the most collusive price may be supported in equilibrium by each firm adopting, say, the following symmetric "grim" strategy in prices: set the collusive price $p = P^W + T$ in each period unless the rival firm has set a different price in a previous period, in which case set the competitive price $p = c$. Assume for now that, given the symmetry, both firms split the market equally (i.e. firm f's share $s_f = \frac{1}{2}$, $f = 1, 2$). Collusion will then be sustainable if each firm's payoff from sticking to the collusive agreement exceeds its payoff from slightly undercutting its rival and selling to the entire market in a single period; that is, collusion is sustainable if

$$\frac{1}{2}\Pi\frac{1}{1-\delta} \geq \Pi$$

where δ is the per-period discount factor. This incentive constraint rearranges to $\delta \geq \frac{1}{2}$, yielding the standard folk theorem whereby for a sufficiently high discount factor the collusive price $p = P^W + T$ (or any other price p such that $c < p \leq P^W + T$) may be supported in equilibrium.

Illustration 2: two firms and two neighboring markets: firm 1 is located in market A and firm 2 is located in market B next door (*Two local markets which come to mind here are the neighboring states of Sergipe (*SE*) and Alagoas (*AL*), equally small in terms of market size and geography. As stated in Illustration 1 of Section 5.3, until 1996 Votorantim operated the only plant in* SE *and Brennand operated the only plant in next-door* AL*. While in 1996 Votorantim commanded an 89% share in* SE*, it attained only a 7% share in* AL*; on the other hand, Brennand commanded an 83% share in* AL *while not supplying to* SE.)



Now assume that there are transport costs $t > 0$ associated with cross-hauling product to the neighboring local market: while the marginal cost of serving a market in which one's plant is located is c (e.g. firm 1 in market A), the marginal cost of serving the market next-door to one's plant rises to $\bar{c} = c + t$ (e.g. firm 1 in market B), where $c < \bar{c} < P^W + T$ ($P^W + T$ as before). Demand is identical in each local market, given as before by $q(p)$. Denoting $\Pi := (P^W + T - c)q(P^W + T)$ as before, let

$\Pi^{xhaul} := (P^W + T - \bar{c})q(P^W + T)$. (This corresponds to firm 1's maximal profit in neighboring market B were it to act as a monopolist in the supply of that market[79]. Clearly $\Pi > \Pi^{xhaul}$.) It is easy to see that the collusive arrangement that maximizes aggregate industry profit in each market involves no wasteful cross-hauling and corresponds to complete market division, where each market is supplied only by the low-cost firm and prices in each market are $p = P^W + T$: firm 1 supplies quantity $q(P^W + T)$ to market A (i.e. shares $s_{1A} = 1$, $s_{2A} = 1 - s_{1A} = 0$) and firm 2 supplies quantity $q(P^W + T)$ to market B (i.e. $s_{2B} = 1$, $s_{1B} = 1 - s_{2B} = 0$). But can this arrangement be supported in equilibrium?

Begin by considering a situation where firms devise strategies *that treat each market separately*, that is, cheating in a market does not trigger retaliation in other markets. Then for the most collusive price $p = P^W + T$ (or any collusive price p above the competitive price, equal to the high-cost firm's cost $\bar{c}$, but lower than $P^W + T$, i.e. $\bar{c} < p \leq P^W + T$) to be sustainable in a given market, the collusive arrangement must prescribe a strictly positive share to *both* firms in that market. In this situation, both firms must enjoy a non-trivial share of the collusive pie in each market, as can be seen by each firm's incentive constraint (IC) in, say, market A[80]:

$$s_{1A}\Pi\frac{1}{1-\delta} \geq \Pi + \Pi^{war}\frac{\delta}{1-\delta} \qquad \text{low-cost firm 1's IC in market A}$$

$$(1 - s_{1A})\,\Pi^{xhaul}\frac{1}{1-\delta} \geq \Pi^{xhaul} \qquad \text{high-cost firm 2's IC in market A}$$

where $\Pi^{war} := (\bar{c} - c)q(\bar{c})$ denotes industry profit under retaliation (price war, when $p = \bar{c}$), earned by the low-cost firm. (Notice that the minimum share to be prescribed to the high-cost firm is higher the lower is the discount factor: simply rewrite the high-cost firm's IC as $1 - s_{1A} \geq 1 - \delta$.) Hence if firms devise strategies that treat each market separately, complete market division ($s_{1A} = s_{2B} = 1$) cannot be sustained in any collusive equilibrium, regardless of the discount factor.

More naturally, firms will devise strategies that take into account the multimarket nature of their contact, since in each market A or B the same two firms 1 and 2 can supply. By modifying each firm's strategy to ensure retaliation is triggered (i.e. setting price equal to the competitive price $\bar{c}$) in *both* markets should any firm undercut the collusive price in *any* market in a previous period, the collusive arrangement that maximizes aggregate industry profits across markets – i.e. setting $p = P^W + T$ with complete

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[79] Implicit in this statement is the regularity assumption that the monopoly price $p^M(c) := \arg\max_p (p - c)q(p)$ is an increasing function of marginal cost c. Thus $p^M(\bar{c}) > p^M(c) > P^W + T$, where $p^M(c) > P^W + T$ is assumed as before, such that were firm 1 to act as a domestic monopolist in the supply of neighboring market B and face the fringe of imports, it would set $p = P^W + T$.

[80] Shipments by firm 1 and firm 2 are then respectively $q_{1A} = s_{1A}q(P^W + T)$ and $q_{2A} = (1 - s_{1A})\,q(P^W + T)$, where $0 < s_{1A} < 1$.

market division – can now be supported in equilibrium for a high enough discount factor. To see this, pool each firm's incentive constraints across both markets; firm 1's (say) IC is now

$$s_{1A}\Pi\frac{1}{1-\delta}+(1-s_{2B})\,\Pi^{xhaul}\frac{1}{1-\delta}\geq\Pi+\Pi^{xhaul}+\,\Pi^{war}\frac{\delta}{1-\delta}\qquad\text{firm 1's pooled IC}\quad(13)$$

Assuming that the collusive arrangement involves the low-cost firm in one market commanding the same share as the low-cost firm in the other market (i.e. $s_{1A}=s_{2B}=s$) (13) can be rearranged to yield firm f's ($f=1,2$) incentive constraint:

$$\delta\geq\frac{(1-s)\,\Pi+s\Pi^{xhaul}}{\Pi+\Pi^{xhaul}-\;\Pi^{war}}\qquad(14)$$

The collusive arrangement can now involve complete market division, $s=1$. (To link this result back to the body of the paper, notice that such a spatial pattern of supply would lead the test of Proposition 2 in Section 5 to reject the null hypothesis of Cournot conduct, in favor of more collusive behavior, with regard to firm 1's supply in market B and firm 2's supply in market A, on the basis of $\varphi_{1B}>0$ and $\varphi_{2A}>0$. Notice further that such a spatial pattern of supply also exhibits gravity-like structure, as in the oligopoly model of full collusion in Section 2 and the statistical analysis of Section 4.) Indeed, for $p=P^{W}+T$, setting $s=1$ in (14) minimizes the discount factor threshold above which collusion is sustainable[81]:

$$\delta\geq\frac{\Pi^{xhaul}}{\Pi+\Pi^{xhaul}-\;\Pi^{war}}\qquad(15)$$

Thus for a high enough discount factor, the collusive scheme that maximizes aggregate industry profit in each market, setting $p=P^{W}+T$ in both markets and completely dividing markets, can now be supported in equilibrium. Intuitively, as Bernheim and Whinston (1990) have shown, through multimarket contact "slack enforcement power" may be shifted from the market where a given firm is located, enjoying low cost, high share and high profit, to the neighboring market where that firm has high cost, low share

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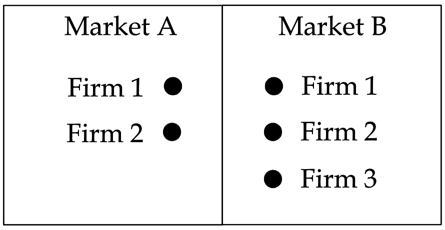
[81] To see this, recall that $\Pi>\Pi^{xhaul}$. Intuitively, when $s=1$ the short-term gain from cheating (equal to $(1-s)\Pi$ in the own market plus $s\Pi^{xhaul}$ in the neighboring market) is lowest (and equal to Π^{xhaul}). Two comments are in order. First, one can show that increasing the transportation cost t may increase the discount factor threshold: though the deviant's profits in the period of deviation fall since Π^{xhaul} falls, profits in each later period rise since Π^{war} rises, meaning that the long-term loss of collusive profits from retaliation may become lower. Thus collusion would seem less likely as t rises, given that it makes the incentive-constraint more stringent (for $s=1$). On the other hand, an increase in t may enhance the *profitability* of colluding, since it may now be more profitable to divide markets and eliminate wasteful cross-hauling. Hence, a greater payoff from collusion through higher t, conditional on it being sustainable, would suggest that firms would have greater incentive to design and implement a collusive scheme. (See Ivaldi et al 2003, footnote 48, on a similar idea applied to the elasticity of demand: a steeper demand curve may raise the profitability of colluding by raising the optimal collusive price.) Second, when $t=0$, then $\bar{c}=c$, $\Pi^{xhaul}=\Pi$ and $\Pi^{war}=0$, implying that incentive constraints (14) and thus (15) collapse to the familiar $\delta\geq\frac{1}{2}$ of Illustration 1.

and low profit[82].

Illustration 3: three firms and two neighboring markets: firms 1 and 2 have plants located in market A and market B next door, while firm 3 has a plant located in market B only (*Two local markets which come to mind here are the neighboring states of Rio de Janeiro (*RJ*) and Minas Gerais (*MG*). Considering these two markets, four firms have plants located in both* RJ *and* MG*, while two firms have plants located in* MG *only. The extent to which these two latter firms cross-haul cement from their plants in* MG *to the* RJ *market is limited: in 1999 Camargo Correa commanded a 20% share in its home market* MG *but did not supply to the neighboring* RJ*, while Soeicom had a 9% share in its home market* MG *and a (somewhat) lower 6% share in neighboring* RJ*.*)



As before, assume that the cost of supplying a market from a plant located in that market is c but rises to $\bar{c} = c + t$ when supplying from a plant located in the neighboring market. Demand $q(p)$ is again identical in each local market, recall $p^M(\bar{c}) > p^M(c) > P^W + T$ and denote Π^{xhaul} and Π as before. Now consider the following collusive agreement: (i) in market A each of firms 1 and 2 supplies a share s_A of the market, with firm 3 accounting for the remaining $(1 - 2s_A)$ share, such that price is $p = P^W + T$; and (ii) in market B firm 3 supplies a share s_B of the market, with firms 1 and 2 accounting for the remaining $(1 - s_B)/2$ each, again such that price is $p = P^W + T$.[83] The (pooled) incentive constraint for each of firms 1 and 2, that operate plants in both markets, becomes:

$$\left(s_A\Pi + \frac{1 - s_B}{2}\Pi\right)\frac{1}{1-\delta} \geq \Pi + \Pi$$

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[82] Notice that I have assumed Bertrand behavior should collusion break down, but could just as well have assumed Cournot competition. In this case, the right-hand side of incentive constraint (13) would have to be modified as follows: (i) a deviant firm would now earn less than $\Pi + \Pi^{xhaul}$ in the period of deviation (the other firm would still supply its collusive quantities in the period of deviation, and the deviant firm would set its output in each market based on its reaction function, as illustrated in Figure 9 of Section 5.3, thus expanding output in the neighboring market where it has a low share), and (ii) upon retaliation either firm would also earn positive payoffs in its neighboring market, where it incurs a higher cost (and, as Figure 9 of Section 5.3 makes clear, the Cournot equilibrium outcome would not necessarily be unique).

[83] In market A, firms 1 and 2 will then supply $q_{1A} = q_{2A} = s_A q(P^W + T)$ and firm 3 will supply $q_{3A} = (1 - 2s_A)\, q(P^W + T)$. In market B, firm 3 will supply $q_{3B} = s_B q(P^W + T)$ and firms 1 and 2 will each supply $q_{1B} = q_{2B} = \frac{1}{2}(1 - s_B)\, q(P^W + T)$.

since a deviation triggers the competitive price $p = c$ in both markets, which can be rearranged to

$$\delta \geq \frac{3 - 2s_A + s_B}{4} \tag{16}$$

The incentive constraint for firm 3, with a plant located in market B only, is

$$\left((1 - 2s_A)\, \Pi^{xhaul} + s_B \Pi\right) \frac{1}{1 - \delta} \geq \Pi^{xhaul} + \Pi$$

which is equivalent to

$$\delta \geq \frac{(1 - s_B)\Pi + 2s_A \Pi^{xhaul}}{\Pi + \Pi^{xhaul}} \tag{17}$$

As in illustration 2, the collusive arrangement that maximizes aggregate industry profit across markets involves no wasteful cross-hauling, where each market is supplied only by the low-cost firms (i.e. $2s_A = 1$ such that firm 3 does not supply to market A) and prices in each market are $p = P^W + T$. Plugging $s_A = 1/2$ and, say, $s_B = 2/3$ such that all three firms produce the same quantity, sustainability constraints (16) and (17) become $\delta \geq \frac{2}{3}$ and $\delta \geq \frac{\Pi/3 + \Pi^{xhaul}}{\Pi + \Pi^{xhaul}}$ respectively.

B Appendix: Demand (see Salvo 2005a) and freight cost (see *Supplementary Section*)

Demand in the local market I briefly reproduce some demand estimates from Salvo (2005a), referring the reader to that paper for greater details, including robustness tests such as fitting alternative functional forms, using fixed-effects IV panel data estimation and reversing the dependent variable. Figure 10 summarizes results across 17 states for the log-linear counterpart to the demand function (7):

$$\log q_{lt} = \alpha_l^1 + \alpha_l^2 Y_{lt} + \alpha_l^3 \log p_{lt} + \alpha_l^4 Y_{lt} \log p_{lt} + \epsilon_{lt}^d$$

and instrumenting for prices with variables that move the delivered price of imports (see above; specification (II) in Salvo 2005a, termed "IV-imports bite"). The pattern is similar across states. Evaluating exogenous demand at its mean value in the post-stabilization phase (post July 1994), the price elasticity of demand is negative for all 17 states, and significant at the 1% level in 15 states. Post-stabilization price elasticities vary from a minimum (in absolute) of -0.14 to a maximum of -0.72, with a mean of -0.41 and a standard deviation of 0.14. Of note, elasticities are low even in states where the supply of cement is highly concentrated, such as the state of Santa Catarina (SC), in which the one-firm concentration ratio is 78% (in 1999). The average price elasticity in the pre-stabilization phase is negative in 16 out of 17 states, 9 of which are significant at the 10% level or higher. The mean pre-stabilization price elasticity across states is lower: -0.22.[84] In sum, Salvo (2005a) estimates very low market price elasticities of demand, of the order of -0.5.

Plant-to-market freight cost Delivered marginal costs are broken down into two components: (i) plant marginal costs (which are further divided into the following subcomponents: kiln fuel, electricity, mineral extraction rights, and labor/packaging/other costs); and (ii) ex-plant (or plant-to-market) marginal costs (further categorized into plant-to-market freight, sales tax, and the reseller's mark-up. (The study considers the entire supply chain from the producer of cement to the retail consumer, encompassing the reseller.)

The reader is referred to the *Supplementary Section* for details and robustness checks regarding the calculation of delivered marginal costs. Given its importance, however, I here reproduce results from the calculation of plant-to-market freight. In the cement industry, freight is a large component of cost. The vast majority of shipments from producers to buyers take place by road and are provided for by the producers. I do not observe the exact freight rates paid by cement producers. But fortunately I do observe a good proxy for the freight of cement. The transportation of agricultural goods such as soybean and maize is reportedly a close substitute to the supply of cement freight, in view of product and market characteristics (Soares and Caixeta Filho 1996)[85]. I use a database containing approximately 30,000 observations on freight prices for some agricultural goods collected over the period 1997 to 2003 for thousands of different routes across Brazil[86]. Figure 11 summarizes the results of some auxiliary reduced-form regressions. These should be seen as hedonic regressions with the purpose of predicting the price of freight. Given that I do not observe quantities demanded and supplied in the market for freight, I cannot estimate a structural model of the market for freight. (Nor do I think this is necessary in view of my objective, which is to predict the freight cost of cement from plant i to local market l based on observed data.) Freight prices (once converted to

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[84] The price elasticity increases upon stabilization in 13 out of the 17 states, in 8 of which at the 5% level of significance. (This follows from the negative interaction coefficients and the fact that exogenous demand rises in *every* state concurrent with stabilization.)

[85] For example, an interview with a cement industry executive revealed that during the soybean harvesting season (March through May) the producer he works for encourages large resellers to themselves pick orders up at the plant, for fear of relying too heavily on the scarce supply of outside truckers observed during these months. This further suggests that freight of cement and freight of soybean are close substitutes, and therefore that their prices should be similar. Most cement producers outsource trucking services, mostly to independent truckers who are registered in their databases and simply turn up at the door and are hired on the spot (or are hired through cooperatives or middlemen). According to this executive, the cement industry is the top industrial contractor of trucking services in the country.

[86] I am indebted to Professor José Vicente Caixeta Filho of ESALQ, at the University of São Paulo, for providing an extract of the SIFRECA freight database. Data pertaining to soybean, maize and (the mineral) limestone was kindly made available.

constant prices as explained in the *Supplementary Section*[87]) are regressed on exogenous variables such as the distance of the route, the squared distance, a shipment-to-port dummy (to capture exports), transportation-mode dummies (by water or by rail, as opposed to by road), seasonal dummies or monthly dummies (to capture the harvesting cycle), the price of diesel oil (the main cost component for freight), a packaging dummy (shipment of bagged produce as opposed to bulk) and product-type dummies (e.g. powdered soybean), in addition to interaction variables. It is clear from the R^2 (around 90%) of the OLS regressions that the fit is very high[88]; the heteroskedasticity-robust standard errors are low. Freight prices (in R$ per tonne) are increasing in distance (and concave, though slightly so over the relevant range). Consider the results for specification (II). At the sample means of the variables (735 km for distance and R$ 0.422 per liter for the price of diesel oil), the predicted price of freight for a tonne of soybean shipped in bulk by road to a destination other than a port and in the month of April amounts to $3.358+0.0405\times 735-5.44\times 10^{-7}\times 735^2+6.519\times 0.422=3.358+29.768-0.294+2.751=R 35.56 (with a standard error of R$ 0.21). Shipping to a port (possibly as a result of longer waiting times to unload) adds $1.813+0.00041\times 735=$R$ 2.12 (s.e. R$ 0.15), and when this shipping to a port takes place during the harvest season freight prices are predicted to increase by a further R$ 2.30 (s.e. R$ 0.32). Shipping by waterway costs $14.269+0.00498\times 735=R 17.93 (s.e. R$ 0.25) less than by road, while shipping by railway costs $2.349+0.01538\times 735=$R$ 13.66 (s.e. R$ 0.28) less than by road. Shipping in bags as opposed to in bulk raises the price of freight by R$ 0.25 though this estimate is not significantly different from zero. Compared to April, the peak month of the harvesting season, shipments in any other month of the year are cheaper (all coefficients on monthly dummies and their interactions with distance are negative). Shipments in January, the month in which prices are lowest, are R$ 4.87 (s.e. R$ 0.25) lower compared to April. Note that the variation in diesel oil prices over the period is R$ 0.38, accounting thus for a R$ 2.49 (s.e. 0.17) variation in freight prices (this is admittedly low, owing possibly to correlation between diesel oil prices and other variables). I choose to predict the plant-to-market freight cost for cement based on specification (II), on account of observables such as distance from the plant to the market, means of transport and the price of diesel oil.

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[87] Freight prices, in units of local currency per tonne of produce shipped, are thus in December 1999 terms.

[88] Notice that such high R^2 contrast with R^2 in the order of 20 - 45% in similar freight rate regressions reported by Hummels (2001), using international shipment data.

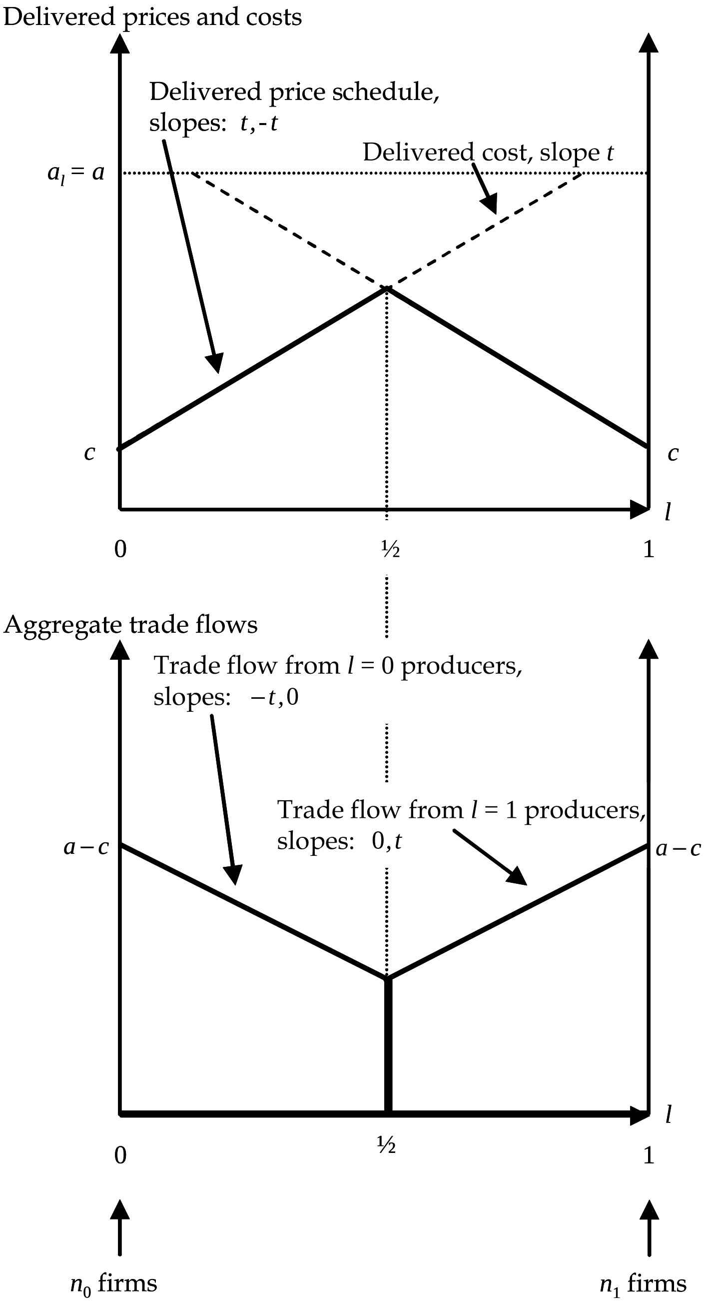


Figure 1: Gravity-like structure in the Bertrand equilibrium: Delivered price schedule and aggregate trade flows. Consumer markets are located along the unit line segment. Drawn holding market size constant over space, i.e. $a_l = a$ (a larger market size in a single local market, say, would result in a spike in one of the trade flow schedules).

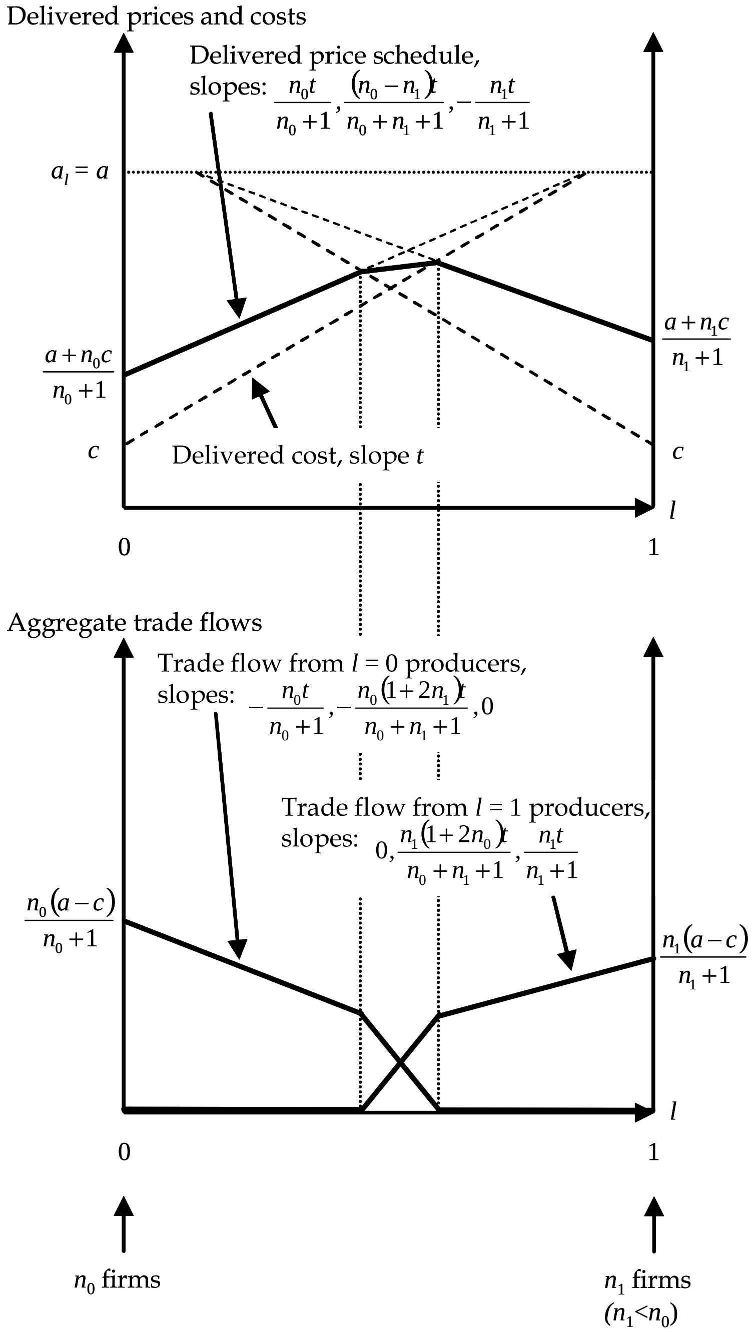


Figure 2: Gravity-like structure in the Cournot equilibrium: Delivered price schedule and aggregate trade flows. Consumer markets are located along the unit line segment. Drawn for $n_0 > n_1$ (besides $n_1 + 1 > (a_l - c)/t$) and holding market size constant over space, i.e. $a_l = a$ (a larger market size in a single local market, say, would result in a spike in the delivered price schedule and in *at least* one trade flow schedule).

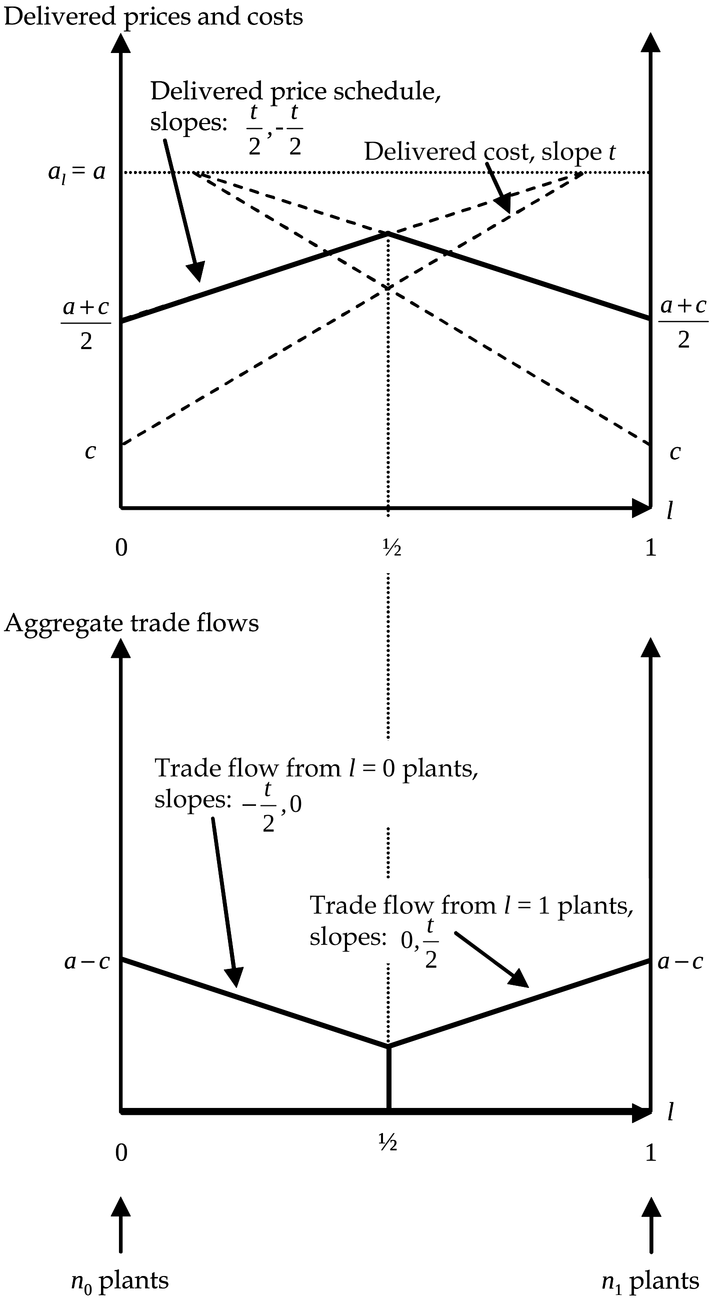


Figure 3: Gravity-like structure in the multi-establishment monopoly equilibrium (full collusion): Delivered price schedule and aggregate trade flows. Consumer markets are located along the unit line segment. Drawn holding market size constant over space, i.e. $a_l = a$.

		Log-linear										Linear	Share
		(1)	(2)	(3)	(4)	(5)	(6)	(6) with cluster. s.e.[1]	(7)	(8)	(9)	(10)	(11)
Average distance		-3.741 ***	-2.701 ***	-2.672 ***	-3.293 ***	-2.089 ***	-2.606 ***	-2.606 ***		-2.607 ***	-0.981 ***	-153.3 ***	-0.00018 ***
		(0.132)	(0.159)	(0.158)	(0.181)	(0.131)	(0.143)	(0.348)		(0.143)	(0.099)	(29.4)	(0.00002)
Market size		1.734 ***	1.547 ***	1.502 ***	9.741 ***	2.176 ***	0.703	0.703	1.032		0.088	498.2 *	
		(0.146)	(0.143)	(0.143)	(1.504)	(0.122)	(1.980)	(1.812)	(2.019)		(1.718)	(257.3)	
1(Firm located in market?)			6.295 ***	6.218 ***	4.276 ***	3.281 ***	1.436 ***	1.436	1.077 *	1.433 ***			
			(0.535)	(0.536)	(0.582)	(0.544)	(0.504)	(1.249)	(0.613)	(0.504)			
Minimum distance									-2.074 ***				
									(0.121)				
Population size										1.205			
										(6.209)			
1(Adjacent market?)											-2.689 ***	-383211 ***	-0.21354 ***
											(0.409)	(22218)	(0.01247)
1(Two state borders?)											-10.352 ***	-619273 ***	-0.31619 ***
											(0.585)	(47345)	(0.02050)
1(Three or more state borders?) x Number of state borders											-5.586 ***	-241979 ***	-0.13257 ***
											(0.234)	(20244)	(0.01099)
Constant		14.216 ***	7.496 ***	10.189 ***	-31.426 ***	2.296	14.257	14.257	8.706	0.472	14.003	332535 ***	0.38771 ***
		(1.372)	(1.452)	(1.562)	(7.804)	(2.343)	(10.723)	(10.260)	(10.879)	(90.035)	(9.136)	(91276)	(0.03812)
Year fixed effects		NO	NO	YES	NO	NO	YES	YES	YES	YES	YES	YES	YES
Market fixed effects		NO	NO	NO	YES	NO	YES	YES	YES	YES	YES	YES	YES
Firm fixed effects		NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES
No. observations	Uncensored	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187	1187
	Total	3484	3484	3484	3484	3484	3484	3484	3484	3484	3484	3484	3484
Log likelihood		-5299.0	-5256.3	-5228.0	-5114.9	-4909.4	-4740.5	-4740.5	-4784.3	-4740.6	-4291.2	-17277.6	285.8
R^2 (OLS counterpart)		0.457	0.508	0.517	0.558	0.605	0.653	0.653	0.644	0.653	0.714	0.448	0.677

Note: Dependent variable is cement flow in (1) to (10), and share of shipments in (11). An observation is a (firm, market, year) triple. Heterosked.-robust standard errors in parentheses. (Two-tailed tests) *** Significant(ly different from zero) at the 1% level; ** Significant at the 5% level; * Significant at the 10% level

[1] Firm-market pairs are defined as clusters, allowing for observations which are not independent within cluster (although they must be independent between clusters)

Figure 4: Traditional gravity equation (tobit) estimates using plant (firm) to market flows

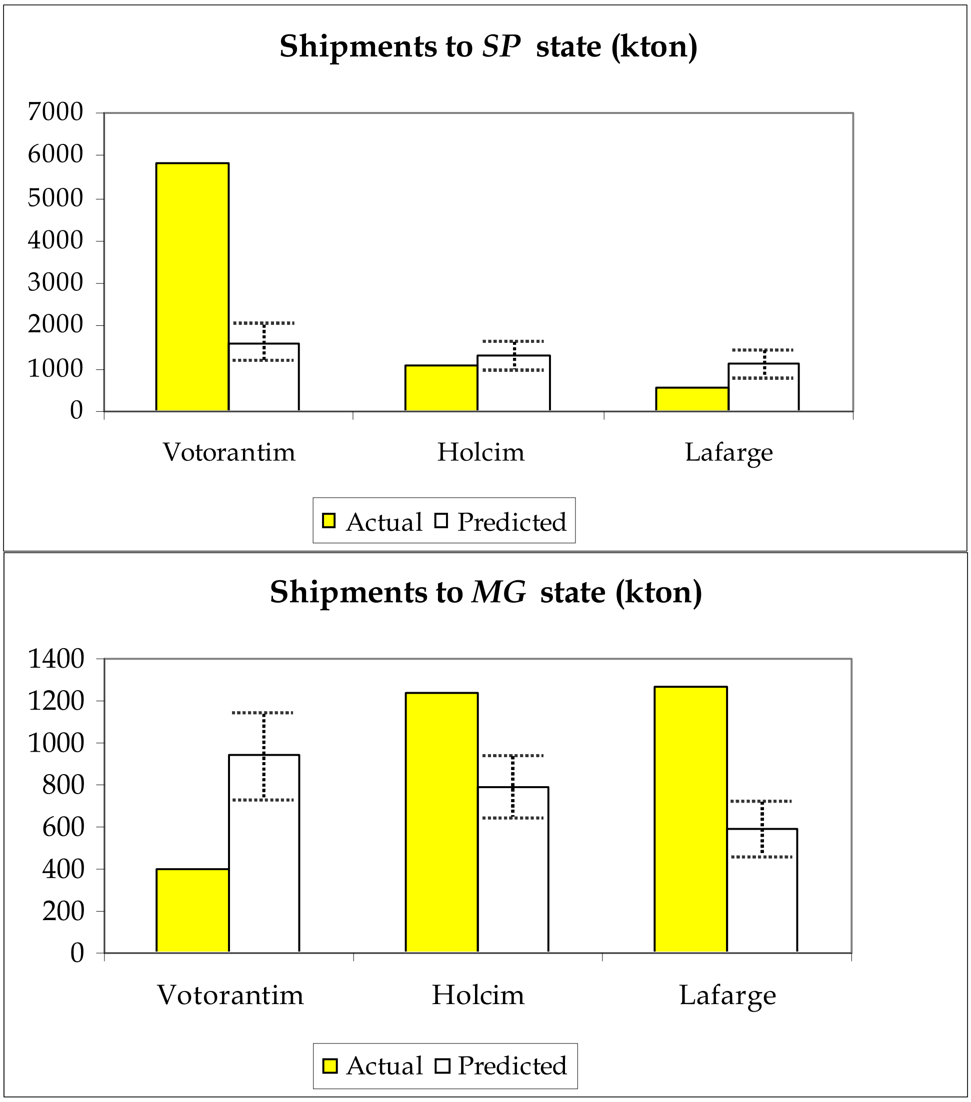


Figure 5: Cement shipments to *SP* and *MG* markets by Votorantim, Holcim and Lafarge, in kton, in 1999: Actual against Predicted (95% C.I.) using the linear version of traditional gravity.

	Log-linear					Linear				
	(1)	(2)	(3)	(3) with cluster. s.e.[1]	(4)	(5)	(6)	(7)	(7) with cluster. s.e.[1]	(8)
Distance	-3.575 ***	-0.909 ***	-0.440 ***	-0.440 **	-0.433 ***	-485.5 ***	-202.9 ***	-257.4 ***	-257.4 ***	-261.8 ***
	(0.080)	(0.099)	(0.080)	(0.191)	(0.079)	(44.3)	(25.5)	(36.4)	(93.8)	(36.9)
Market size in source state	2.610 ***	2.420 ***	-5.056 **	-5.056 ***	-8.177 ***	231.1 ***	237.1 ***	52.3	52.3	53.1
	(0.132)	(0.130)	(2.247)	(1.605)	(2.382)	(37.3)	(34.0)	(246.2)	(165.8)	(248.2)
Market size in host state	0.730 ***	0.287 **	1.805	1.805	2.591	204.3 ***	218.9 ***	354.8	354.8	356.4
	(0.151)	(0.143)	(1.974)	(1.628)	(2.000)	(33.9)	(31.6)	(309.8)	(224.1)	(308.6)
Number of state borders		-5.709 ***	-6.987 ***	-6.987 ***	-7.020 ***		-220502 ***	-285149 ***	-285149 ***	-286465 ***
		(0.223)	(0.229)	(0.471)	(0.227)		(25783)	(32741)	(81726)	(32929)
1(Within state shipment?)							503691 ***	577322 ***	577322 ***	573148 ***
							(71478)	(74674)	(211801)	(74285)
Average price in source state					-9.785 ***					-63324 ***
					(1.798)					(16706)
Average price in host state					6.138 ***					48016 ***
					(1.811)					(15930)
Constant	-0.743	-1.090	38.372 ***	38.372 ***	57.940 ***	-6177	27942	482026 ***	482026 **	603662 ***
	(1.364)	(1.159)	(14.528)	(11.209)	(16.938)	(35021)	(33731)	(132912)	(207999)	(202916)
Year fixed effects	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Source-state fixed effects	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Host-state fixed effects	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
No. observations Uncensored	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185
Total	6084	6084	6084	6084	6084	6084	6084	6084	6084	6084
Log likelihood	-5905.5	-5458.2	-4747.2	-4747.2	-4730.2	-18486.9	-18287.2	-17826.1	-17826.1	-17818.1
R^2 (OLS counterpart)	0.392	0.431	0.502	0.502	0.503	0.115	0.295	0.311	0.311	0.311

Note: Dependent variable is cement flow. An observation is a (source-state, host-state, year) triple. Heteroskedasticity-robust standard errors in parentheses.
(Two-tailed tests) *** Significant(ly different from zero) at the 1% level; ** Significant at the 5% level; * Significant at the 10% level

[1] (Source-state, host-state) pairs are defined as clusters, allowing for observations which are not independent within cluster

Figure 6: Traditional gravity equation (tobit) estimates using source-state to host-state flows

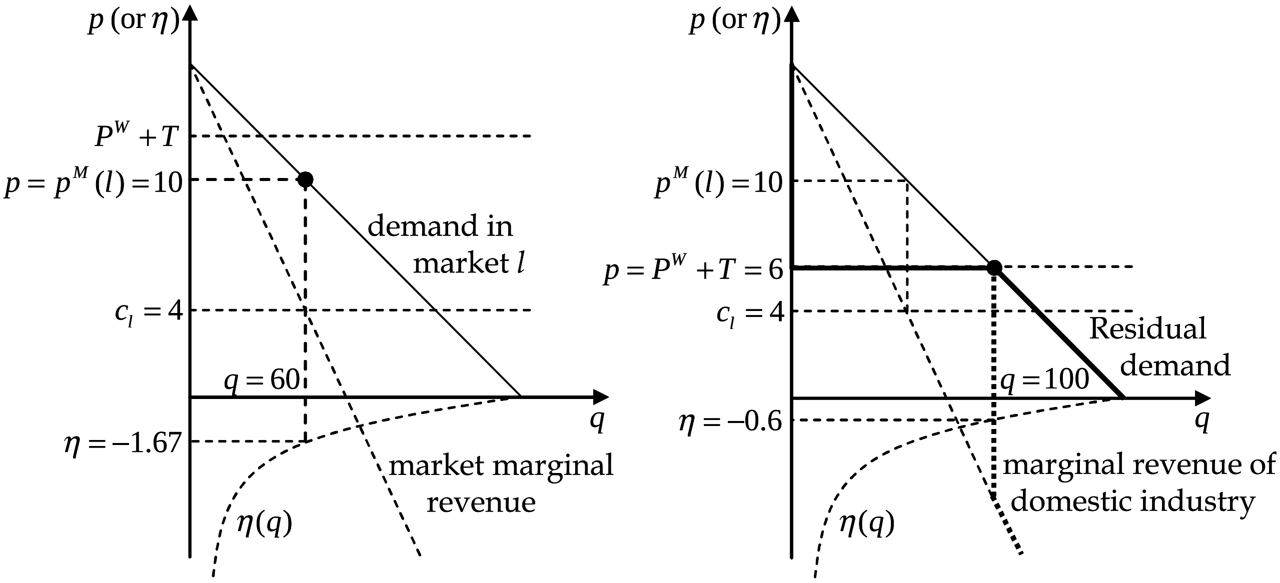


Figure 7: Domestic monopolist facing a competitive foreign fringe in local market l. Drawn for linear demand, given by $q = 160 - 10p$, and $c_l = 4$. Left panel: Imports have no "bite" ($p^M(l) < P^W + T$). Right panel: Imports constrain price in equilibrium ($p^M(l) \geq P^W + T = 6$, as drawn).

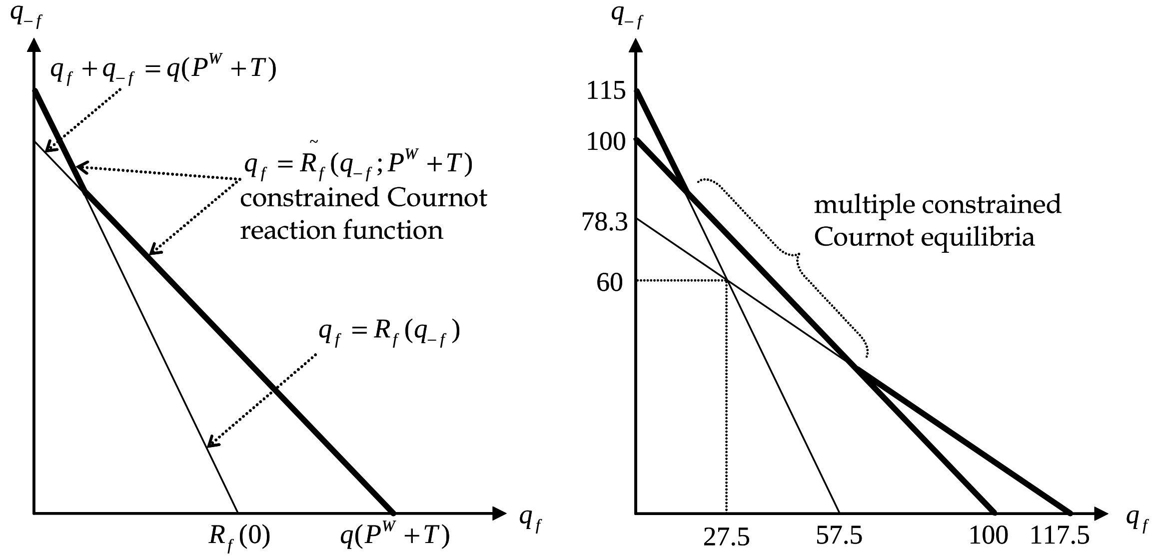


Figure 8: Domestic Cournot oligopoly facing a competitive foreign fringe (in a given local market). Left panel: Cournot firm f's reaction function, facing domestic rivals and imports. Right panel: Cournot equilibria. Drawn for linear demand $q = 160 - 10p$ and $P^W + T = 6$, as in the constrained monopoly of Figure 7, now adding the assumptions that there are 3 domestic firms, that the marginal cost of the firm of interest f is $c_f = 4.5$ and that $\sum_{j \neq f} c_j = 8.5$. Notice that joint output in the constrained Cournot oligopoly is 100, identical to that in the constrained monopoly. In the absence of imports, joint Cournot output would be 87.5.

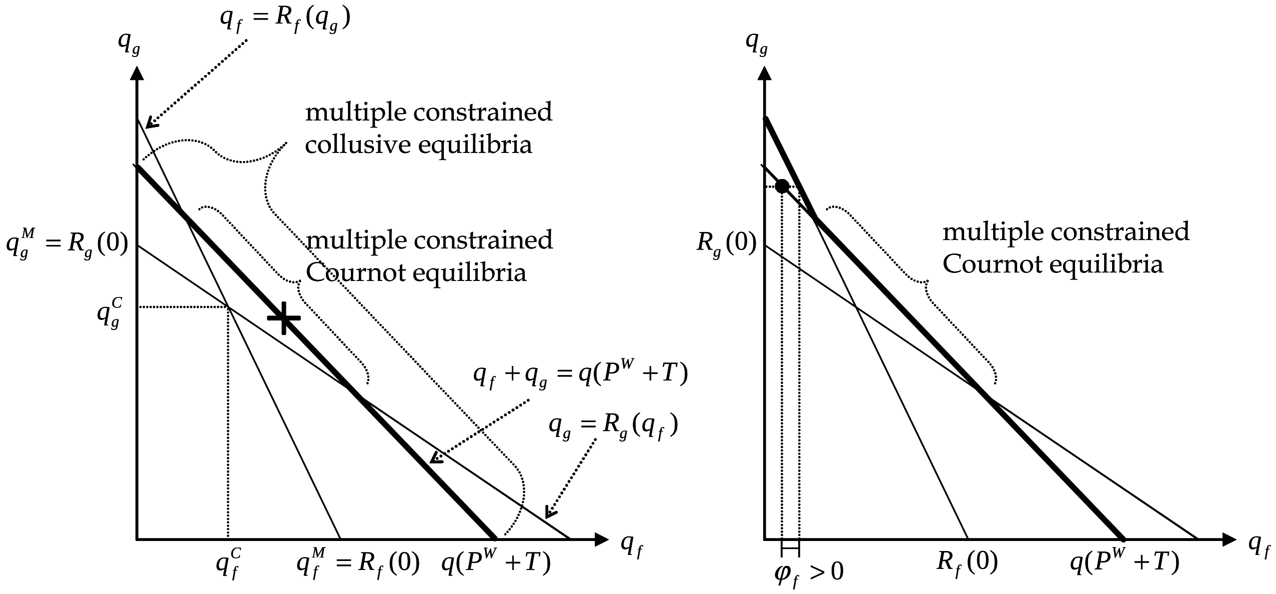


Figure 9: Identifying collusion from Cournot when imports constrain equilibrium prices under both behavioral models. Left panel: The imports constraint binds at the market outcome marked "+", which is consistent with both Cournot conduct and more collusive firm conduct for either firm f or firm g. Right panel: The imports constraint again binds at the market outcome marked "•", but Cournot behavior for firm f is rejected since $\varphi_f > 0$.

		(II)					
		IV-imports bite					
	Cement			Log Price: Y evaluated at			
	consumption	Interaction		mean pre-stabilization		mean post-stabilization	
State	in 1999 (kt)	coef	s.e.	coef	s.e.	coef	s.e.
20 *SP*	11,723	-0.000355	(0.000163) **	-0.171	(0.056) ***	-0.333	(0.060) ***
17 *MG*	5,090	-0.001067	(0.000235) ***	-0.147	(0.063) **	-0.549	(0.059) ***
19 *RJ*	3,809	-0.002660	(0.000575) ***	-0.137	(0.059) **	-0.481	(0.057) ***
16 *BA*	2,461	-0.003048	(0.000815) ***	-0.027	(0.065)	-0.361	(0.079) ***
21 *PR*	2,321	-0.001015	(0.000647)	-0.137	(0.087)	-0.278	(0.088) ***
23 *RS*	2,221	-0.001057	(0.000762)	-0.228	(0.037) ***	-0.379	(0.097) ***
22 *SC*	1,648	-0.003488	(0.002647)	0.020	(0.091)	-0.180	(0.095) *
13 *PE*	1,225	-0.003389	(0.001675) **	-0.285	(0.093) ***	-0.469	(0.061) ***
10 *CE*	1,139	-0.005347	(0.001662) ***	-0.142	(0.125)	-0.562	(0.113) ***
18 *ES*	837	-0.003029	(0.002317)	-0.370	(0.078) ***	-0.480	(0.068) ***
8 *MA*	765	-0.020114	(0.007056) ***	-0.097	(0.187)	-0.564	(0.126) ***
12 *PB*	565	-0.036712	(0.007397) ***	-0.123	(0.081)	-0.715	(0.111) ***
11 *RN*	531	-0.005411	(0.004692)	-0.145	(0.146)	-0.300	(0.078) ***
25 *MS*	454	0.000899	(0.004419)	-0.431	(0.047) ***	-0.415	(0.071) ***
14 *AL*	384	0.080309	(0.030990) **	-0.475	(0.127) ***	-0.351	(0.112) ***
9 *PI*	379	0.015324	(0.012214)	-0.657	(0.272) **	-0.330	(0.103) ***
15 *SE*	282	0.003937	(0.020794)	-0.145	(0.136)	-0.136	(0.099)

Note: Heteroskedasticity and autocorrelation-robust standard errors (Newey-West 1 lag)

*** Significant(ly different from zero) at the 1% level; ** Significant at the 5% level; * Significant at the 10% level

Figure 10: Demand estimates by state (reproduced from Salvo 2005a, Figure 14)

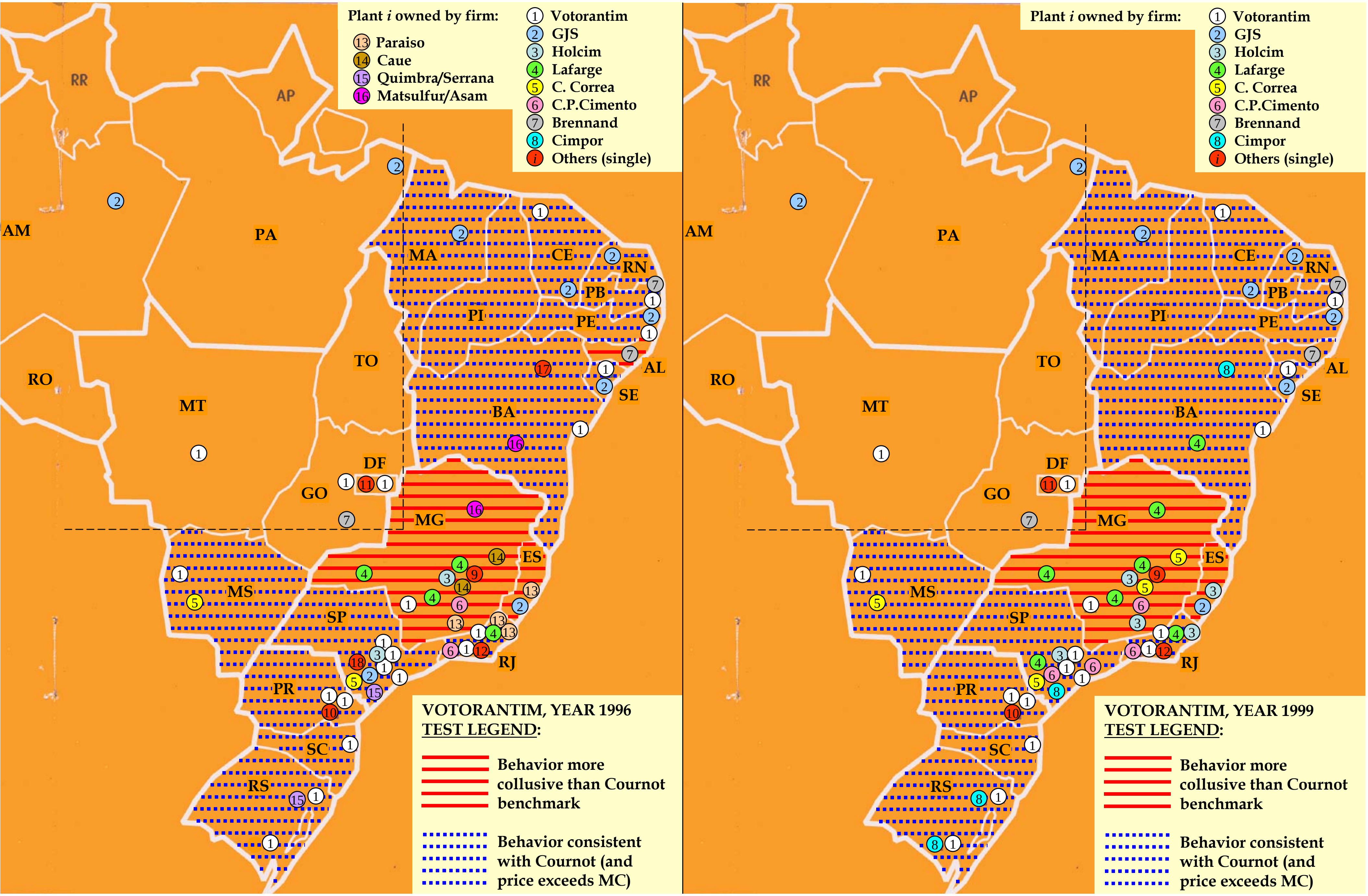
	(I)		(II)		(III)	
	coef	s.e.	coef	s.e.	coef	s.e.
No. obs.	27974		27974		30367	
R^2	0.894		0.899		0.904	
Intercept	1.423 ***	(0.244)	3.358 ***	(0.361)	5.413 ***	(0.447)
Distance of route	0.0387 ***	(0.0005)	0.0405 ***	(0.0007)	0.0433 ***	(0.0008)
Distance of route squared	-8.12E-07 ***	(2.49E-07)	-5.44E-07 **	(2.56E-07)	-9.62E-07 ***	(2.38E-07)
Port destination dummy	2.135 ***	(0.166)	1.813 ***	(0.267)	1.720 ***	(0.238)
Water transport dummy	-17.405 ***	(0.212)	-14.269 ***	(1.094)	-11.516 ***	(1.246)
Rail transport dummy	-12.410 ***	(0.343)	-2.349 ***	(0.571)	-3.149 ***	(0.540)
Harvest season dummy	2.341 ***	(0.118)				
Port during harvest dummy	2.802 ***	(0.311)	2.295 ***	(0.318)	2.248 ***	(0.277)
Price of diesel oil	6.815 ***	(0.441)	6.519 ***	(0.443)		
Shipment in bags dummy			0.249	(0.204)	0.489 **	(0.201)
Powdered soya dummy			1.510 ***	(0.134)	1.749 ***	(0.127)
Maize dummy			-0.755 ***	(0.096)	-0.976 ***	(0.097)
Limestone dummy			-2.136 ***	(0.151)	-1.819 ***	(0.140)
Monthly dummies			Included (except April)		Included (except April)	
Year dummies					Included (except 1997)	
Distance interacted with:						
Port dummy			0.00041	(0.00031)	0.00062 **	(0.00028)
Water transport dummy			-0.00498 ***	(0.00164)	-0.00859 ***	(0.00184)
Rail transport dummy			-0.01538 ***	(0.00088)	-0.01317 ***	(0.00084)
Monthly dummies			Included (except April)		Included (except April)	
Year dummies					Included (except 1997)	

Note: Heteroskedasticity-robust standard errors

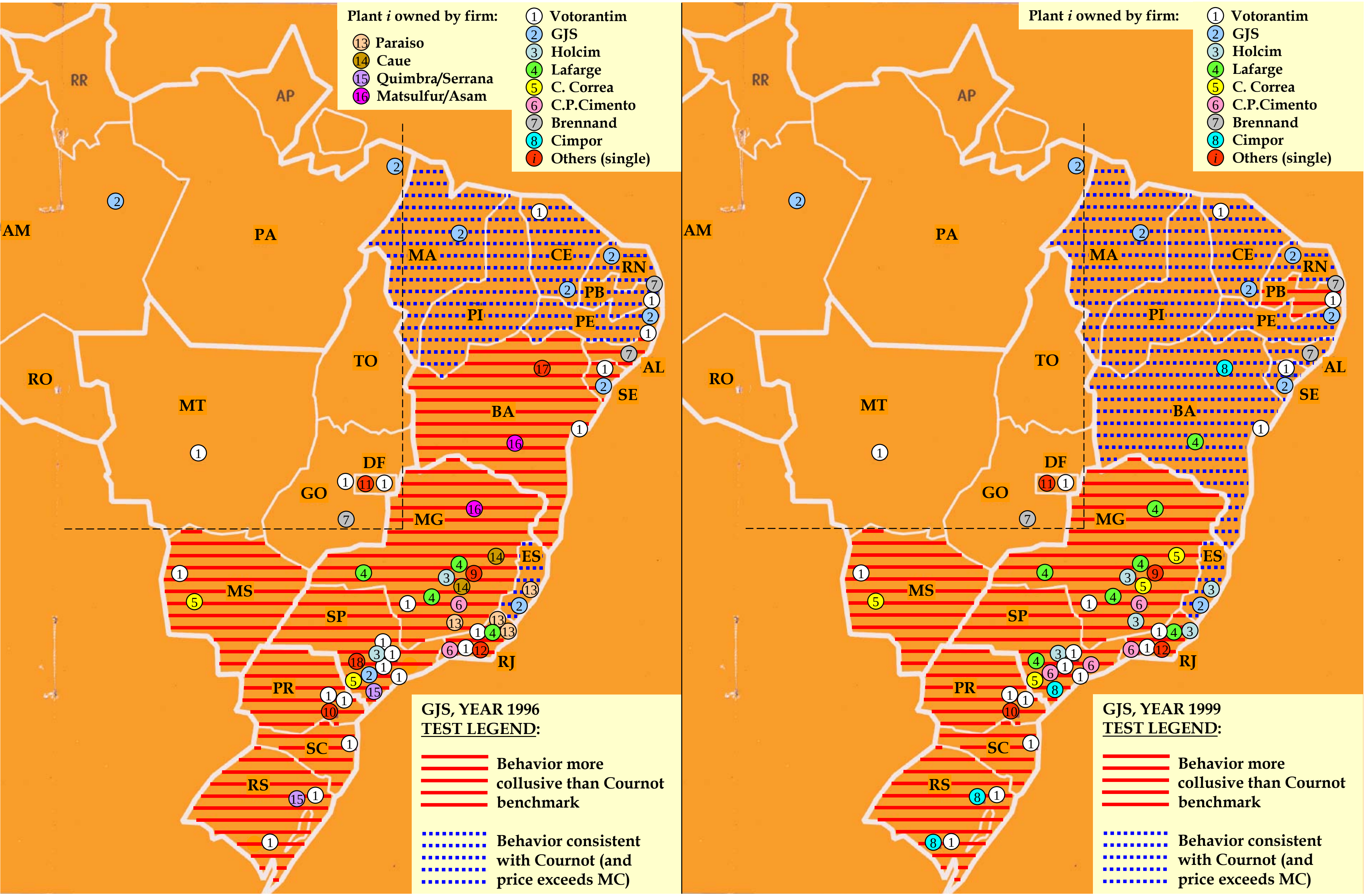
*** Significant(ly different from zero) at the 1% level; ** Significant at the 5% level; * Significant at the 10% level

Dependent variable is Freight Price in units of local currency (at December 1999 prices) per tonne of produce shipped

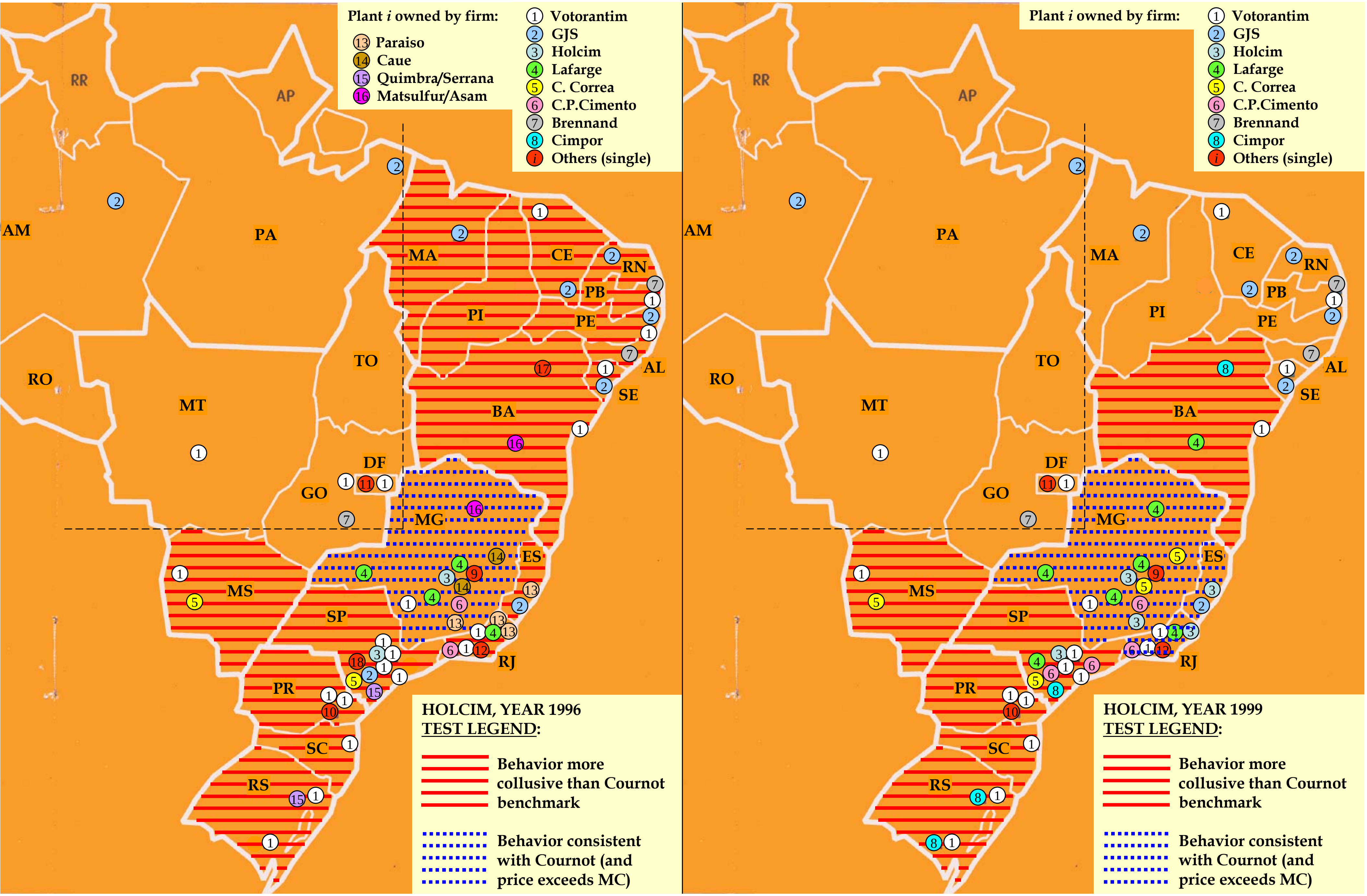
Figure 11: Auxiliary OLS regressions for plant-to-market freight cost



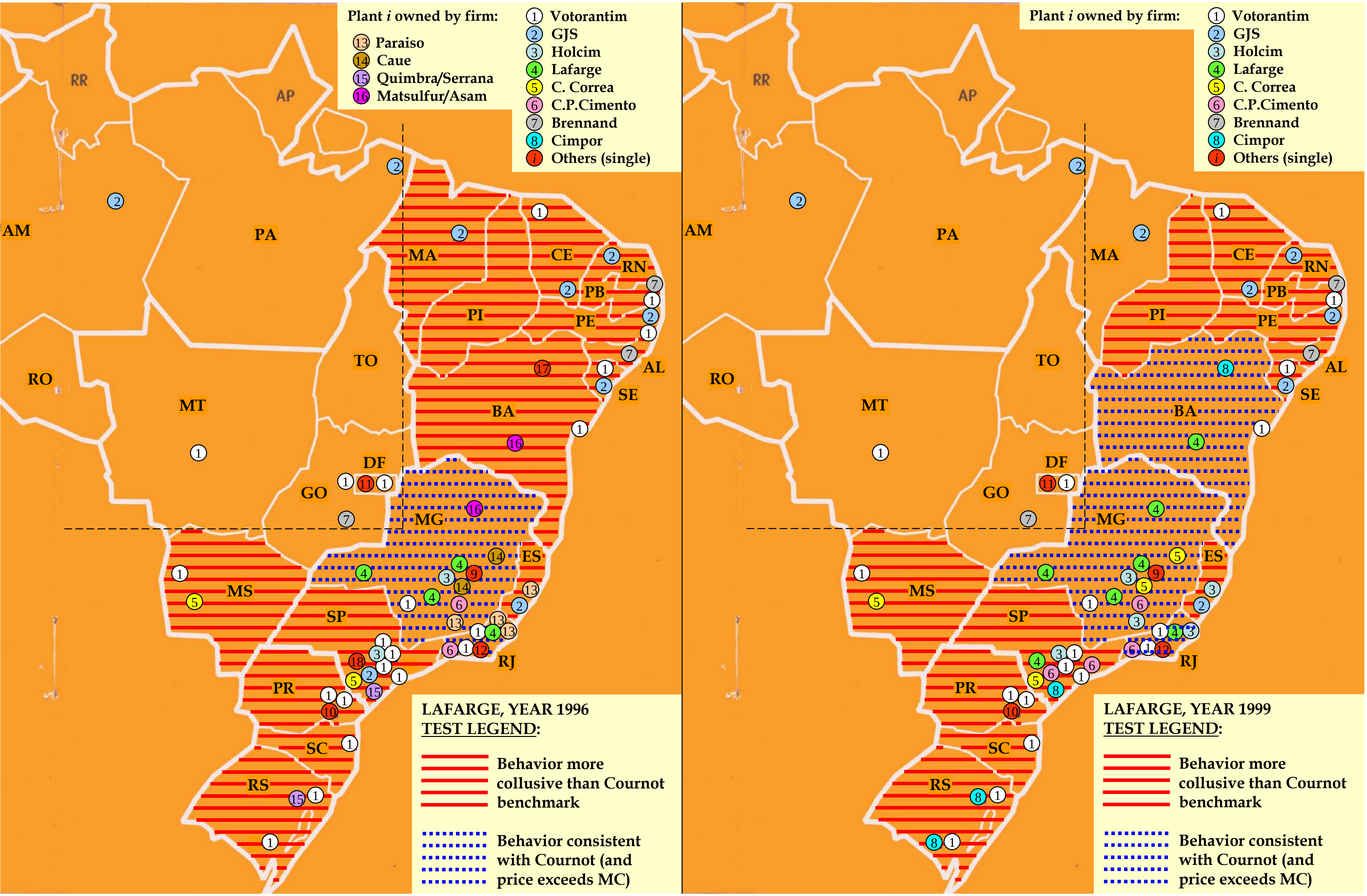
Map 1: Testing behavior supporting Votorantim's supply decisions to 17 local markets in 1996 (left panel) and in 1999 (right panel). (These 17 local markets, located to the southeast of the marked lines, account for 89% of the country's cement consumption in 1999.)



Map 2: Testing behavior supporting GJS's supply decisions to 17 local markets in 1996 (left panel) and in 1999 (right panel). (These 17 local markets, located to the southeast of the marked lines, account for 89% of the country's cement consumption in 1999.)



Map 3: Testing behavior supporting Holcim's supply decisions to 17 local markets in 1996 (left panel) and in 1999 (right panel). (These 17 local markets, located to the southeast of the marked lines, account for 89% of the country's cement consumption in 1999.)



Map 4: Testing behavior supporting Lafarge's supply decisions to 17 local markets in 1996 (left panel) and in 1999 (right panel). (These 17 local markets, located to the southeast of the marked lines, account for 89% of the country's cement consumption in 1999.)