Inferring Conduct under the Threat of Entry: The Case of the Brazilian Cement Industry

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Abstract

This paper demonstrates that when an industry faces potential entry and this threat of entry constrains pre-entry prices, cost and conduct are not identified from the comparative statics of equilibrium. In such a setting, the identifying assumption behind the well-established technique of relying on exogenous demand perturbations to empirically distinguish between alternative hypotheses of conduct is shown to fail. The Brazilian cement industry, where the threat of imports restrains market outcomes, provides an empirical illustration. In particular, price-cost margins estimated using this established technique are considerably biased downward, underestimating the degree of market power. A test of conduct is proposed, adapted to this constrained setting, which suggests that outcomes in the industry are collusive and characterised by market division.

Keywords: Conduct; Multimarket competition; Market division; Limit pricing; Cement

JEL classification: L13, L41, L70, F14

1 Introduction

Empirical industrial organisation has long been concerned with attempting to measure the degree of market power enjoyed by firms in an industry. Where marginal cost is observed, or can be constructed from known technological parameters, market power can be inferred from the distance between price and cost, informing the researcher of the pattern of firm conduct in the industry. More often than not, marginal cost is not observed. In such cases, a well-established approach in the literature attempts to ascertain firm conduct, along with cost, from the comparative statics of equilibrium. By this

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approach, a static structural model is specified, typically consisting of a parametric system of demand and firm pricing equations (first-order conditions). One then proceeds to jointly estimate demand, cost and a conduct parameter – indexing the degree of market power – from price and quantity data, as these are moved around by observed exogenous shocks to supply and demand. Such a methodology for estimating cost and conduct, developed by Bresnahan (1982) and Lau (1982), turns on the identifying assumption of orthogonality between the errors of the firm's pricing equation and the excluded exogenous variables which move the demand curve. Intuitively, shocks to demand allow one to observationally distinguish between the hypothesis of a high-cost competitive industry and the hypothesis of a low-cost collusive industry because the response of prices to these shocks is different according to the kind of firm behaviour in the industry: while price-taking firms set price equal to marginal cost as demand moves exogenously, firms with market power change prices to ensure that marginal revenue is equated to marginal cost.

In this paper I examine the identification of supply (cost and conduct) in a more general dynamic setting where an industry faces potential entry and this threat of entry constrains pre-entry prices. I develop a structural model of a domestic oligopoly which faces a competitive fringe of elastically-supplied high-cost imports. In equilibrium no imports are observed yet the threat of imports sets an upper limit on prices, equal to the marginal cost of imports. I show that when this price limit binds at the industry equilibrium, the identifying assumption of orthogonality between the error term of the conventional pricing equation and the excluded exogenous demand variables does not hold. Because the constraint posed by the threat of imports is unaccounted for, the standard pricing equation specification does not identify cost and conduct from the comparative statics of demand. In this setting, the standard methodology does not allow one to empirically distinguish the hypothesis of a high-cost competitive industry from the hypothesis of a low-cost cartel where imports restrain prices at the equilibrium. Intuitively, the response of prices to fluctuations in demand is no longer distinct because the threat of imports acts to constrain the ability of the cartel to set marginal revenue equal to marginal cost. Viewed from a different angle, equilibrium market price elasticities of demand are no longer informative since, irrespective of the hypothesis of conduct, the equilibrium remains at the kink of the residual demand curve facing the domestic oligopoly as demand fluctuates.

It is natural that upon not observing imports in equilibrium, or observing no more than a minimal amount, a researcher may come to overlook the restraining effect of imports, thereby misspecifying the structural model for the industry and estimating a static pricing equation imposing the regular moment conditions. It follows that if the industry enjoys market power, in the sense that equilibrium price-cost margins are positive, and yet the threat of high-cost imports constrains equilibrium prices, the lack of responsiveness of prices to fluctuations in demand will lead to the underestimation of the true degree of market power.

To illustrate, I turn to an industry in a country where potential imports restrain market outcomes: the Brazilian cement industry. Unlike its US counterpart, where the penetration of imports has ranged between 10 and 20% of domestic consumption in the past decades, the Brazilian cement industry has historically managed to keep imports at bay[1]. This has been achieved thanks to a combination of domestic price controls,

[1] The rise of international trade in cement, though puzzling to some, is a fairly recent phenomenon and

trade barriers, poor infrastructure and a depreciated local currency. At the turn of the 1990s, as price controls were lifted and Brazil began opening up to trade, the threat of imports began to develop "bite" on the industry, reinforced by an appreciating local currency. I consistently estimate demand in each local market (state of the Brazilian federation) and find very low market price elasticities of demand in equilibrium, of the order of -0.5. Two main possibilities arise to rationalise why an industry facing such inelastic demand does not cut output to raise prices to a point where demand is less inelastic: (i) there is weak pricing power (e.g. competition or low concentration), or (ii) some dynamic story is appropriate, such as the threat of entry (imports) restraining pre-entry prices[2]. In line with the standard methodology, I estimate a pricing equation, instrumenting with exogenous demand. I obtain cost estimates that are close to prices, suggesting that outcomes in the Brazilian cement industry are competitive (and the standard conduct parameter is estimated to be close to zero). To check these estimates, I construct actual marginal cost from observed factor prices, the simple fixed-coefficient nature of cement production technology, and the observed flow of cement from plants to markets. In contrast to the estimated price-cost margins that are centred around zero, actual price-cost margins are large, amounting to 40-65% of producer prices (net of sales tax). Producers enjoy considerable market power despite the binding high-cost imports constraint[3]. Thus the standard methodology fails to identify supply, severely underestimating the observed degree of market power[4]. This illustrates the theoretical result that when the threat of entry constrains prices, joint inference of cost and conduct will not be consistent because of the lack of responsiveness of prices to fluctuations in demand.

Given that cost and conduct cannot be jointly identified from the comparative statics of equilibrium in this constrained setting, the immediate question is: but what if the researcher *observes marginal cost*? Clearly, a direct comparison of marginal cost to price will provide a test of perfectly competitive behaviour against less competitive models of firm behaviour (and where imports restrain prices). But, other than perfect competition, how may one empirically distinguish between two alternative models of behaviour when *market outcomes* under either alternative hypothesis are constrained by the threat of imports, and are thus equal across both alternative models? In the Brazilian cement industry, for example, where high-cost imports restrain equilibrium prices, one may wish to identify the model of firm behaviour supporting the constrained outcomes. I propose a test of conduct against a standard benchmark, the Cournot oligopoly solution. The measure I develop uses firm-level quantity data to test the hypothesis of Cournot conduct against the alternative of "more collusive" firm behaviour. It is predicated on the notion that no Cournot firm can perceive that marginal revenue (taking rivals' output as given on the margin) exceeds marginal cost, otherwise the firm would optimally expand

has been documented carefully by Dumez and Jeunemaître (2000). Despite high inland transportation costs, cement can travel – and does travel – quite cheaply from afar by sea via specialised equipment.

[2]A third possibility hinges on a very special class of models of spatial competition, where a firm is restricted to set only a "mill" price, with delivered prices to consumers who are distributed over space being equal to the sum of this mill price and the transportation cost.

[3]That the high price ceiling set by the high-cost imports binds is then a consequence of the steepness of the demand curve and this strong price discipline in the industry.

[4]The estimated coefficients on factor prices and other supply-shifters are mostly of the expected sign and significant, which could again mislead a researcher into thinking that the econometric model is appropriately specified. But this owes only to the fact that the estimated coefficients are picking up the expected correlation between cement prices and factor prices.

output, and this notion holds regardless of whether the imports constraint binds or not in equilibrium[5]. The requirements on the data are large, but the value of the test lies in uncovering firm-level behaviour when market outcomes are constrained by the threat of entry and thus the comparative statics of equilibrium are not informative.

I illustrate the proposed test of conduct by reference to the Brazilian cement industry. I find that conduct across local markets is considerably more collusive than the Cournot benchmark. Market outcomes are characteristic of (tacit) market division, *and this can be identified despite the threat of imports restraining prices.* A story where firm 1 tacitly agrees to give firm 2 the upper hand in market B in exchange for the latter staying away from market A – with typically firm 1 (firm 2) being located slightly closer to market A (market B) than the rival firm[6] – helps to explain the observed shipments. Plants ship to local markets located at their doorstep, while restricting supply to adjacent markets, despite supplying to these latter markets being highly profitable under the static Cournot conjecture. I also consider, in light of the different local market structures observed in the Brazilian cement industry, simple dynamic multimarket games which give rise to such a pattern of conduct in equilibrium. This indicates the rationality of a strategy of market division in an industry where firms meet in different (geographic or product) markets.

This paper thus makes three contributions. *First*, it demonstrates that the standard pricing equation specification does not identify cost and conduct in industries where potential entry restrains pre-entry market outcomes, such as domestic oligopolies facing (underlying) competition from abroad[7]. The conventional identifying assumption is not satisfied; in particular the estimated degree of market power will be biased downward. The implication of this latent effect of imports for antitrust authorities attempting to measure the competitiveness of conduct is increasingly relevant in a world where trade barriers are being pulled down[8]. *Second*, I develop a test of conduct in such settings where potential entry may constrain equilibrium prices. By reference to this test, I show that market outcomes in the Brazilian cement industry are indicative of (tacit) market division. The *third* contribution has policy implications in relation to the cement industry, particularly in developing countries. In a developing country such as Brazil, with its huge housing deficit and infrastructure needs, the importance of the cement industry cannot be overstated. Cement is an essential input to construction and building activity for which there are few substitutes. The industry regularly attracts attention from competition authorities, consumer associations and the financial media for its alleged pricing power. Yet to date no study has been undertaken to empirically ascertain the degree of competition in the industry by estimating a structural model using a rich original dataset. This study attempts to fill this void. A clear policy recommendation is that

[5]The reverse notion, that a Cournot firm optimally cuts output when its perceived marginal revenue (were imports not to exist) falls short of marginal cost, no longer holds when the price ceiling imposed by imports binds in equilibrium: cutting output in an attempt to raise price above the price ceiling simply opens the door to imports.

[6]"Slightly closer" is employed in the sense that the freight cost, while important to the cost structure of the industry, clearly does not explain the observed market division.

[7]In addition to potential entry, other "invisible" constraints may be conceived, such as pressure from competition authorities.

[8]The constraint of imports on market outcomes is not new, however. As I later comment, in a study of the US sugar industry at the turn of the 20th century, Genesove and Mullin (1998) state that "industry pricing was constrained by threats of (domestic) entry or of foreign imports" (p. 367).

fostering imports can play an important role in curbing the ability of domestic producers to raise prices above marginal cost. In Brazil, recent policy experience has been the opposite; the government has succumbed to the industry's "anti-dumping" lobby and raised the barriers to entry of imports, to the detriment of consumer welfare.

The plan of the paper is as follows. In Section 2 I develop the theoretical framework and address identification. I then turn to institutional aspects of the cement industry, and present the data. Section 4 presents the application. (Appendices A and B provide a discussion of the sources and treatment of the data used, and all manner of robustness checks regarding the construction of marginal cost and the structural estimation.) Finally, I conclude, reflecting on the policy implications of this paper.

2 Theoretical framework: Towards a test of conduct

In this section I develop a structural model of an oligopoly facing potential entry, where this threat of entry may limit pre-entry prices. Potential entry is modelled as a competitive fringe of foreign suppliers (imports) to the domestic oligopoly market. I then extend the analysis of identification of cost and conduct underlying the standard methodology from the static setting considered by Bresnahan (1982, 1989) to the present constrained setting, where the threat of imports may be constraining market outcomes. I show that the identifying assumption of orthogonality between the error term of the conventional pricing equation error and the excluded exogenous demand variables does not hold. Estimates of cost and conduct parameters will be inconsistent; in particular, the degree of competition will tend to be overestimated.

Next I consider how a researcher may learn about conduct in an oligopoly facing potential competition from imports. I consider a situation where firms in the domestic oligopoly meet in different spatial (or product) markets and two data requirements on the part of the researcher are met: (i) direct measures of marginal cost *are* available, and (ii) firm-level quantity data is available (at the local market level). I specify a test of conduct based on Cournot behaviour adapted to the constrained setting. This test can reveal details regarding the pattern of conduct prevailing in the industry, despite aggregate outcomes being constrained in equilibrium by the presence of imports.

2.1 Domestic monopoly facing competition from imports

Consider a monopolist M producing a homogeneous good at flat marginal cost c_M. The monopolist faces a competitive fringe of foreign suppliers (labelled I for imports), with perfectly-elastic supply at marginal cost $c_I > c_M$. In general, the equilibrium is given by either of two situations. If the marginal cost of imports is lower than the monopoly price in the absence of imports (denoted p^M), the price in equilibrium will be equal to the marginal cost of imports, the monopolist will supply the entire domestic market, yet the foreign fringe exerts downward pressure on price. Alternatively, if the marginal cost of imports exceeds the monopoly price p^M, imports have no "bite" and the equilibrium price will be p^M, with the monopolist again supplying the entire market though in an unconstrained manner. Formally, the equilibrium price p is given by

$$p = \begin{cases} c_I & \text{if} \quad p^M \geq c_I \\ p^M & \text{otherwise} \end{cases}$$

where $p^M = p(q^M)$, $p(q)$ is the inverse demand function and q^M is the quantity that equates the market marginal revenue $MR(q)$ to the monopolist's marginal cost c_M. Given the assumption that $c_I > c_M$, the monopolist always supplies the entire market. Clearly, when $p^M \geq c_I$, the extreme result of imports commanding zero sales rests on the assumption of perfectly-elastic supply from the foreign fringe[9].

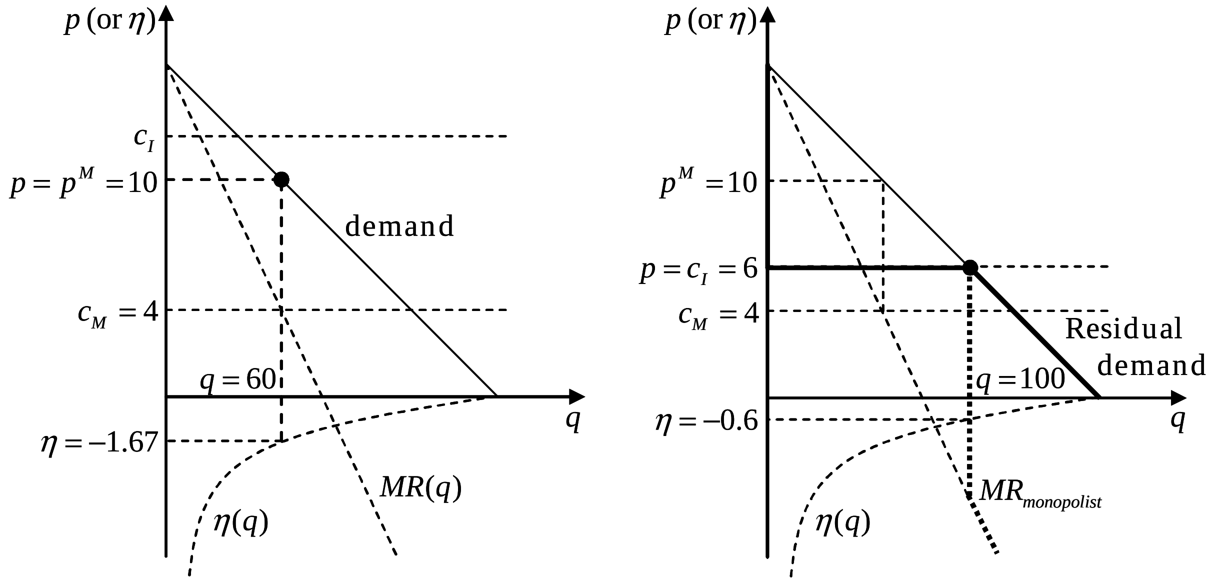


Figure 1: Monopolist facing a competitive fringe. Left panel: Imports have no "bite" ($p^M < c_I$). Right panel: Imports constrain price in equilibrium ($p^M \geq c_I$).

An illustration 1 Assume demand is linear, given by $p = 16 - \frac{1}{10}q$ and $c_M = 4$. As shown in Figure 1, the monopoly price is $p^M = 10$. If $c_I \geq 10$ (left panel), the equilibrium price is $p = 10$ and the monopolist supplies $q = 60$. Notice that the equilibrium market price elasticity of demand $\eta(q) := \frac{\partial \ln q}{\partial \ln p(q)} \simeq -1.67$. Now consider $(4 <)c_I \leq 10$, say $c_I = 6$ as illustrated in the right panel. The market equilibrium now lies at the kink in the residual demand curve faced by the monopolist: $p = 6$ and the monopolist supplies $q = 100$. At the equilibrium, while the price elasticity of demand faced by the

[9] As is typically the case with "limit price" models such as the one developed here, one needs to deal with the following question: why does the monopolist need to set a price as low as the limit price, in order to stave off entry (imports), if what is relevant to the entry decision is the post-entry price rather than the pre-entry one? In considering such a question, one could ponder why (in the situation of interest where imports do have bite, $p^M \geq c_I$) the monopolist would not set the monopoly price p^M if it is able to cut its price to the importer's cost c_I immediately upon entry. When entry (and exit) is free and there is no entry lag, as is the case in the setting I am considering, where the entrant consists of opportunistic imports in a well-functioning international trading market, the monopolist will set the limit price. In this paper's application to the Brazilian cement industry, I later consider institutional aspects of the industry that further support the use of a limit-price model. More generally, it may also be argued that the threat of entry does constrain pre-entry prices, even if entry were not free, since pre-entry prices reveal information to the entrant about post-entry prices, such as the cost of the incumbent and/or its disposition to fight if faced with entry (i.e. a predation story of the reputational type). Finally, note that for the purpose of this paper one need not strictly interpret c_I as the exact cost of imports, but more loosely as a price lower than that set by the monopolist were it to act in an unconstrained manner.

monopolist is infinitely high in absolute value, the market price elasticity of demand is only $\eta(100) = -0.6$. Around this latter equilibrium, fluctuations in the marginal cost of imports, say due to fluctuations in the exchange rate, allow one to trace out the demand curve since the kinked equilibrium shifts up and down along the market demand curve.

2.2 Econometric identification of conduct when costs are not observed

Market demand parameters may be identified from standard cost-shifters excluded from the demand function (left panel of Figure 1) or, in the case where imports restrain prices, from fluctuations in the marginal cost of imports, such as movements in the exchange rate (right panel). But, in the absence of information on cost, will conduct (and thus cost) be identified from the comparative statics of demand?

In the absence of potential entry, conduct is identified (Bresnahan 1982) When imports do not constrain prices, as in the left panel of Figure 1, conduct is identified from fluctuations in the demand curve. Suppose we wish to distinguish between alternative behavioural hypotheses generating observed price and quantity data: on the one hand a low-cost monopoly or cartel (with cost c_M), and on the other hand a high-cost competitive industry (with cost c_C). When marginal cost is flat in quantity, mere shifts in the demand curve suffice to empirically distinguish the behaviour of a cartel from that of a competitive industry. Rotations of the demand curve will likewise identify conduct. (When marginal cost varies in quantity, only rotations of the demand curve will identify conduct.) Thus demand, cost and conduct parameters are jointly estimated from observed price and quantity data and observed exogenous demand and cost shifters. The reasoning is captured intuitively in Figure 2, where marginal cost is flat. The left panel indicates how a shift in the demand curve has different effects on the initial industry equilibrium E_1 according to the hypothesis of conduct: the equilibrium shifts to E_2^C if pricing is competitive while shifting to E_2^M if there is market power (output expands only to where marginal revenue equals marginal cost). Similarly, the right panel illustrates how demand rotators identify conduct: there is no effect on the industry equilibrium if pricing is competitive (i.e. $E_1 = E_3^C$), yet the equilibrium shifts to E_3^M under a cartel.

When potential entry constrains pre-entry prices, conduct is *not* identified Now modify the cartel hypothesis so that the domestic industry with low cost c_M faces a competitive fringe of imports, with perfectly-elastic supply at high cost c_C that constrains price, as in the model of Section 2.1 (with $c_I = c_C$). In other words, under the hypothesis of a cartel, imports restrict the price to be c_C and the equilibrium lies at the kink in the residual demand curve facing the domestic industry (otherwise, for a high enough marginal cost of imports, we are back to the unconstrained situation considered in Bresnahan 1982). We wish to empirically distinguish this constrained low-cost cartel hypothesis from the alternative hypothesis of a high-cost competitive (domestic) industry, with cost c_C (and where the presence of imports becomes irrelevant). In Figure 3, the equilibrium is initially at E_1. In the left panel, a shift in the demand curve moves the equilibrium to E_2 under both alternative hypotheses. In the right panel, a rotation of the demand curve around the equilibrium point E_1 does not move the equilibrium

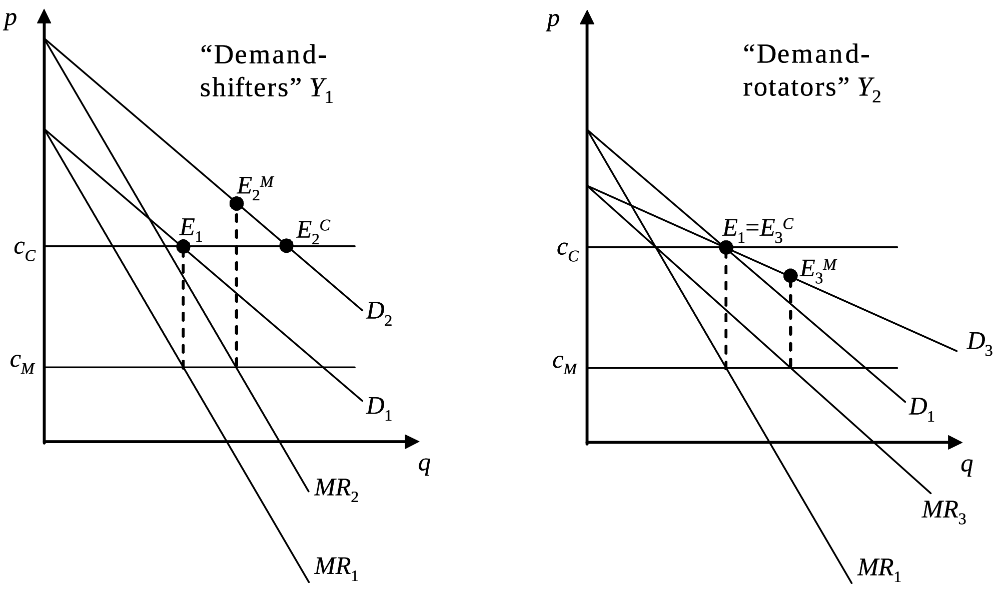


Figure 2: Identification in a static model. Left panel: Demand shifts. Right panel: Demand rotates.

point under either hypothesis. Thus, in this dynamic setting, unless marginal costs are observed, there is no observable distinction between the hypothesis of a low-cost cartel (with imports restraining prices to be c_C) and the hypothesis of high-cost (domestic) competition[10].

Why is conduct no longer identified? Consider, say, rotations of the demand curve. Intuitively, in the absence of imports, such rotations identify conduct because firms with market power change prices when demand moves exogenously to ensure that marginal revenue is equated to marginal cost. Now, the threat of imports acts to constrain their ability to set (market) marginal revenue equal to marginal cost and therefore removes the source of price variation which allows conduct to be identified. Viewed from a different angle, equilibrium market price elasticities of demand are no longer informative since the equilibrium lies at the kink of the residual demand curve facing the domestic oligopoly (see below).

Thus, comparing figures 2 and 3, notice that while fluctuations in the demand curve in the former figure lead to changes in prices under monopoly but not under competition, these same fluctuations in the latter figure leave prices unchanged under both monopoly (facing imports) and competition. In the right panel of Figure 3, for example, a rotation of the demand curve around the initial equilibrium point E_1 does not change the equilibrium price (and quantity) under both hypotheses of competition and collusion. Overlooking the effect of imports and misspecifying the structural model to be that captured in the right panel of Figure 2 (Bresnahan 1982), a researcher would interpret the stationarity of equilibrium prices as evidence to reject (low-cost) collusion in favour of (high-cost) competition, regardless of the true behavioural model generating the data.

[10]Fluctuations in the demand curve can be broken down into rotations around the price intercept and parallel shifts. When marginal cost is flat, identification is possible only from parallel inward shifts of the demand curve, when these shifts are sufficiently large (we are then back to the situation considered in Bresnahan 1982). Identification is not possible for rotations around the price intercept.

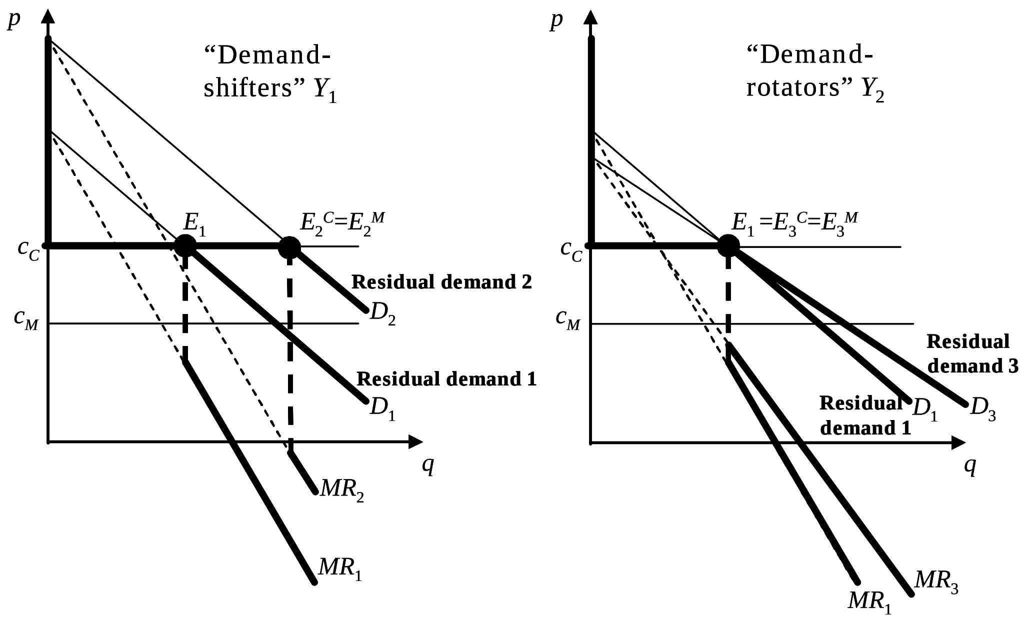


Figure 3: Conduct is no longer identified under the threat of entry. Left panel: Demand shifts. Right panel: Demand rotates.

(Similarly, for a shift in the demand curve as depicted in the left panel of Figure 3, the equilibrium price would again remain unchanged under both hypotheses of competition and collusion. By misspecifying the structural model to be that captured in the left panel of Figure 2, one would mistakenly reject collusion in favour of competition, since no price change is observed following a shift in the demand curve.) The more general point is that by misspecifying the structural model and not accounting for the price-constraining effect of imports (or entry), a researcher could be misled into overestimating the extent of competition in the industry, further (residually) overestimating costs.

Estimation of a static pricing equation In the empirical literature on conduct, the following static pricing equation is typically specified on the supply side[11]:

$$p + \theta q \frac{\partial p(q)}{\partial q} = c \tag{1}$$

where p is price, q is industry output, c is marginal cost and θ is a conduct parameter. One reason why specification (1) may have become so popular is that it nests first-order conditions corresponding to the oligopoly models of monopoly or perfect collusion (where the firm internalises the aggregate inframarginal revenue change from a marginal change in output, so that $\theta = 1$) and perfect competition (where $\theta = 0$), among other models (e.g. symmetric Cournot, θ being the reciprocal of the number of firms in the industry)[12]. Pricing equation (1) can be rearranged to the familiar "elasticity-adjusted

[11] Examples include Gollop and Roberts (1979), Roberts (1983), Suslow (1986), Bresnahan (1987), Nevo (2001) and Slade (2002). Note that here I abstract from a criticism that has been made regarding this approach on the grounds that oligopoly theory to date does not underpin a continuum of values for conduct that would support its free estimation (see, e.g., Reiss and Wolak 2002).

[12] Note that (1) can be specified at the industry or at the firm level. In the latter case one may include a subscript f for the conduct and cost parameters, to denote the firm. An industry-level

Lerner index" (or price-cost mark-up):

$$\theta = -\eta(p)\frac{p-c}{p} \tag{2}$$

where $\eta(p)$ is the market price elasticity of demand. Clearly, such a specification captures the supply decisions depicted in Figure 2, in the absence of imports, under the alternative hypotheses of conduct[13]. Econometrically, (1) may be implemented by including a zero-mean error term ε^s and proceeding to the estimation of

$$p = -\theta q\frac{\partial p(q)}{\partial q} + c + \varepsilon^s \tag{3}$$

where p and q are observed, $\frac{\partial p(q)}{\partial q}$ has previously been consistently estimated, and one wishes to estimate θ and c. Since $q\frac{\partial p(q)}{\partial q}$ is endogenous, one needs to find excluded instruments from (3). In the absence of imports, exogenous demand variables Y will serve as instruments, since they are correlated with the endogenous variable but uncorrelated with the error ε^s. This is clear from the exogenous fluctuations in demand pictured in Figure 2. Specification (3) is then estimated by IV or GMM and the identifying assumption is

$$E(Y'\varepsilon^s) = 0$$

The problem with the standard methodology arises in the presence of potential imports (entry), since to the extent that imports constrain market outcomes, fluctuations in the demand curve will be correlated with the error in the specified pricing equation. Due to the price ceiling set by imports, the true model – the data generating process – is given by[14]

$$p = \min\left(-\theta q\frac{\partial p(q)}{\partial q} + c + \varepsilon^s, c_I\right) \tag{4}$$

The standard pricing equation which is taken to the data – the estimated model – is, however:

$$p = -\theta q\frac{\partial p(q)}{\partial q} + c + \xi^s \tag{5}$$

where the pricing equation error is denoted ξ^s. The theoretical specification (1) that underlies the estimated model (5) fails to adequately capture the supply decisions (4) of

pricing equation can be viewed as the average across firms' individual pricing equations (weighted or not by firms' shares), in which case θ has the interpretation of "the average collusiveness of conduct" (Bresnahan 1989). Note also that a common alternative to (1) in the literature consists of replacing the inframarginal revenue term $\theta_f q\frac{\partial p(q)}{\partial q}$ by $\theta_f q_f\frac{\partial p(q)}{\partial q}$, i.e. replacing industry output q by firm output q_f in firm f's pricing equation. From the first-order condition, the conduct parameter then corresponds to dq/dq_f, which some have interpreted as a "conjectural variation": by this view, upon expanding its output by dq_f, firm f would hold a "conjecture" dq with respect to the resulting aggregate output expansion.

[13]Notice that the vertical distance between the (inverse) demand function and the marginal revenue function is equal to $-q\frac{\partial p(q)}{\partial q}$. Under the unconstrained monopoly equilibrium of Figure 2 this distance is always equal to $p-c$. In contrast, in the constrained monopoly equilibrium of Figure 3 this distance will exceed $p-c$.

[14]It is clear from (4) that, ceteris paribus, the likelihood that the imports constraint binds and thus $p = c_I$ is higher (i) the more collusive is conduct, i.e. the higher is θ; (ii) the steeper is the demand curve, i.e. the higher is $-q(\partial p(q)/\partial q)$; (iii) the higher is the domestic industry's marginal cost c; and (iv) the lower is the marginal cost of imports c_I.

an industry with pricing power facing the threat of high-cost imports. This is summarised in the following proposition.

Proposition 1 *(Non-identification of conduct) When the threat of entry constrains prices set by an industry with market power, the residual ξ^s in the standard pricing equation is negatively correlated with the excluded exogenous demand variables Y:*

$$E(Y'\xi^s) < 0$$

Consequently, IV (or GMM) estimation using demand perturbations Y will yield inconsistent estimates of conduct and cost. In particular, the true degree of market power θ will be underestimated.

Proof. Let $X_1 := -q\frac{\partial p(q)}{\partial q}$. From (4) and (5), the DGP can be rewritten as $p = \min(\theta X_1 + c + \varepsilon^s, c_I)$ and the estimated model is $p = \theta X_1 + c + \xi^s$. We wish to determine $E(Y'\xi^s)$. The error of the estimated model is

$$\begin{aligned} \xi^s &= \varepsilon^s \mathbf{1}[\theta X_1 + c + \varepsilon^s < c_I] + (c_I - \theta X_1 - c)(1 - \mathbf{1}[\theta X_1 + c + \varepsilon^s < c_I]) \qquad (6) \\ &= \varepsilon^s \chi + (c_I - \theta X_1 - c)(1 - \chi) \end{aligned}$$

where the indicator function $\chi := \mathbf{1}[\varepsilon^s < c_I - \theta X_1 - c] = 1$ when the market equilibrium is unconstrained by the threat of entry (imports have no bite) and $\chi = 0$ when the equilibrium is constrained. (It is clear from (6) that the data generating process is a generalisation of the static model considered by Bresnahan (1982); this static model would correspond to a specific situation where $\chi = 1$ for all market outcomes, i.e. market outcomes are never constrained.) Assuming that the unobserved supply shock ε^s is orthogonal to the excluded exogenous demand variables Y, $E(Y'\varepsilon^s) = 0$, one may write

$$\begin{aligned} E(Y'\xi^s) &= E\left(Y'\varepsilon^s \chi + Y'(c_I - \theta X_1 - c)(1 - \chi)\right) \\ &\leq E\left(Y'\varepsilon^s \chi + Y'\varepsilon^s(1 - \chi)\right) = E\left(Y'\varepsilon^s\right) = 0 \end{aligned}$$

where the inequality follows from the fact that $1 - \chi = 1$ when $\varepsilon^s \geq c_I - \theta X_1 - c$ (i.e. when the equilibrium is constrained) and $1 - \chi = 0$ otherwise, along with the assumption that $Y > 0$.

Further, let marginal cost be linear in X_2, where X_2 is an $N \times (K - 1)$ matrix of observed variables, both exogenous (such as factor prices, including a constant) and endogenous (such as quantity): $c = X_2\beta_2$. Group the regressors of the estimated model into an $N \times K$ matrix, $X := (X_1, X_2)$, and the parameters to be estimated into a $K \times 1$ vector $\beta := (\theta, \beta_2)$. The estimated model is then $p = X\beta + \xi^s$. Denote as Z the matrix of instruments, containing the exogenous elements of X_2 and the excluded exogenous demand variables Y, and assume the rank condition for identification holds. The 2SLS estimator is given by

$$\begin{aligned} \hat{\beta} &= (X'Z(Z'Z)^{-1}Z'X)^{-1}X'Z(Z'Z)^{-1}Z'p \\ &= \beta + (\frac{1}{N}X'Z(\frac{1}{N}Z'Z)^{-1}\frac{1}{N}Z'X)^{-1}\frac{1}{N}X'Z(\frac{1}{N}Z'Z)^{-1}\frac{1}{N}Z'\xi^s \end{aligned}$$

Noting that (i) $E(X'Z)$ and $E(Z'Z)$ are positive definite, and (ii) $E(Z'\xi^s)$ contains either 0 or negative elements (since $E(Y'\xi^s) < 0$), the application of the law of large numbers to each term along with Slutsky's theorem yields

$$\text{plim } \hat{\beta} < \beta$$

In particular, plim $\hat{\theta} < \theta$. ■

The failure of the orthogonality condition can readily be seen in the linear demand example of Figure 3, as I show next.

Example: Shifts and rotations with linear demand Begin by considering a shift in the demand curve as depicted in the left panel of Figure 3. Say the inverse linear demand curve $p = a - bq$ shifts outward to $p = a' - bq$, where $a' - a = da > 0$. Recall that under both alternative hypotheses of conduct – low-cost cartel constrained by imports, and high-cost competitive industry – the equilibrium shifts from E_1 to E_2, where $dp = 0$ and $dq = \frac{da}{b}$. Plugging this into the total derivative of the static pricing equation (3)[15] and noting that the demand slope $\frac{\partial p(q)}{\partial q}$ remains unchanged at $-b$, one obtains $0 = -\theta\left((-b)(\frac{da}{b}) + 0\right) + d\xi^s$. Thus

$$d\xi^s = -\theta da$$

from which it is clear that shifts in the demand curve are correlated with the error in the pricing equation (unless, of course, there is competition: $\theta = 0$) . Now consider a rotation in the demand curve around E_1 (right panel of Figure 3). Say the inverse demand curve $p = a - bq$ rotates anticlockwise around $E_1 = (q_1, p_1)$ to $p = a' - b'q$, where $b' - b = db < 0$ and thus $a' - a = da = db.q_1 < 0$. Under both alternative hypotheses of conduct, the equilibrium remains stationed at E_1, and thus $dp = dq = 0$. Plugging this into the total derivative of the static pricing equation and noting that the change in the demand slope $d(\frac{\partial p(q)}{\partial q}) = -db$, one obtains $0 = -\theta\left(0 + (-db)q_1\right) + d\xi^s$. Recalling that $da = q_1 db$, this translates into

$$d\xi^s = -\theta q_1 db = -\theta da$$

so that rotations in the demand curve around the equilibrium are correlated with the error in the pricing equation.

The limit-price model considered in this paper provides an example where joint estimation of conduct and costs from a static pricing equation will perform poorly. Another example is provided by Corts (1999) who considers a dynamic model of collusion in a simple linear-demand, homogeneous-good oligopoly with symmetric and flat marginal costs, in which punishment is characterised by Cournot behaviour forever[16]. He simulates market outcomes according to varying assumptions on the persistence of exogenous demand shocks and then shows that estimation of a static pricing equation will in many instances underestimate the degree of market power, as measured by the elasticity-adjusted Lerner index (2). The thrust of his argument is that while the estimated conduct parameter

[15] This may be written $dp = -\theta\left(\frac{\partial p(q)}{\partial q}dq + d(\frac{\partial p(q)}{\partial q})q\right) + d\xi^s$, considering θ and c are constant.

[16] Corts' (1999) illustration is reminiscent of the Rotemberg and Saloner (1986) supergame model of collusion with stochastic demand.

is determined by the *marginal* responsiveness of equilibrium quantity (and thus price and the mark-up) to exogenous perturbations of demand, market power is defined by the *level* of the price-cost margin. The estimated conduct parameter will accurately capture market power "only if the true process underlying the observed equilibrium generates behaviour that is identical *on the margin*, and not just *on average*, to a conjectural variations game" (p. 234; by a "conjectural variations" model the author means a model nested in (1) – see my footnote 12). This is clearly not the case for the imports-constrained oligopoly just outlined. As the above discussion makes clear, another way of putting Corts' argument is by stating that the errors in the pricing equation (5) are correlated with the demand shocks Y typically used as instruments.

The implications of Proposition 1 for empirical work are clear. Consider an industry where firms have market power ($\theta > 0$) and the threat of high-cost imports constrains prices in equilibrium for at least a subset of the data. (In the notation of the proof of Proposition 1, this corresponds to $\Pr(\chi = 0) = \Pr(\varepsilon^s \geq c_I - \theta X_1 - c) > 0$ in the available sample.) Suppose a researcher, observing the negligible penetration of imports in equilibrium, fails to realise the price-restraining effect of imports and runs specification (5) on the data, thinking that the data generating process is (3), when it is actually (4). Thinking that he is imposing $E(Y'\varepsilon^s) = 0$, when in fact he is incorrectly imposing $E(Y'\xi^s) = 0$, the researcher would obtain inconsistent estimates of conduct and cost. The estimated conduct parameter $\hat{\theta}$ is likely to lie below the "true" value $\theta = \eta(p)\frac{p-c}{p}$, as defined in (2), underestimating the degree of market power. Intuitively, since prices do not respond to demand shocks as seen above, the coefficient on $-q\frac{\partial p(q)}{\partial q}$ will be biased toward zero. The extent to which potential imports (and entry in general) constrain market outcomes is an empirical question. I briefly illustrate the relevance of the restraining effect of imports by reference to a seminal study of the US sugar industry.

US sugar industry (Genesove and Mullin 1998): constrained market outcomes? Genesove and Mullin (1998) examine the US sugar industry at the turn of the 20th century to test the estimation of cost and conduct using the standard static pricing equation (3). Thanks to the simple production technology of the industry, marginal cost is observed and can be used to check the performance of the estimation methodology, which they find "performs reasonably well in estimating θ" (p. 370). However, though the difference is small, the estimated conduct parameter $\hat{\theta}$ is lower than the direct measure of market power θ obtained from (2). Interestingly, the authors state that this *direct measure* of market power θ would "suggest a more competitive environment than one would expect from an industry that averaged six firms and whose largest firm had an average market share of 63%" (p. 367), and that the "likely explanation is that industry pricing was constrained by threats of (domestic) entry or of foreign imports" (p. 367), despite "very little" sugar actually being imported into the US[17]. Genesove and Mullin point out that: "Although we acknowledge the influence of these competitive fringes,

[17] Further evidence of the price-constraining effect of imports is provided: "Although very little refined sugar was ever imported into the United States, in the early years of the Sugar Trust (the largest firm) the threat of European imports affected U.S. prices. In 1888 and 1894, Havemeyer (the Sugar Trust's president) acknowledged setting the price of refined sugar so that none would be imported from Europe" (p. 358; parentheses added). Note that the authors' low direct measure of market power θ stems from a low observed price-cost mark-up $\frac{p-c}{p}$ and a moderate elasticity $\eta(p)$ (of around -1.05 for most part of the year).

they are not formally incorporated into our analysis" (p. 359). This section's analysis suggests that to the extent that market outcomes in the sugar industry were constrained by the threat of entry, this would lead to a downward bias in the estimated degree of market power.

In Section 4 I develop an example using the Brazilian cement industry where market outcomes are constrained by the threat of imports. I illustrate how in such a setting the standard methodology performs poorly: the estimated conduct parameter considerably understates the direct measure of market power (based on a direct measure of marginal cost). I then use firm-level data to delve deeper into the pattern of conduct in the industry. To this end, we need to consider other models of conduct in the imports-constrained oligopoly model, in addition to the model of monopoly seen at the beginning of this section.

2.3 From monopoly to oligopoly

The next question is: what are the equilibrium outcomes when there is a domestic oligopoly comprised of $n \geq 2$ firms, instead of a monopoly? Clearly this will depend on the conduct of the domestic firms facing the competitive fringe of imports. I will consider the non-trivial case of imports (possibly) restraining prices $p^M \geq c_I$ (right panel of Figure 1), since the complementary case where imports do not restrain even a monopolist $p^M < c_I$ is standard (left panel of Figure 1). I now consider the benchmark models of collusion, Bertrand and Cournot.

Under the most collusive outcome, the equilibrium price is $p = c_I$ and the oligopoly's joint output is $q = p^{-1}(c_I)$, the same output as that of a monopolist (recall Section 2.1). In a non-cooperative framework with heterogeneous firms, where side payments are not allowed, output will need to be shared among the firms according to some rule or historical pattern[18]. In a spatial context, where the oligopoly consists of firms with multiple plants scattered across space, meeting each other in different local markets, one possibility is to have the most efficient firm in a given local market supply a large share of output. The most efficient (lower cost) firm in a local market could be the firm with the plant located closest to that market, thus incurring lower transport costs. To the extent that firms' plant configurations are "sufficiently" symmetric, with different firms being the low-cost producer in different markets, the restriction of no side payments can be circumvented and aggregate industry profits can be increased[19]. I return to collusion under multimarket contact (as it applies to the Brazilian cement industry) in Section 4.4.2.

Under the other polar model of Bertrand competition, the equilibrium price is equal to the marginal cost of the second most efficient plant. Label firms 1 and 2 as the lowest-cost firm and the next lowest cost firm respectively, i.e. $c_1 \leq c_2 (< c_I)$. The equilibrium

[18] As before, assume flat marginal costs. With homogeneous firms, sharing output equally among the firms – as well as any alternative allocation – maximises joint profits. With heterogeneous firms, were side payments allowed, the optimal allocation rule is to have the low cost firm supply the entire market.

[19] Bernheim and Whinston (1990) explore the incentive constraints under multimarket contact. By pooling a firm's incentive constraints across markets, its share in those markets where it enjoys a low cost (i.e. "on its own turf") may be increased at the expense of its share in markets where it has a high cost. See Section 4.4.2.

price is then $p = c_2$, with firm 1 supplying the entire market with $q_1 = p^{-1}(c_2)$. This situation is similar to that depicted in the right panel of Figure 1, where it is the next lowest cost firm 2 rather than imports that restrains prices.

Consider finally the standard case of Cournot behaviour among the n firms in the domestic oligopoly. Consider the output decision of firm f. In the absence of imports, denote firm f's reaction function $q_f = R_f(q_{-f})$, where $q_{-f} := \sum_{j \neq f} q_j$ is the joint output of its (domestic) rivals. (This reaction function is derived from the firm's Cournot first-order condition and is drawn as the steeper line in the left panel of Figure 4.) In the presence of imports, imports occur if $p(q_f + q_{-f}) > c_I$, or equivalently if $q_f + q_{-f} < p^{-1}(c_I)$, i.e. if domestic output is restricted to fall short of the quantity level at which the marginal cost of imports crosses the demand curve. In this case, where $q_f + q_{-f} < p^{-1}(c_I)$, the quantity of imports is positive and equal to $q_{imports} = p^{-1}(c_I) - q_f - q_{-f}$, so that total supply is $q_f + q_{-f} + q_{imports} = p^{-1}(c_I)$. Thus $q_f + q_{-f} \geq p^{-1}(c_I)$ defines the "imports constraint": its boundary is drawn as the less steep line, of slope -1, in the left panel of Figure 4. Clearly, the perfectly-elastic supply of imports ensures that, given the joint output of its rivals q_{-f}, Cournot firm f will set its output such that price is at most equal to the marginal cost of imports, such that imports do not occur. Hence, in the presence of imports, firm f's best response to the joint output of its rivals q_{-f} will correspond to the outer envelope to its reaction function in the absence of imports, $R_f(q_{-f})$, and the boundary to the imports constraint, $q_f + q_{-f} = p^{-1}(c_I)$; denote this "constrained" reaction function as

$$q_f = \tilde{R}_f(q_{-f}; c_I) := \max(R_f(q_{-f}), p^{-1}(c_I) - q_{-f})$$

$\tilde{R}_f(q_{-f}; c_I)$ is illustrated in the left panel of Figure 4 as the thick curve. Notice that when $R_f(0) < p^{-1}(c_I)$, as drawn, $R_f(q_{-f})$ will cross $q_f + q_{-f} = p^{-1}(c_I)$. For high enough q_{-f} such that $\tilde{R}_f(q_{-f}; c_I) + q_{-f} \geq p^{-1}(c_I)$, firm f's optimal reply in the presence of imports is to set the same quantity that it would set in the absence of imports (and the corresponding market price is lower than c_I). This steeper upper segment of firm f's constrained reaction function $\tilde{R}_f(q_{-f}; c_I)$ is collinear with the reaction function in the absence of imports $R_f(q_{-f})$, and the standard Cournot pricing equation holds:

$$p(q) + \frac{p(q)}{\eta(q)} \frac{q_f}{q} = c_f \tag{7}$$

where as before $\eta(q)$ is the market price elasticity of demand and $q = q_f + q_{-f}$. Now, for lower q_{-f} such that $\tilde{R}_f(q_{-f}; c_I) + q_{-f} = p^{-1}(c_I)$ (i.e. $\tilde{R}_f(q_{-f}; c_I) \geq R_f(q_{-f})$), firm f's optimal reply in the presence of imports *exceeds* the quantity that it would set in the absence of imports, and price equals c_I (since otherwise imports would occur and price would still be equal to c_I). Here, along the flatter segment of firm f's constrained reaction function $\tilde{R}_f(q_{-f}; c_I)$, firm f's (perceived) marginal revenue falls short of marginal cost:

$$p(q) + \frac{p(q)}{\eta(q)} \frac{q_f}{q} < c_f \tag{8}$$

Conditions (7) and (8) combine to prove the following proposition:

Proposition 2 *("Constrained" Cournot first-order condition) In the presence of imports, if firm f behaves as a Cournot player, it will be the case that*

$$p(q) + \frac{p(q)}{\eta(q)} \frac{q_f}{q} \leq c_f \tag{9}$$

This condition holds as a strict inequality when the "imports constraint" $q_f + q_{-f} \geq p^{-1}(c_I)$ binds, in which case price is equal to the marginal cost of imports c_I.[20]

The set of Cournot equilibria is found by similarly deriving the rival firms' constrained joint reaction function $q_{-f} = \tilde{R}_{-f}(q_f; c_I)$, which is again the outer envelope of the joint reaction function in the absence of imports $q_{-f} = R_{-f}(q_f)$ and the boundary to the imports constraint, $q_f + q_{-f} = p^{-1}(c_I)$. The set of equilibria is the intersection of $q_f = \tilde{R}_f(q_{-f}; c_I)$ and $q_{-f} = \tilde{R}_{-f}(q_f; c_I)$. For a low enough cost of imports (i.e. an imports boundary sufficiently far from the origin, as drawn in the right panel of Figure 4 for the next illustration), there are multiple equilibria and imports restrain prices at the Cournot equilibrium[21].

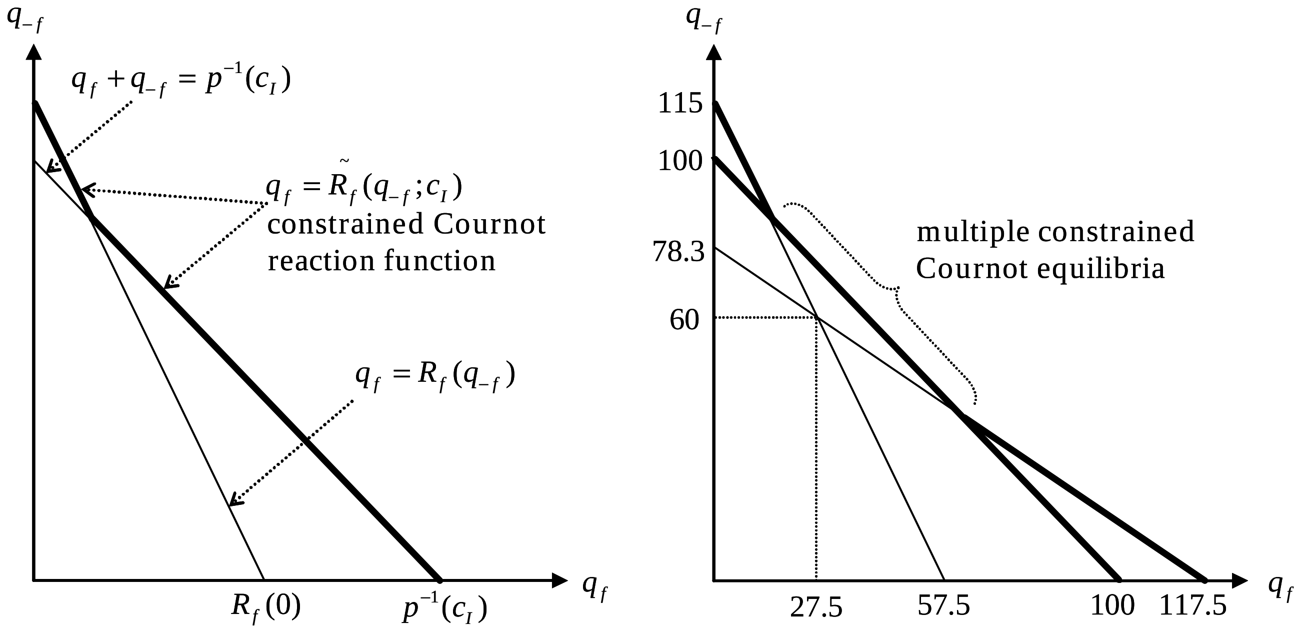


Figure 4: Cournot oligopoly facing a competitive fringe of imports. Left panel: Cournot firm f's reaction function, facing domestic rivals and imports. Right panel: Cournot equilibria. Drawn for linear demand and $c_I = 6$ as in the right panel of Figure 1.

An illustration 2 This is illustrated in the right panel of Figure 4, drawn assuming the linear demand function $p = 16 - \frac{1}{10}q$ and $c_I = 6$ of the earlier illustration to the domestic monopoly case (see the right panel of Figure 1), and adding the assumption that there are $n = 3$ firms, that the marginal cost of the firm of interest f is $c_f = 4.5$ and that $\sum_{j \neq f} c_j = 8.5$.[22] In the absence of imports (or were $c_I > p(87.5) = 7.25$ instead of

[20]Condition (9) also holds as an inequality in the case of a corner solution (i.e. $p(q_{-f}) < c_f$ such that $q_f = R_f(q_{-f}) = 0$), but this is standard so is omitted from the proposition.

[21]In the absence of imports, the unique Cournot equilibrium outcome (q_f^C, q_{-f}^C) is defined implicitly by $q_f^C = R_f(R_{-f}(q_f^C))$ and $q_{-f}^C = R_{-f}(R_f(q_{-f}^C))$. Formally, imports have bite under Cournot conduct if $p(q_f^C + q_{-f}^C) > c_I$, or equivalently when $q_f^C + q_{-f}^C < p^{-1}(c_I)$.

[22]For example, if one of firm f's rivals has the same marginal cost as the earlier monopolist, of 4, then the remaining rival has a marginal cost equal to that of firm f, of 4.5.

6), joint output and price in the Cournot oligopoly would respectively be 87.5 and 7.25 in equilibrium. In the presence of imports, where $c_I = 6$, joint output and price in the constrained Cournot equilibrium are respectively 100 and 6. This joint outcome is the same as the most collusive outcome of Illustration 1 in Section 2.1.

2.4 From theory to application: identification of conduct in the presence of potential imports (when costs are observed)

I argued in Section 2.2 that, in the presence of potential imports, estimation of a static pricing equation imposing the regular moment conditions yields inconsistent estimates of conduct and cost parameters. The immediate question is then: But what if the researcher *observes (domestic firms') marginal cost*? In a setting where imports restrain prices at the industry equilibrium, how can one then identify firm conduct?

Clearly, a direct comparison of marginal cost to price will provide a test of competitive behaviour against less competitive models of firm behaviour (and where imports may restrain prices). However, consider the following hypothetical situation. Suppose that prices exceed observed costs and that imports restrain prices were firms to behave à la Cournot, let alone restrain prices were firms to alternatively engage in collusion. One wishes to identify, from the constrained prices and quantities and the observed costs, the underlying model of conduct in the industry. It is not obvious how one can distinguish, say, collusive conduct from Cournot conduct when the equilibrium price under either alternative model of conduct is constrained to be the same and equal to the marginal cost of imports. This situation, for a domestic duopoly, is pictured in the left panel of Figure 5. The observed equilibrium outcome is marked with a "+", where clearly the imports constraint binds (since "+" lies on $q_f + q_g = p^{-1}(c_I)$, where the duopolists are labelled f and g). From the observed constrained equilibrium, it is not possible to tell whether firms in the industry behave in Cournot fashion (in which case aggregate equilibrium output in the absence of imports would equal $q_f^C + q_g^C$) or whether firm behaviour is more collusive than the Cournot benchmark (in which case the aggregate equilibrium output in the absence of imports would be lower than $q_f^C + q_g^C$). The example provided by Illustrations 1 (monopoly) and 2 (Cournot) above should clarify. In the example, the cost of imports, in addition to demand and domestic cost conditions, is picked to be such that under either model of conduct the aggregate equilibrium outcome is constrained to be the same. Under either the hypothesis of collusion or firms behaving à la Cournot, aggregate industry output is 100 (imports are zero) and price is 6 (equal to the marginal cost of imports). Thus, industry outcomes under full collusion and under Cournot are observationally equivalent in this example in which $p(q^C) > c_I$, where q^C is the "unconstrained" Cournot equilibrium industry output (recall $q^C > q^M$)[23].

Yet even in the case illustrated – where imports constrain prices not only when behaviour is collusive but also under Cournot – it may be possible to distinguish between competing hypothesis of conduct, despite industry outcomes being equivalent, *if firm-level quantity data is available* (in addition to costs being observed). The point is to recognise that for a Cournot firm, the general (i.e. allowing for the constraining effect of imports) pricing condition (9) of Proposition 2 has to hold. That is, for no Cournot

[23] Had I taken $(p^M >) c_I > p(q^C)$ in the example, imports would not have had bite under Cournot conduct and thus outcomes under full collusion and Cournot would be distinct.

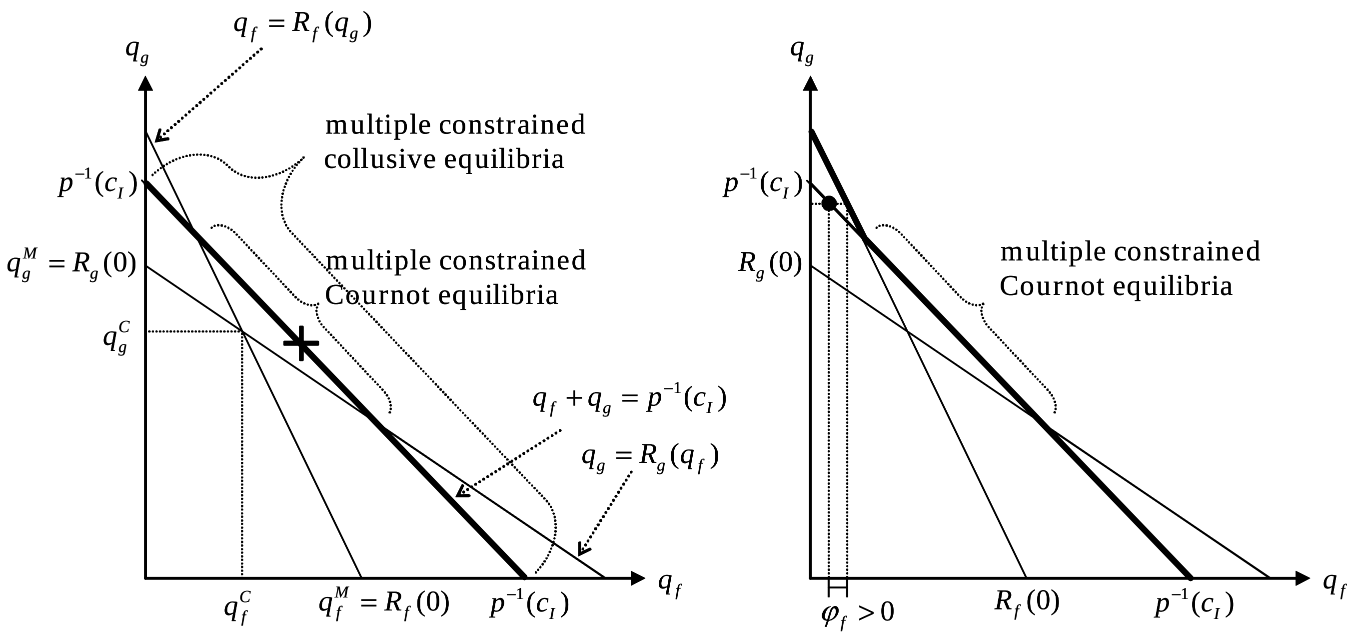


Figure 5: Identifying collusion from Cournot when imports constrain equilibrium prices under both models of conduct. Left panel: The imports constraint binds at the industry equilibrium marked "+", which is consistent with either Cournot conduct or more collusive firm conduct. Right panel: Rejection of Cournot behaviour for firm f: $\varphi_f > 0$.

firm can (perceived) marginal revenue *exceed* marginal cost, otherwise the firm would optimally expand output, and this holds irrespective of whether the imports constraint binds or not. This pricing condition can be used with observed marginal cost and the estimated market price elasticity of demand to test for Cournot behaviour. Under the hypothesis of Cournot behaviour, one may well observe a firm choosing output to the right of its unconstrained reaction function, given the (joint) output of its rivals, since imports may be restraining price at the constrained Cournot equilibrium: here, the Cournot firm would not cut output in an attempt to raise price above c_I, as an unconstrained Cournot firm would do, since this would only open the door to imports. However, under the hypothesis of Cournot behaviour, one should not observe a firm choosing output to the *left* of its unconstrained reaction function. This is illustrated in the right panel of Figure 5. While firm g's behaviour is consistent with Cournot (it does not cut output as a Cournot firm would do in an unconstrained equilibrium, since the imports constraint is binding), firm f's behaviour is not consistent with Cournot: firm f is restricting output. This translates into the following test. Rewrite the Cournot pricing condition (9) as an equality:

$$p(q) + \frac{p(q)}{\eta(q)}\frac{q_f}{q} = \varphi_f + c_f \tag{10}$$

Proposition 3 *(Sufficient statistic to reject Cournot behaviour) Under the null of Cournot behaviour,* $\varphi_f \leq 0$*. When the imports constraint binds,* $\varphi_f < 0$ *is consistent with Cournot behaviour. The finding that* $\varphi_f > 0$ *allows one to reject the hypothesis that firm* f *is behaving in Cournot fashion, in favour of more collusive behaviour, regardless of whether the imports constraint binds or not.*

As I will argue, there is strong evidence to suggest that outcomes across the different local markets in the Brazilian cement industry can be characterised as follows. The market price elasticities of demand are estimated to be very low, of the order of -0.5. Demand across local markets with widely differing market structures (i.e. concentration indices or number of firms) is consistently inelastic: elastically-supplied imports appear to restrain prices. Yet consumer prices considerably exceed the marginal cost of even the least efficient producers serving a given local market. I observe many instances in the data where the hypothesis of Cournot behaviour on the part of firms in local markets can be rejected in favour of what appears to be (tacit) market division. Typically, a firm with a plant located within a given local market will correspond to firm g in the right panel of Figure 5. It ships more than what it would ship in any constrained or unconstrained Cournot equilibrium. Other firms with plants located within this given local market, or with plants located nearby, will correspond to firm f in Figure 5, whose shipments to this local market fall short of their Cournot best responses. In Section 4.4.2 I show how such an arrangement may be sustained in equilibrium in a spatial dynamic model where firms meet in different markets.

3 Industry and data

3.1 The cement industry

Cement is a homogeneous good produced largely from limestone and clay in weight proportion of roughly 5 to 1. Described simply, limestone and clay are ground and the mixture is burned at a very high temperature in a rotary kiln producing cement clinker. The clinker pellets – once cooled – are then ground and mixed with a retarding agent (gypsum) and varying types of additives to form different formulations of cement[24]. Despite the relative simplicity of the product, the production of cement is capital intensive and is characterised by substantial economies of scale. Labour basically performs a supervisory role (Norman 1979). The process is also energy intensive, not only due to the operation of the kiln but also due to the grinding of raw material and clinker[25].

The process exhibits a fixed factor production function since factor inputs are not substitutable. Yet marginal costs do vary across kilns and plants, according to the technology, capacity, age and fuel employed (Jans and Rosenbaum 1996). The last major innovation to the production process took place in the 1970s in response to the energy price shocks. The "wet" process kiln system was replaced by the "dry" process,

[24]The different formulations of cement are substitutes in most types of user applications. While clinker comprises around 96% of ordinary cement, this proportion can be considerably reduced in other formulations, such as (blast furnace) slag cement or pozzolanic cement. Usually the supply of these different formulations will depend on the availability of additives (i.e. slag or pozzolane) in the proximity of the cement plant, such as a steelworks in the case of slag cement. Each type of cement usually needs to conform to legislation that specifies its (physical and chemical) properties. Thus differentiation based on formulation is limited.

[25]In many regions, such as in the Americas and Europe, the supply of limestone is ubiquitous; the raw material is thus usually extracted from a quarry located within the plant complex. The setup of a modern plant with capacity of 1.5 million tonnes per annum (mtpa), including the prospecting rights over limestone reserves, can require a capital outlay of up to US$300 million (US$200 per tonne of capacity).

which consumes less than half the respective energy (since no heat is needed to evaporate water). With the energy crisis in the foreground, firms invested in bigger, more energy-efficient kilns. Maximum kiln capacity in the four decades leading up to 2000 has increased six-fold to four million tonnes per annum (mtpa) (World Cement 2000)[26]. Although equipment suppliers and cement producers work closely together, most innovations seem to originate from the equipment suppliers, and technology can be purchased off-the-shelf[27].

As cement is a low-value commodity relative to weight, transportation costs may assume a significant proportion of cost, leading to geographically segmented markets. Scherer et al (1975, p. 429) list cement as having the second highest freight cost index for shipments out of 101 US industries. In order to meet dispersed demand, firms may trade in (production) scale economies for lower transport costs by scattering their plants across markets[28].

Demand for cement is essentially driven by the construction industry and is, similarly, cyclical. In developed markets, shipments are largely made in bulk to ready-mixed concrete firms and construction firms. By contrast, the lion's share of the industry's production in developing countries is dispatched in bags to resellers (retailers) who sell on to individuals ("do-it-yourself buyers"), reinforced by the fact that over the past decade or two many governments in such markets have been scaling down on infrastructure investments. The (short-run) price elasticity of demand for cement is low since cement makes up only a moderate part of most construction projects and there are few substitutes (Jans and Rosenbaum 1996).

World demand, estimated at 1620 mt in 2000, has been growing at around 3% p.a. (International Cement Review 2001). Growth is concentrated in emerging markets while demand in North America and Western Europe has been growing slowly or is stagnant[29]. Over the past 15 years, a significant process of consolidation has been running its course in the global cement industry. While family-run and state-owned firms have been put on sale, a few multinational firms have been on a buying spree, aggressively moving into new markets or expanding in markets where they previously operated. The combined production share (excluding China) of the world's six largest firms (C_6) in 2000 was estimated at 35%, up from 23% in 1995 and 14% in 1985.

3.2 The Brazilian cement industry in the 1990s

On the basis of output, Brazil ranks sixth in the league of cement-producing countries, with output of approximately 40 mtpa in the period 1998 to 2000 (SNIC 2002[30]). As

[26] See Rosenbaum (1989) and Johnson and Parkman (1983) on process and capacity changes in the US industry.

[27] "Turn-key" plants may be ordered from suppliers. Research and development (R&D) spending by the cement producers themselves is limited: operating at the forefront of cement-production technology, the Japanese producer Taiheiyo (Chichibu Onoda prior to 1998) spends less than 1% of sales revenue on R&D.

[28] See Scherer et al (1975) and Newmark (1998). Pre-empting entry may further reduce initial plant scale (Johnson and Parkman 1983).

[29] Around 30% of consumption occurs in China, notoriously a producer of low-quality cement in energy-inefficient, environmentally-unfriendly "backyard" mini cement plants.

[30] Unless specified otherwise, facts from this section are drawn from reports of the Brazilian cement industry's trade association (SNIC), backed up by other sources. See Appendix A.

shown in Figure 6, in 1999 57 active plants were scattered across a geographic area slightly smaller than that of the US[31]. This spatial distribution is not even, however, as consumer markets and thus plants are concentrated along the coastal states, in particular the relatively wealthy and populated states in the Southeast and South regions of the country[32]. States to the northwest of the centre of the country are sparsely populated and are largely covered with jungle.

In 1999, as also depicted in Figure 6, these 57 plants were owned by 12 firms. The two largest firms, Votorantim and Grupo João Santos, respectively with nationwide shipment shares of 41% and 12% in 1999, were both domestically-owned, traditional family-run businesses. The subsidiaries of the large multinational firms Holcim and Lafarge followed, with shipment shares of 9% and 8% respectively. As Figure 7 indicates, this national picture hides a lot of variation at the local, statewide level[33].

The 1990s saw two distinct periods in the history of the Brazilian cement industry. Up until mid 1994, a period of very high inflation and low macroeconomic growth, cement consumption was stagnant at around 25 mtpa. With the successful implementation of the *Real* economic stabilisation plan in July 1994 (see below), cement consumption resumed its growth at a rate of 10% p.a., reaching 40 mtpa by 1998-99, pulled by exogenous growth in the construction sector[34]. The post-stabilisation phase of the 1990s also saw a flurry of acquisition activity in the cement industry, with the expansion of incumbents and the entry of foreign firms which did not previously own assets in Brazil. Compared to the 12 firms that ran operations by 1999, the industry had consisted of 19 producers in 1991.

Given the short shelf life of cement, firms produce for immediate consumption. Stocks at producers amount to approximately one week of sales, with roughly another week of sales being stocked down the trade. Around 90% of shipments from producer plants to buyers in consumer markets is carried out by road – as opposed to rail or water. In line with other developing countries, as mentioned above, 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-mixed concrete firms, large construction firms or producers of construction aggregates.

I now provide a few comments on the 1994 economic stabilisation plan and on the role of imports in the cement industry, given their relevance to the present study.

The July 1994 stabilisation plan The *Real* economic stabilisation plan, enacted in July 1994, successfully brought (very high) inflation under control. Between 1991 and June 1994, the first period covered in this study, inflation as measured by the change in the General Price Index averaged 26% *per month* (i.e. prices doubling every quarter).

[31] With a population corresponding to two-thirds that of the US, cement consumption per capita in Brazil amounts to 232 kg as compared to 415 kg in the US (SNIC 2002).

[32] 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*).

[33] In terms of geography, the most disaggregated level at which demand-side data are observed is the state level. For this practical reason, I will take each state to represent a market. More fundamentally, I argue that this is sound in the data discussion of Appendix A.

[34] As will be discussed shortly, real cement prices also fell in the early days post stabilisation.

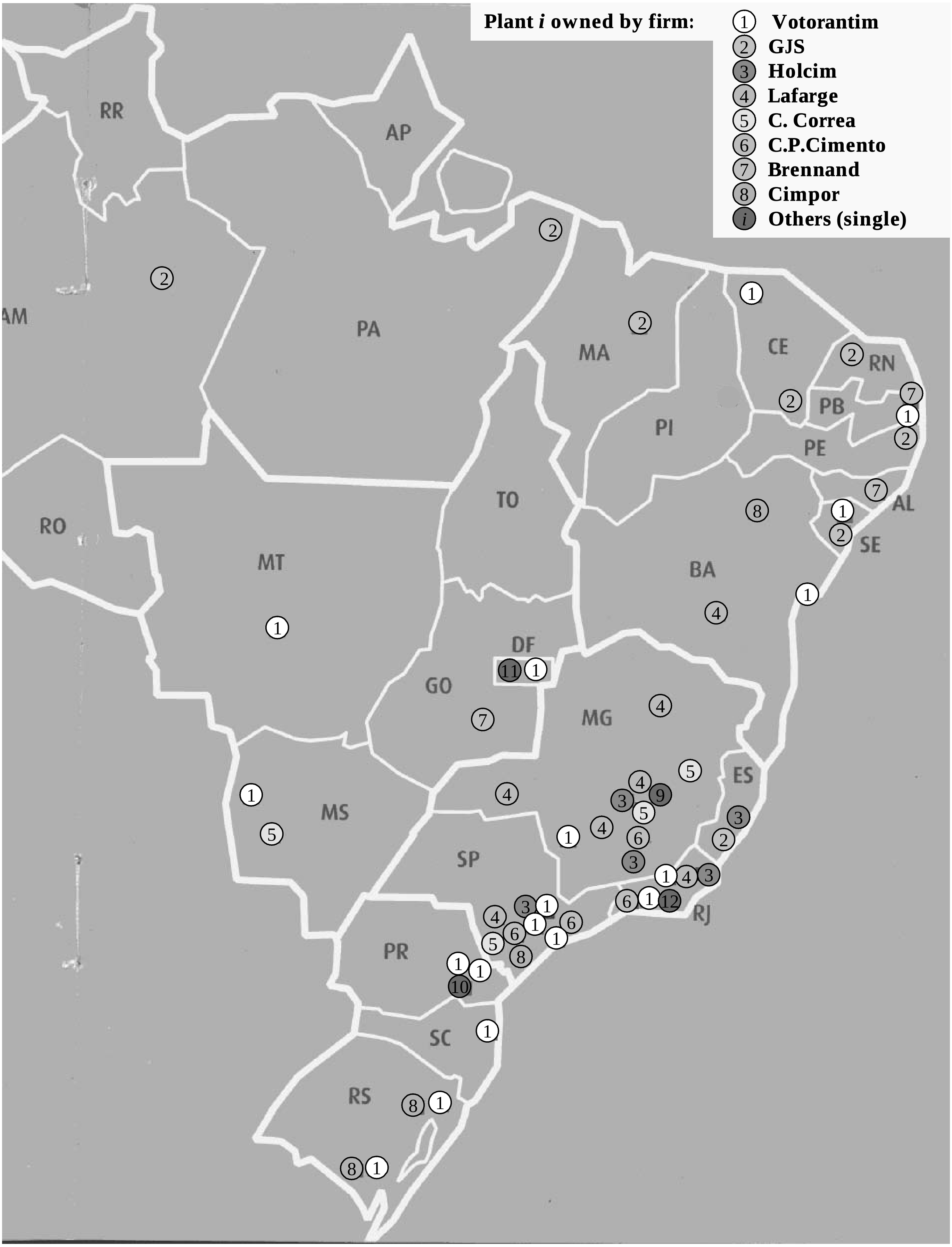


Figure 6: Active plants in 1999

	Mean	Standard Deviation	Maximum	Minimum	Memo: Total across 27 states
Cement consumption in state (kt)	1,483	2,324	11,723	55	40,045
Number of (active) cement plants located within state[0]	2.1	2.6	11	0	57
Number of cement firms (producers) shipping to state	5.7	2.8	11	1	12
One-firm concentration index in state[1]	57%	17%	100%	25%	41%
Two-firm concentration index in state[1]	83%	13%	100%	49%	52%
Four-firm concentration index in state[1]	97%	6%	100%	77%	70%
Hirschmann-Herfindahl index in state[1]	4494	1823	10000	1830	2106
% shipments originating from state destined for that state[2]	60%	22%	100%	14%	
% shipments origin. from state destined for that and bordering states[2]	92%	9%	100%	70%	
Value Added (volume decomposition) in Construction Sector[3]	475	726	3,431	9	12,352
Land area (x 1000 square kilometres)[4]	315	370	1,571	6	8,515
Population (m, mid 1999)[4]	6.1	7.3	35.8	0.3	163.9
Population density (/sq km)	56.9	84.1	339.5	1.2	19.3
Per capita cement consumption in state (kg p.c.)	211	67	353	104	244
Per capita Value Added in Construction Sector[3]	61	26	108	16	75

[0] Of the 57 plants, 7 were grinding-only operations (with clinker being shipped from a nearby plant with integrated facilities)

[1] Based on shipments from producers located anywhere to buyers located in a given state

[2] Applies only to states from which shipments originate (i.e. states where plants are located)

[3] In rescaled constant monetary units

[4] Source: Brazilian Institute for Geography and Statistics (IBGE)

Figure 7: Variation across 27 states of the Brazilian federation, Summary Statistics (time-varying figures refer to 1999)

With the implementation of the stabilisation plan, inflation fell to 22% per annum in the period July 1994 through December 1995, further falling to 10% per annum in the six years between 1996 and 2001.

One of the outcomes of the stabilisation plan was its large positive effect on the level of economic activity. The sharp slowdown in inflation, through the reduction in "inflationary tax", represented a reduction in the transfers from the private sector to the government. In particular, the large mass of consumers among the lower-income groups who previously had no access to instruments of monetary protection, such as price-indexed savings accounts, saw a significant rise in real incomes. Given their high propensity to consume, this boosted the demand for consumer goods – notably food, clothing and durables – and the demand for housing. Coupled with commercial construction projects resulting from a more favourable investment climate, the demand for housing led to a significant increase in the activity of the construction sector of the Brazilian economy, and thus in the demand for cement.

The four years following stabilisation also saw the appreciation of the local currency, of direct relevance to the competitiveness of cement imports. This period of a strong local currency abruptly came to an end with the devaluation of January 1999.

The role of imports in Brazil Imported cement (including the intermediate product clinker) constitutes a small share of domestic consumption. As shown in Figure 8, in the period 1989 to 2003, this share has amounted to at most 2-3% of consumption across Brazil, though the trend appears to be rising since the trade liberalising reforms of the early 1990s (and despite a dip in 1999 and 2000 following the devaluation of the local currency – see below). This low level stands in stark 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%[35]. The presence of imports in Brazil thus pales in comparison to the US, despite most of its markets being located along (or in proximity to) an extensive Atlantic coastline.

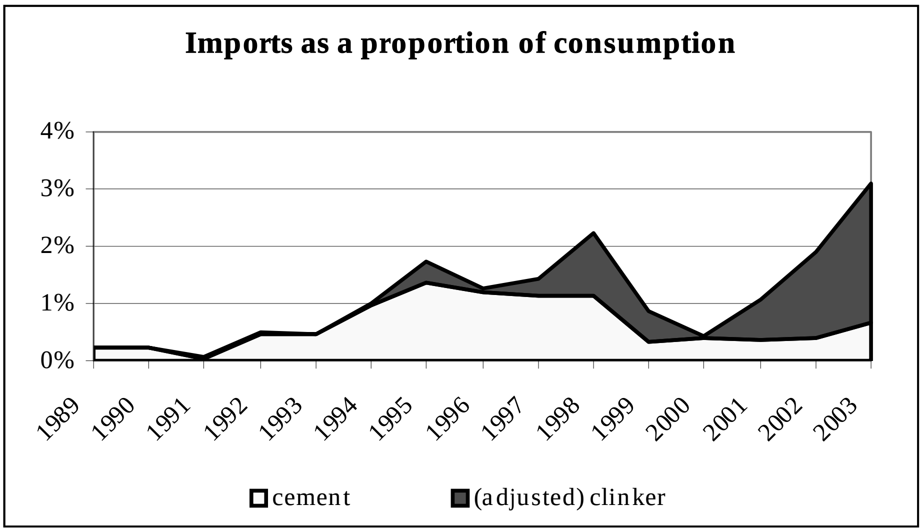


Figure 8: (Official) Imports of cement and clinker as a proportion of domestic consumption. Source: SECEX, MDIC. Clinker quantities are adjusted by the author to reflect usage in the production of cement (assumes 80% of clinker imports used in production of slag cement, with a 40% clinker content).

As this study finds, however, the limited penetration of imports hides their welfare-enhancing role in restraining domestic prices, curbing the market power of domestic producers. The trade liberalising reforms of the early 1990s, coupled with the appreciation of the local currency in the four years following stabilisation in mid 1994, opened the door to the threat posed by the entry of imports. To provide a flavour, Figure 9 depicts the evolution of cement prices in the state of Rio Grande do Sul – where one-firm and two-firm concentration ratios respectively amounted to 55% and 84% in 1999 – both in current local currency (the *real*, R$) and in a currency of foreign trade, proxied by the US dollar. Domestic cement prices in local currency are highly correlated with the price of the US dollar in local currency (i.e. the exchange rate), to the extent that despite the

[35] Despite the bulkiness of cement relative to its price, the development of specialised seaborne handling and transportation equipment from the 1970s 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).

occurrence of large variations in the exchange rate during the period, and thus in the domestic cement price in local currency, the domestic cement price converted into US dollars is quite steady since 1995[36] [37]. In the cross-section of local markets, one would also expect cement prices to be increasing in the market's distance from the coast. This is verified to be the case. It is important to add, however, that neither of these two observations – regarding (i) the correlation of cement prices in local currency and the exchange rate, and (ii) that prices appear to be increasing in distance – are offered as proof of the claimed role of imports in restraining prices. While consistent with the claim, they are also consistent with alternative stories, such as factor prices being set in hard currency on the world market (fuel oil and diesel?), or with producers incurring higher transport costs to distribute cement in less densely populated areas. The estimation of a very low market price elasticity of demand in equilibrium, in Section 4.2, coupled with high price-cost margins and supported by interview evidence, will be the key element in support of my claim.

3.3 Data available: Plant-to-market cement flows and the construction of marginal cost

A detailed account of the sources and treatment of the data is provided in Appendix A. Here I offer a short description and briefly discuss how I compute the marginal cost of each plant in serving each local market.

On the demand side, I observe monthly cement consumption and consumer prices (i.e. prices set by retailers, also referred to as resellers) across the 27 states in the period 1991 to 2003. I take each state to represent a local market. As demand shifters, I observe alternative series of economic activity, either in the construction and building sector or aggregated across sectors of the economy, which I use as proxies for the exogenous demand for cement.

[36] Until January 1999 Brazil had an exchange rate fixed by the government. The local currency (the *real*) was floated in January 1999 in the midst of the "Brazil currency crisis", depreciating by 70% against the US dollar in one month, but later partially receding. Other periods of above-average exchange-rate instability took place in 2001 (commonly attributed to the Argentina crisis next door) and in the second half of 2002, with the uncertainty surrounding the outcome of the presidential election late that year. The relatively flat evolution of domestic cement prices in US dollars is consistent with imports setting a price ceiling of between 6-7 US dollars per bag of cement (this would correspond to the US-dollar equivalent of c_I, as defined in Section 2). The observation that it seems to take domestic producers between 6-12 months to raise domestic prices back to this ceiling in US dollars upon large unexpected devaluations in the local currency (i.e. in 1999, in 2001 and in 2002) suggests that raising domestic prices in local currency is not friction free (perhaps the industry is wary of attracting negative publicity).

[37] To provide an example, an equity analyst of an investment bank wrote that "(a)lthough imports accounted for only 1.6% of the Brazilian total consumption in 1995, reaching 451.3 thousand tons, it represents a constant threat to domestic producers, pressuring down domestic prices and imposing a price ceiling of US$ 70 per ton" (Zaghen 1997; pp. 24). The author refers to the price "at the coast" as the exporter's FOB price plus international insurance and freight, excluding cost upon arrival in Brazil, such as inland freight, sales taxes and resellers' markups. Further evidence suggesting concern by domestic producers as to the threat of imports is provided by their successful lobbying of government in passing antidumping measures – namely a 23% import tariff – against Venezuelan and Mexican cement producers in the late 1990s who were starting to make inroads into local markets particularly in the north and northeast of the country.

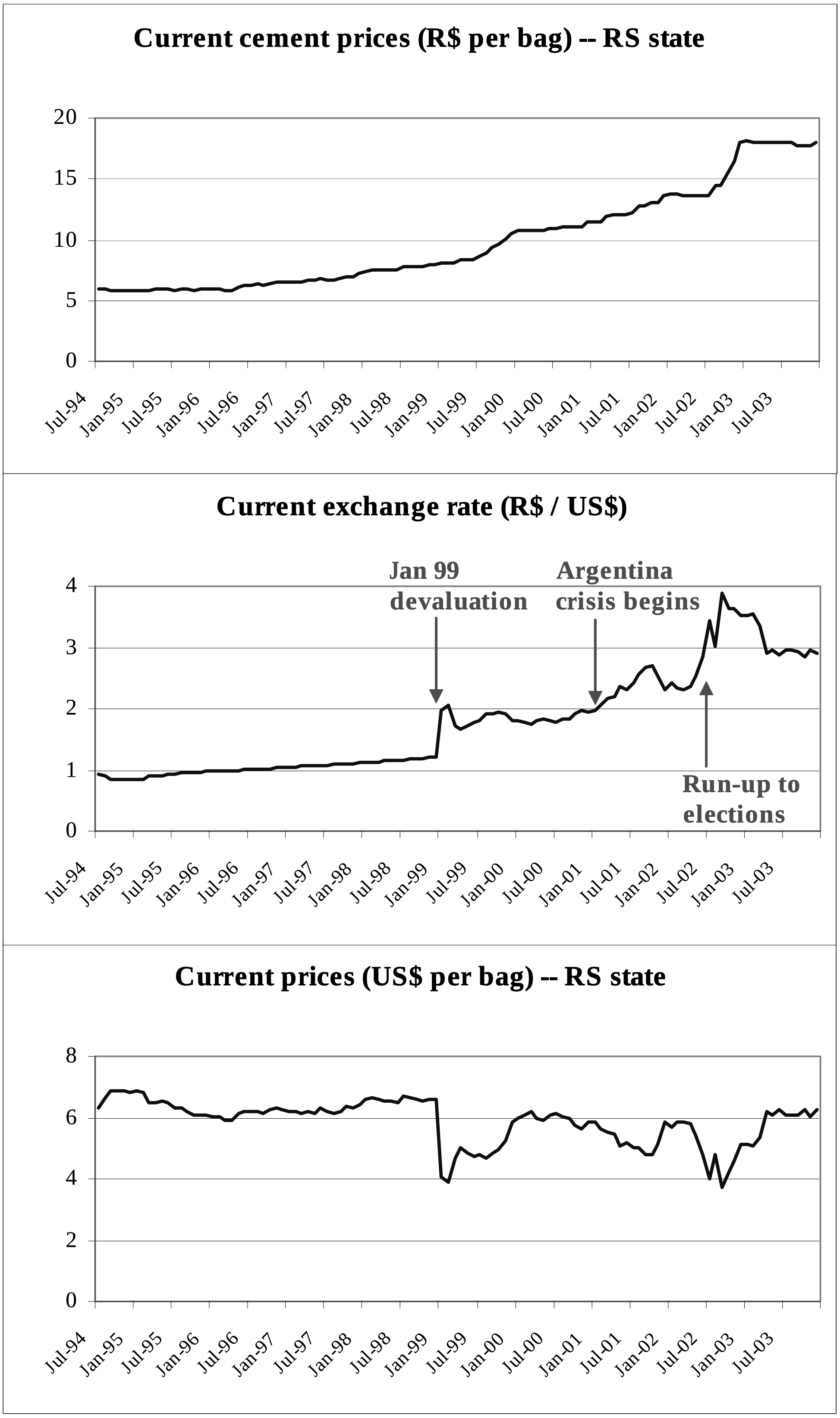


Figure 9: Evolution of cement prices in *RS* state since July 1994. In current local currency units (R$) per bag and US$ per bag

The key ingredient on the supply side is the observed breakdown of shipments from each plant to each of the local markets (states), enabling me to map the flow of cement from the plant to the consumer. In addition to plant ownership, I observe plant characteristics – e.g. capacity, number of kilns, type of fuel usage, proportion of shipments in bags as opposed to bulk[38] – and local factor prices, such as fuel oil, coal, electricity and wages. I do not observe freight prices paid by cement producers but 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. The transportation of goods such as soyabean and maize are reportedly close substitutes in the supply of cement freight (Soares and Caixeta Filho 1996).

Considering that the technology of cement production is of the fixed coefficients type, I use engineering estimates, factor prices and plant characteristics to directly calculate the marginal cost of each plant in serving each market. As I argue in Appendix A, these marginal costs are indeed estimated upper bounds to the true marginal costs. (When I turn to the testing of conduct in Section 4.4, such a bias, however, reinforces the results.) In view of the fixed-coefficient technology and my understanding of the industry, I model plant marginal cost as flat in quantity up to capacity. Notice that I do not observe producer prices, only consumer prices. However, I back out producer prices assuming competition at the retail (reseller) level and taking into account the high proportional sales taxes. The assumption of competition among resellers follows from several field interviews, including interviews with producers' sales representatives and resellers. (I also check the robustness of this assumption by, for example, comparing *observed* producer prices that I was able to obtain from a subset of producers to the backed-out producer prices.) This study thus considers the entire supply chain from the producer of cement (and extractor of the raw material) to the retail consumer, encompassing the reseller: in addition to plant marginal cost, total plant-to-market marginal cost consists of plant-to-market freight, sales taxes and the reseller's mark-up.

Figure 10 depicts cement prices (in units of local currency for the standard 50 kg bag, at a constant December 1999 level[39]), cement consumption and exogenous demand (activity in the construction sector) from January 1991 through December 2003 for the largest market, the state of São Paulo (*SP*). The month in which the stabilisation plan was implemented, July 1994, corresponds to observation (month) 43 in the graphs (marked by dotted lines). Following the lifting of price controls in November 1991, prices approximately doubled in the first two years of the pre-stabilisation period I cover, remaining in the high R\$ 14 to R\$ 16 / bag range until 1994. In the post-stabilisation period they gradually declined back to R\$ 7 by late 1996, gradually rising thereafter. The sharp increase in consumption following stabilisation, from a level of 600 mt per month to 1000 mt per month within two years, pulled by a 20% jump in the level of construction activity, is evident from the graphs. Some factor prices are also portrayed. It is interesting to note that in the post-stabilisation phase the correlation

[38] Aggregating across all plants, between 1997 and 1999 81% of shipments were in bags. In terms of the means of transportation, 91% of shipments were by road. The breakdown of shipments among different buyer channels is also available, with resellers accounting for 76% and ready-mixed concrete firms accounting for 11%, in this same period.

[39] This is done using an economy-wide General Price Index (GPI). Owing to the high levels of inflation prevailing in the first 42 months (out of 156) that I consider, particular attention has been paid to the conversion of current cement prices to constant prices – see Appendix A. Factor prices are similarly converted. In contrast, Figure 9 presents current prices (albeit for another state).

between cement prices and the prices of fuel oil and diesel oil (the two major components of cost, used respectively in the kiln and in freight) is high[40]. This is expected in view of (i) my earlier claim (at this point) that imports set a price ceiling for cement and thus cement prices (in local currency) are highly correlated with the exchange rate, and (ii) oil is a global commodity and policy in the oil sector from the second half of the 1990s has prescribed domestic oil prices varying in line with the world price (and hence with the exchange rate). Though the picture varies across states, if only due to different changes in industry structure and demand conditions, the case for the state of São Paulo is broadly representative for Brazil as a whole, in addition to accounting for around one-third of the nation's cement consumption.

A glance at price-cost margins and the robustness of constructed marginal cost With respect to firm profitability, Figure 11 shows the evolution of average consumer prices, marginal cost and price-cost margins on the leading firm Votorantim's actual sales across Brazil, in constant local currency units per bag. (Figure 18 in the Appendix breaks this figure down into figures for each of the 25 states where Votorantim is present.) Prices and marginal cost have been increasing since late 1996, the latter owing chiefly to increases in the price of fuel oil and diesel (freight) and the fact that sales taxes are proportional to prices – recall that cost relates to the entire supply chain, including freight, sales taxes and the reseller's cost. The picture is similar across firms. In sum, the industry wields considerable market power, despite the threat of imports. 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).

I conduct two robustness checks of the calculated marginal costs and the resulting price-cost margins (for further details, see Appendix A). The first check consists of comparing my measures of price-cost margins as a percentage of net producer sales (i.e. net of sales taxes) to reported EBITDA (earnings before income tax and depreciation allowance, also known as operating cash flow) as a percentage of net sales for the firm Cimpor, over the period 1998 to 2003. (This firm, which bought its way into Brazil in 1997, is listed on the Lisbon stock exchange, and fortunately reports its financial results broken out by country of operation and line of business.) The time series fit between constructed and reported figures is good. For example, I estimate Cimpor's average price-cost margins as a percentage of net producer sales rising from around 47% in 2000 to 56% in 2002. Cimpor reports a similar rise in this period, from 44% to 55%. If anything, my calculated price-cost margins are slightly higher than the EBITDA figures Cimpor reports. This is to be expected, for while my cost estimates include only (constant) marginal cost, Cimpor's EBITDA figures are net of other costs such as plant overhead and sales and administrative expenses. Indeed, my price-cost margins appear to be conservative (on the low side), as flagged above. The second check is based on accounting data sampled among establishments in the cement industry on an annual basis by the Brazilian Institute for Geography and Statistics (IBGE) as part of their Annual Industry Survey (PIA) series. Producers' average accounting gross margin (Net Sales minus Cost of Goods Sold) as a percentage of net sales hovers around 50% during

[40]From July 1994, correlation coefficients (all highly significant) are as follows: 0.72 between cement prices and the (US dollar) exchange rate; 0.86 between cement prices and the price of fuel oil; 0.77 between the price of fuel oil and the exchange rate.

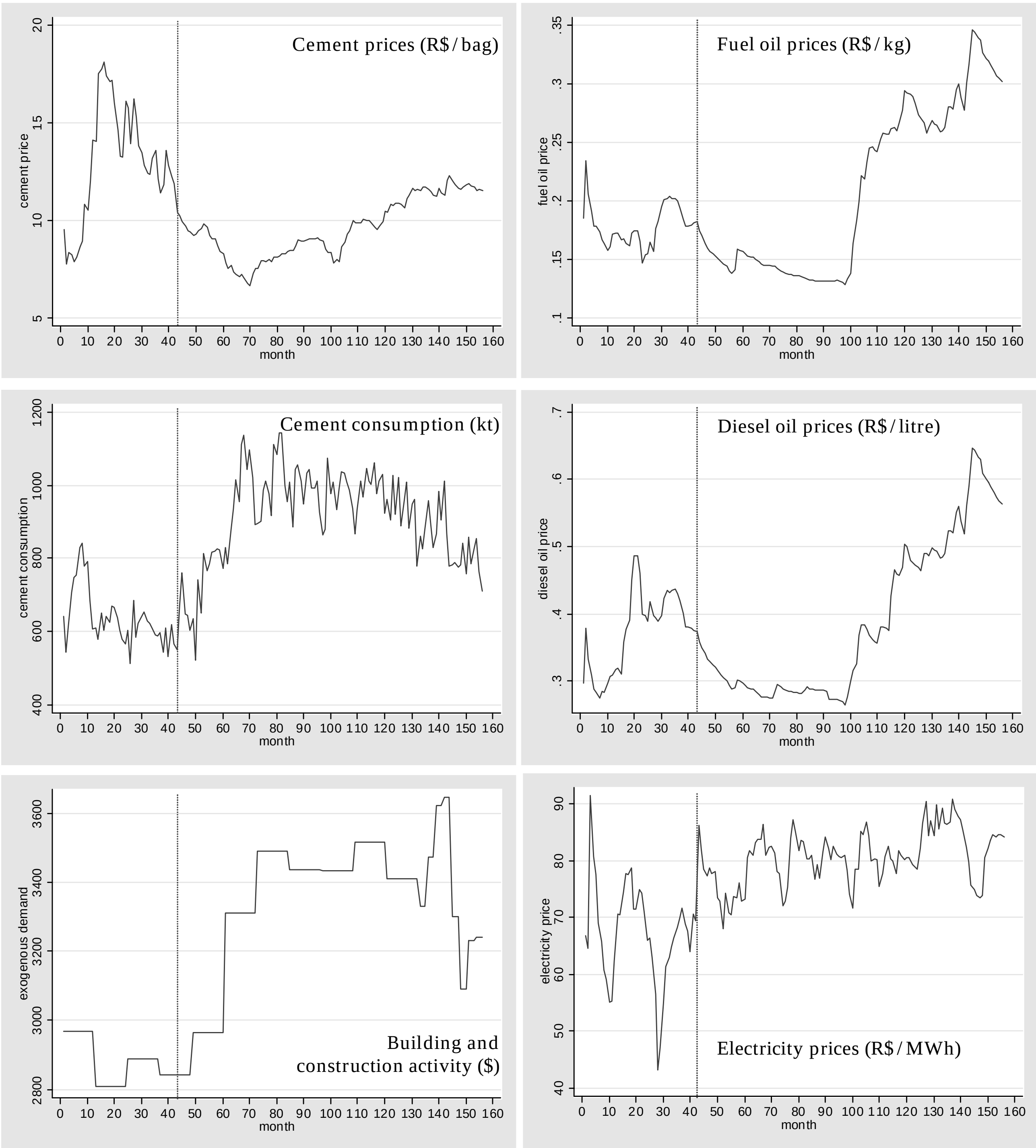


Figure 10: Cement prices, consumption, exogenous demand and factor prices for the state of São Paulo. All prices are in constant December 1999 values. Monthly observations, observation 1 corresponding to January 1991. July 1994, the month in which the stabilisation plan was enacted, is marked by the dotted lines.

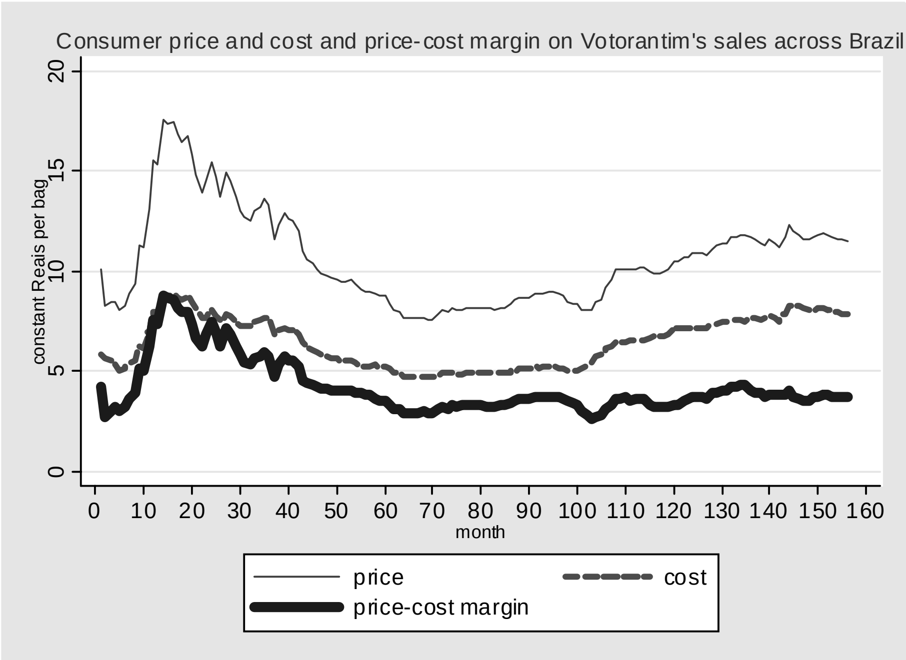


Figure 11: Evolution of consumer prices, marginal costs and price-cost margins on Votorantim's sales. Averaged across all states. In constant Reais per bag (at December 1999 values).

the 1990s; further, its variation is in line with the observed fall in prices beginning in 1992 and the rise in prices commencing in 1997. (Note that the Cost of Goods Sold does not include freight but it includes depreciation.)

A final word on capacity utilisation Throughout the time period, capacity considerably exceeds production, including the three years post stabilisation of steep consumption growth (1995 to 1997), although the slack is lower. Capacity utilisation hovers around an average 65%. The reader is referred to Appendix A for details (and a discussion of a strategic role for capacity is provided in 4.4.2).

4 Inferring demand and conduct in the Brazilian cement industry

4.1 A "road map"

Having laid out the theoretical framework and provided an outline of the industry and the data, this Section turns to the empirical application. Section 4.2 begins by estimating demand in each local market (state). The market price elasticities of demand are estimated to be very low, of the order of -0.5. Demand across local markets is consistently inelastic at the equilibrium, including local markets where the one-firm concentration ratio is as high as 80%. Recall that observed (constructed) price-cost margins are high in equilibrium. I argue that the reason why the industry, with its considerable pricing power, does not further raise prices (and further restrict output) is that the competitive fringe of imports sets a price ceiling which binds at the industry equilibrium. As such, while the market elasticity is low (-0.5), the price elasticity of the demand that the *domestic* industry faces is much higher: the equilibrium lies at the kink in the residual demand curve facing the domestic oligopoly (recall the right panel of Figure 1 in the theoretical framework developed earlier).

I have argued that when the threat of entry constrains prices, joint inference of conduct and cost from the estimation of a static pricing equation will not be consistent. The lack of price variation as demand moves exogenously will lead to the overestimation of competition; econometrically, the exogenous demand variables will be correlated with the error in the misspecified pricing equation. This is what Section 4.3 shows with regard to the industry at hand. *I assume costs are not known* and proceed to estimating a market-level pricing equation, instrumenting with exogenous demand. The conduct parameter is estimated to be close to zero and costs are estimated to be close to prices, wrongly suggesting that the outcomes in the Brazilian cement industry are competitive. The negative bias in the estimated price-cost margins is severe in view of the high price-cost margins I measure directly, as presented earlier in Section 3.3.

Having rejected competitive conduct based on the known price-cost margins, Section 4.4 delves deeper into the pattern of conduct in the industry, taking into account the constraint posed by imports on industry outcomes. I use the test of Proposition 3, which is based on direct measures of costs and the observed firm-level quantity data (i.e. the flow of cement from plants to local markets), to show that conduct is considerably more collusive than the Cournot benchmark. Market outcomes are characteristic of (tacit) market division, *and this can be identified despite the threat of imports restraining prices.* Finally, in Section 4.4.2 I show how such an arrangement may be sustained in equilibrium in a context where firms meet in different markets. Inspired by the Brazilian cement industry, I provide examples of simple dynamic games which give rise to such collusive behaviour in equilibrium.

4.2 Demand

There are L (geographic) markets (identified with states of the Brazilian federation), indexed by $l = 1, ..., L$. Scattered across these L markets are I plants, indexed by $i = 1, ..., I$.[41] Let $i = 0$ index the aggregate fringe of foreign suppliers. The flow of cement for consumption can be summarised in a set of $(I + 1) \times L$ matrices, one matrix for every time period t, where element q_{ilt} denotes the quantity of cement shipped by plant i for consumption in market l in that time period. Let q_{lt} denote total shipments to market l in period t, i.e. consumption; then $q_{lt} = \sum_{i=0}^{I} q_{ilt}$. The demand function in each market l can then be written:

$$q_{lt} = D(p_{lt}, Y_{lt}, \alpha_l, \epsilon_{lt}^d) \tag{11}$$

where p_{lt} is the price of cement to the consumer, Y_{lt} are exogenous variables shifting demand (e.g. output in the construction and building sector), α_l are market-specific parameters to be estimated and ϵ_{lt}^d is an econometric error term. (Demand function

[41] Not all plants are active (in the sense that cement is shipped from them) in each time period t; in a given time period, some plants may be yet to enter (or reenter), while others may have exited.

$D(.)$ is the inverse of the inverse demand function $p(.)$ considered in the theoretical framework, i.e. $D(.) = p^{-1}(.).)$

Estimation of (11) must deal with the (potential) endogeneity of prices. The choice of instruments will depend on whether imports restrain domestic prices at the industry equilibrium (i.e. whether the imports constraint binds, in which case prices are given by the marginal cost of imports c_I, as in Figure 5), which in turn depends on the behaviour of domestic firms[42]. There are therefore two situations to consider.

Identification 1: Imports restrain domestic prices at the industry equilibrium In practice, due to the presence of frictions, cement prices will not be exactly equal to c_I. Prices and c_I should be highly correlated however. As mentioned in Section 2 (recall the right panel of Figure 1), fluctuations in the marginal cost of imports allow one to trace out the demand curve (assuming c_I does not rise to the extent where imports no longer have bite). The marginal cost of imports is a function of factors such as the exchange rate, world fuel prices (used in the production of clinker abroad and in the international transport of cement), tariffs and port handling charges, and domestic freight to the consumer (the latter being highly correlated with the domestic price of diesel oil). Observed factors such as the exchange rate, world fuel prices and domestic diesel oil prices (all in local currency in constant terms) can then be used as instruments for prices in the estimation of (11) (under the identifying assumption that these factors are not correlated with the unobserved market-specific demand shocks ϵ^d_{lt}).

To the extent that the "frictions component" of cement prices – i.e. the part of prices not determined by the marginal cost of imports c_I – is orthogonal to the unobserved demand shocks across local markets, prices can be treated as predetermined and (11) can be estimated by OLS[43].

Identification 2: Imports do *not* restrain domestic prices at the industry equilibrium When imports do not restrain domestic prices, traditional cost-shifters may be used to instrument for cement prices. 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 supply-shifters such as plant capacity, to the extent that changes to scale impact (flat) marginal cost[44].

[42] Recall that in the case of full collusion and $p^M \geq c_I$, as in the right panel of Figure 1, the equilibrium price is $p = c_I$. Likewise, in the case of Cournot, imports will have bite if the aggregate Cournot output in the absence of imports falls short of $p^{-1}(c_I)$ – see footnote 21 and the right panel of Figure 4.

[43] The model I have in mind when imports restrain domestic prices is as follows. Cement prices p are determined by the marginal cost of imports c_I and a frictions component ζ, i.e. $p = c_I + \zeta$. As for c_I, I observe as the econometrician some cost drivers V^1 but not others V^2, where $c_I = V^1\kappa + V^2\phi$, and κ and ϕ are parameters. Under the identifying assumption that $E(V^1\epsilon^d) = 0$, where ϵ^d captures the unobserved demand shocks in (11), V^1 (e.g. the exchange rate) can be used to instrument for prices in the estimation of (11). In addition, if $E(\zeta\epsilon^d) = 0$ (and of course $E(V^2\epsilon^d) = 0$ as well), demand equation (11) can be estimated consistently by OLS.

[44] Other instruments can be used as a robustness check, such as Hausmann-type instruments (prices of cement in other local markets) or lagged prices or first differences.

4.2.1 Demand specification

I begin by specifying the market-level demand function (11) in loglinear form as:

$$\log q_{lt} = \alpha_l^1 + \alpha_l^2 Y_{lt} + \alpha_l^3 \log p_{lt} + \alpha_l^4 Y_{lt} \log p_{lt} + \epsilon_{lt}^d \tag{12}$$

For each market there are 156 monthly observations, from January 1991 to December 2003. Given the quarterly seasonality of sales, three quarterly dummies – not shown in (12) – are included. The inclusion of an interaction term between (log) price and the exogenous demand variable (construction and building activity), $Y_{lt} \log p_{lt}$, allows the demand curve in logs to rotate – in addition to shift, through the level term Y_{lt} – as exogenous demand varies.

By the earlier discussion, (12) is estimated, for each local market, by (I) OLS, (II) 2SLS using the exchange rate and other prices relevant to the marginal cost of imports (such as world oil prices and local diesel oil prices) as instruments (all in constant local currency), and (III) 2SLS using factor prices as instruments. These three sets of results are depicted in Figure 12 for the state of São Paulo (*SP*), denoted respectively as "OLS", "IV imports bite" and "IV imports no bite"[45]. (I illustrate using results for the state of *SP*, as this is the largest market, accounting for 29% of national cement consumption in 1999; as shown below, however, results across states follows a common pattern.) Most estimated coefficients are significantly different from zero, many at the 1% level of significance. The interaction term is found to be negative and highly significant: the demand curve (in logs) rotates anticlockwise as exogenous demand expands[46]. Each fitted equation is evaluated at two different values for the exogenous demand variable: at the mean for the pre-stabilisation (high inflation) phase, $\bar{Y}_{SP,pre} = 2883$, from January 1991 through June 1994 (42 observations), and at the mean for the post-stabilisation (low inflation) phase, $\bar{Y}_{SP,post} = 3338$, from July 1994 through December 2003 (114 observations). The (average) market price elasticity of demand during the pre-stabilisation phase amounts to (an inelastic) -0.17, rising to -0.33 during the post-stabilisation phase (see the respective coefficients on log price in column (II), respectively $\hat{\alpha}_{SP}^3 + \hat{\alpha}_{SP}^4 \bar{Y}_{SP,pre}$ and $\hat{\alpha}_{SP}^3 + \hat{\alpha}_{SP}^4 \bar{Y}_{SP,post}$). Thus, as prices in the economy stabilise and an average 16% exogenous increase in the demand for cement occurs, the price elasticity seems to double from around -0.2 to around -0.4. Clearly, a formal test that the price elasticity has increased is equivalent to verifying that the coefficient on the interaction term is significantly negative. This is so: the p-value for this (one-tailed) test is 1.5%. Importantly, to check the robustness of the low elasticity I repeat regressions (II) and (III) using only the 114 observations from the post-stabilisation subsample (July 1994 on). This confirms a low elasticity of -0.4 (results are not shown). Figure 13 plots the fitted demand curve for the pre- and post-stabilisation phases (i.e. evaluated at the respective means $\bar{Y}_{SP,pre}$ and $\bar{Y}_{SP,post}$), indicating that as stabilisation took place and exogenous demand grew, the demand curve shifted out and rotated anticlockwise. In addition to the state of São Paulo (*SP*), similar plots are drawn for the three next largest markets, the states of Minas Gerais (*MG*), Rio de Janeiro (*RJ*) and Bahia (*BA*). These suggest that this pattern may be typical across states, as I argue after considering some specification tests.

[45] Standard errors are heteroskedasticity and autocorrelation-robust (1-lag Newey-West errors). Estimates for the three quarterly dummies are not shown, but are usually significantly negative in the first quarter, significantly negative or insignificant in the second quarter, and insignificantly negative, insignificant or significantly positive in the third quarter.

[46] Estimation of specification (11) *excluding* the interaction term renders a significantly positive coefficient on the level of exogenous demand, as expected (results are not shown).

		(I) OLS		(II) IV imports bite		(III) IV imports no bite		(II B) IV subset imports bite		(III B) IV subset imports no bite	
No. obs.		156		156		156		156		156	
R^2		0.840									
Intercept	coef	2.241	*	2.828	**	2.439	*	0.212		0.729	
	s.e.	(1.202)		(1.210)		(1.236)		(1.357)		(1.333)	
Exog. demand	coef	0.00159	***	0.00141	***	0.00152	***	0.00225	***	0.00203	***
	s.e.	(0.00038)		(0.00039)		(0.00039)		(0.00043)		(0.00042)	
Log Price	coef	1.093	**	0.852	*	1.003	*	1.954	***	1.702	***
	s.e.	(0.498)		(0.504)		(0.514)		(0.564)		(0.554)	
Interaction	coef	-0.000428	***	-0.000355	**	-0.000396	**	-0.000709	***	-0.000607	***
	s.e.	(0.000160)		(0.000163)		(0.000166)		(0.000181)		(0.000176)	
Quarterly dummies		Included		Included		Included		Included		Included	
Evaluating at the mean of exogenous demand pre-stabilisation: 2,883											
Intercept	coef	6.825	***	6.898	***	6.815	***	6.699	***	6.594	***
	s.e.	(0.143)		(0.144)		(0.145)		(0.155)		(0.167)	
Log Price	coef	-0.142	**	-0.171	***	-0.138	**	-0.091		-0.048	
	s.e.	(0.055)		(0.056)		(0.056)		(0.060)		(0.065)	
Evaluating at the mean of exogenous demand post-stabilisation: 3,338	16% growth versus pre-stabilisation phase										
Intercept	coef	7.549	***	7.541	***	7.507	***	7.724	***	7.521	***
	s.e.	(0.129)		(0.136)		(0.135)		(0.142)		(0.141)	
Log Price	coef	-0.337	***	-0.333	***	-0.318	***	-0.414	***	-0.325	***
	s.e.	(0.058)		(0.060)		(0.060)		(0.063)		(0.062)	
Test of overidentifying restrictions				Fail		Fail		Pass		Pass	

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

Dependent variable is Log Consumption

Quarterly dummy variables for quarters 1, 2 and 3 are included but estimates are not shown

Figure 12: Demand estimates for the state of *SP*

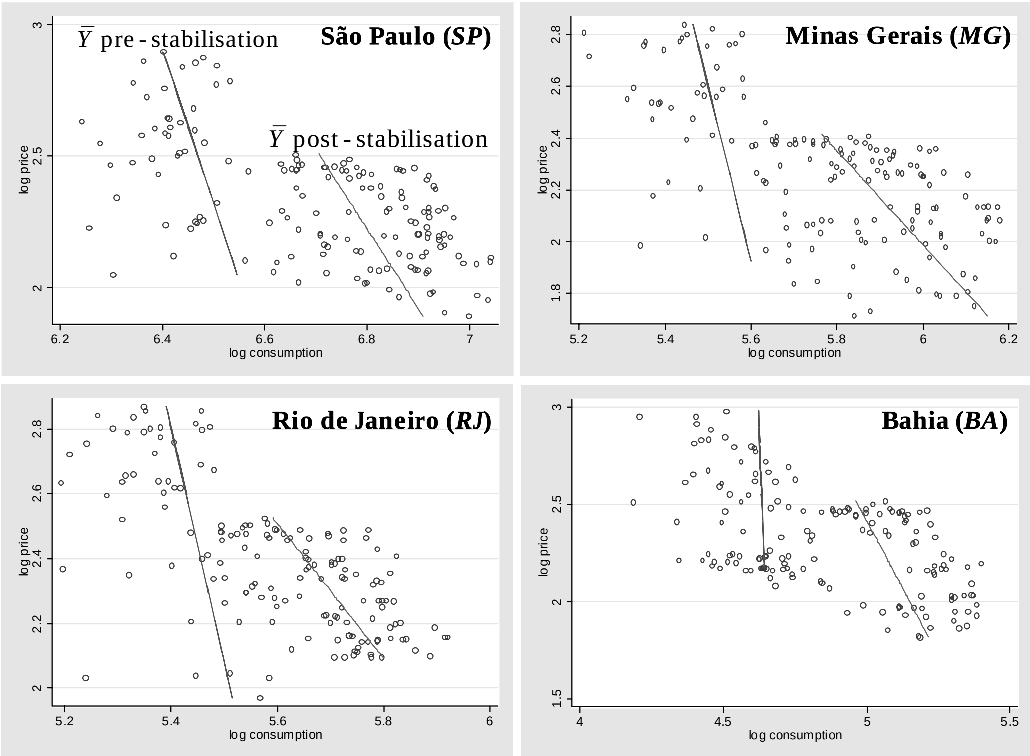


Figure 13: Fitted demand curves for the four largest markets. (Log) Price against (Log) Consumption. Evaluated at the respective means of exogenous demand Y for the pre- and post-stabilisation phases

Specification tests I test for the presence of heteroskedasticity and serial correlation using diagnostic tests such as Pagan and Hall (1983). While under OLS I can clearly reject homoskedasticity, I can no longer reject homoskedasticity under 2SLS. In any case, I choose to allow for heteroskedasticity and serial correlation by calculating heteroskedasticity and autocorrelation-robust standard errors (1-lag Newey-West errors). As for the choice of instruments, I verify the overidentifying restrictions in specifications (II) and (III) using different tests such as those based on Hansen's J statistic or variations of the Sargan statistic (see Wooldridge 2002, or Baum, Schaffer and Stillman 2003). In both specifications (II) and (III), I can reject the null that the set of instruments is orthogonal to the error term, casting doubt on the validity of the set of instruments, despite the finite sample properties of such statistics suggesting that the test results should be interpreted with caution. (Further, from the structural model one would not expect that market-specific demand shocks be correlated with the instruments, such as the exchange rate and the price of diesel oil.) To check the extent to which overidentification may be driving efficiency in the estimation at the expense of consistency, I reestimate specifications (II) and (III) in each case using only a subset of the initial set of instruments such that the validity of instruments can no longer be rejected. This is shown in Figure 12 as regressions (II B) and (III B) respectively. Comparing estimates for (II B) against those for (II), for example, the estimated elasticities are similar. I also test for the endogeneity of prices (and the interaction term) using endogeneity tests à la Durbin-Wu-Hausman (Wooldridge 2002). Under specifications (II) and (III), using the initial set of instruments for each specification, I cannot reject the null hypothesis that prices are orthogonal to the error, lending some credibility to the OLS estimates, as explained earlier. However, repeating these tests under specifications (II B) and (III B), using only a subset of the instruments, I can reject the null of orthogonality in some instances, but not all. Finally, given the efficiency of GMM under heteroskedasticity, I reestimate specifications (II) and (III) (and their counterparts which use a subset of the initial number of moment conditions) using GMM. Results – not shown – are similar.

Results by state Figure 14 summarises results across states, from regression (II) using the full sample (pre- and post-stabilisation phases). At first glance, the picture is mixed when compared to the results just described for the state of *SP*. The estimated price elasticity for 3 out of the 27 states is positive (evaluating at the mean for exogenous demand during the post-stabilisation phase), 2 of which significantly so, suggesting that for these states the demand curve slopes upward! The estimated coefficient for the interaction term is positive for 9 out of the 27 states (4 of which significantly so), suggesting that as exogenous demand expands in the post-stabilisation phase – and indeed it does expand in every one of the 27 states – the demand curve for these states rotates *clockwise*. The estimates for these states stand in contrast to the results obtained for the state of *SP*, which I claimed represented a typical pattern across states. Upon closer inspection, however, one notices that these "outlier" states are mostly located to the northwest of the centre of the country, an area which is sparsely populated and largely covered in jungle. Together they account for 60% of Brazil's land area but only 13% of its population and only 11% of its cement consumption in 1999 (see Figure 6). It is thus reasonable to believe that the measurement error associated with data collected for these states is large[47]. I thus choose to drop these 10 states from the analysis, segregating their estimates at the bottom of Figure 14.

For the remaining 17 states, the pattern is similar and consistent with the results reported for the state of *SP*. Evaluating exogenous demand at its mean annual value in the post-stabilisation phase, the price elasticity of demand is negative for all 17 states, and significant at the 1% level in 15 states. Price elasticities in the post-stabilisation phase 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[48]. It is worth pointing out that elasticities

[47] Indeed the leading global market research and data collection firm, ACNielsen, well-known to marketing professionals in consumer goods industries, and with over 30 years of experience in Brazil, does not audit any of these "outlier" states, to the northwest of the centre, except for the Federal District (*DF*) and the state of Goiás (*GO*). I also choose to drop *DF* because it consists essentially of a city, the federal capital Brasília, with a large population of 2m and two cement plants, embedded at the corner of the state of *GO*, near to the borders of the states of *MG* and *BA*, over which product must flow which I do not observe. For this reason the measurement error associated with consumption figures for *DF* may be large. I also drop *GO* on the basis of probable measurement error: in addition to its low population density, until 1988 the states of *GO* and *TO* comprised one single state, previously known as Goiás, when in 1988 the northern half of the state broke away to form the state of Tocantins (*TO*).

[48] Other studies of cement have found low market price elasticities in equilibrium. For example, Röller and Steen (2002) find an average -0.46 for Norway (treating it as a single market) using yearly observations between 1955 and 1968. Also using yearly observations, over 25 years up to 1989, Jans and Rosenbaum (1996) report an average fitted elasticity of -0.81 across 25 regional US markets. It is conceivable that in these markets imports have also been restraining 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 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*. To rationalise why an industry facing such inelastic

		(II) IV-imports bite					
	Cement			Log Price: Y evaluated at			
	consumption	Interaction		mean pre-stabilisation		mean post-stabilisation	
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)
Memo: States to the northwest of the centre of the country, mostly sparsely populated							
26 *GO*	1,152	0.002590	(0.002127)	-0.163	(0.053) ***	-0.040	(0.079)
5 *PA*	802	0.000622	(0.004211)	-0.369	(0.144) **	-0.318	(0.246)
27 *DF*	694	-0.038925	(0.015687) **	0.014	(0.074)	-0.153	(0.078) *
24 *MT*	540	0.012129	(0.004524) ***	-0.300	(0.100) ***	0.210	(0.121) *
3 *AM*	327	-0.023351	(0.007191) ***	0.107	(0.101)	-0.611	(0.166) ***
7 *TO*	282	0.000000	(0.000000)	-1.052	(0.218) ***	-1.052	(0.218) ***
1 *RO*	217	-0.028803	(0.020138)	-0.152	(0.440)	-1.194	(0.344) ***
6 *AP*	78	0.357032	(0.192129) *	0.126	(0.315)	0.744	(0.215) ***
4 *RR*	66	1.217022	(0.340927) ***	-1.366	(0.307) ***	0.190	(0.305)
2 *AC*	55	-0.222964	(0.109062) **	-1.406	(0.437) ***	-2.673	(0.352) ***

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 14: Demand estimates by state, Summary

are low even in states where the supply of cement is highly concentrated, such as the state of Santa Catarina (SC), where the one-firm concentration ratio is 78% (in 1999). Evaluating exogenous demand at its mean value in the pre-stabilisation phase, price elasticities are negative in 16 out of 17 states, 9 of which are significant at the 10% level or higher. In the pre-stabilisation phase the mean price elasticity is lower: -0.22.[49]

demand does not cut output further to raise prices to a point where demand is less inelastic, one would expect either weak pricing power (e.g. competition or low concentration) or some dynamic story, such as the threat of entry restraining prices.

[49] Given that exogenous demand – activity in the construction and building sector – rises on average in *every* state concurrent with stabilisation, this finding that the price elasticity of demand also increases is equivalent to estimating a negative coefficient for the interaction term. Indeed the fitted interaction coefficient is negative in 13 out of the 17 states, in 8 of which at the 5% level of significance. See footnote 85 for one possible explanation behind the increase in elasticity upon stabilisation.

Summary of demand and robustness checks (see Appendix B) Regardless of the type of price instruments employed (or using prices themselves, under OLS), which depends on whether one accepts that imports restrain domestic prices at the industry equilibrium, I estimate very low market price elasticities of demand, of the order of -0.5. In Appendix B I consider further robustness checks: (i) estimating the state-level demand equations simultaneously, allowing the unobserved demand shocks across states to be correlated; (ii) using fixed effects instrumental-variables panel data estimation, specifying each state as a unit and calculating clustered standard errors (i.e. clustering the observations pertaining to a given state). Notice that, given the vastly larger number of observations (156 months $\times$ 17 states as opposed to 156 months in each state-level estimation above), this specification increases efficiency at the expense of cross-unit restrictions; (iii) fitting alternative functional forms, such as semi-log-linear and linear, as opposed to the log-linear specification (12); (iv) reversing the dependent variable; (v) considering the possibility that instruments are weak; and (vi) considering a dynamic demand function. The overall conclusion arising from these checks is that this section's finding – that demand is inelastic (of the order of -0.5) at the equilibrium in each local market – is robust.

4.3 Estimation of a static pricing equation: inconsistent cost and conduct estimates

I now *ignore the constraint posed by imports* on the prices set by the domestic oligopoly. Based on the estimates of demand of Section 4.2, and *assuming costs are not known*, I proceed to estimating a pricing equation such as (3), as is standard in the empirical literature on market power[50]. I then compare the estimates for cost and conduct, summarised in the estimated elasticity-adjusted price-cost mark-ups (2), to the observed (constructed) values. I show that the estimation exercise considerably overestimates the degree of competition and the marginal cost, incorrectly suggesting that price-cost margins in the Brazilian cement industry are centred around zero.

I begin by specifying the (standard) structural econometric model. Recall the market-level demand function (11) defined at the beginning of Section 4.2 and write its inverse ($D^{-1}(.) = p(.)$) as

$$p_{lt} = p(q_{lt}, Y_{lt}, \alpha_l, \epsilon^d_{lt})$$

Define plant i's costs as

$$C_{it} = C(q_{it}, \mathbf{q}_{it}, W_{it}, Z_{it}, \beta, \varepsilon^s_{it})$$

where $q_{it} := \sum_{l=1}^{L} q_{ilt}$ denotes plant i's shipments aggregated across markets l (equal to production), W_{it} are the prices it pays for its factors, and Z_{it} are other exogenous variables that shift supply. Note that costs by plant will not only depend on the plant's total shipments q_{it} but also on the destination of these shipments $\mathbf{q}_{it} := (q_{i1t}, q_{i2t}, ..., q_{iLt})$, owing to market-specific factors such as freight. β is a vector of common parameters to be estimated and ε^s_{it} is a plant-specific error. The I plants are owned by F firms, indexed by $f = 1, ..., F$. Define $\mathcal{O}_{ft}$ as the set of plants owned by firm f in month t. In

[50] Since I ignore that the true model is (4) and that the estimated model is thus (5) with $E(Y'\xi^s) < 0$, here I refer to the pricing equation error as ε^s and not ξ^s, as a researcher overlooking the price-constraining effect of imports would do, thinking that he is specifying (3) with $E(Y'\varepsilon^s) = 0$.

period t firm f solves

$$\max_{q_{ilt}|i\in\mathcal{O}_{ft},\forall l}\sum_{l=1}^{L}\left[p(q_{lt},.)\left(\sum_{i\in\mathcal{O}_{ft}}q_{ilt}\right)\right]-\sum_{i\in\mathcal{O}_{ft}}C(q_{it},\mathbf{q}_{it},.)$$

In words, firm f sets shipments from each plant it owns to each market to maximise its profits, which correspond to the difference between the sum of revenues across markets and the sum of costs across plants. Denote the derivatives of the (inverse) demand and cost functions with respect to q_{lt} and q_{ilt} respectively as $p_1(.)$ and $c(.)$. Following Bresnahan (1989), the first-order condition for multi-plant firm f with regard to shipments from its plant $i\in\mathcal{O}_{ft}$ to market l, i.e. q_{ilt}, yields a pricing equation for each plant i - market l pair:

$$p_{lt}+p_1(q_{lt},Y_{lt},\alpha_l,\epsilon^d_{lt})q_{lt}\theta_{flt}\leq c(q_{it},\mathbf{q}_{it},W_{it},Z_{it},\beta,\varepsilon^s_{it})$$

The pricing equation can be written as an equality when $q_{ilt}>0$ (i.e. an interior solution). Recall from the earlier discussion of Section 2.2 that this specification encompasses alternative models of conduct. At the two extremes, $\theta_{flt}=1$ captures full collusion while $\theta_{flt}=0$ reflects price-taking behaviour (competition); a θ_{flt} equal to firm f's market share, i.e. $\theta_{flt}=s_{flt}:=\frac{\sum_{i\in\mathcal{O}_{ft}}q_{ilt}}{q_{lt}}$ corresponds to firm f behaving as a Cournot player. For $q_{ilt}>0$ and specifying an additive econometric pricing error, one may implement this pricing equation as

$$p_{lt}=-\theta_{flt}\frac{p_{lt}}{\eta_{lt}}+c(q_{it},\mathbf{q}_{it},W_{it},Z_{it},\beta)+\varepsilon^s_{ilt} \tag{13}$$

(recall η is the market price elasticity of demand).

In what follows, I present estimation results corresponding to a market-level counterpart to the plant-level pricing equation (13). As mentioned in footnote 12, the market-level equation should be viewed as an average across plants' pricing equations[51]. In view of the fixed-coefficient technology of production, I specify average market marginal cost c as being linear in average market factor prices W_{lt} (namely fuel oil, coal, electricity, labour and freight[52]) and flat in quantity (though in other specifications I have also allowed average market marginal cost to vary in quantity). I allow cost to shift according to the average size and age of the plants shipping into the market (weighted by shipments), Z_{lt} (e.g. marginal cost in a market served by high-capacity plants should be lower). The average factor price for a market, say electricity, is calculated as the average prices of that factor paid by the plants sourcing the market (weighted by shipments). (Finally,

[51] Owing to the lack of firm-level data, most empirical IO studies have no choice but to estimate a market-level equation. Though I have the luxury of observing plant-level data, I here choose to follow suit to simplify the exposition. Importantly, I have estimated a plant-level pricing equation and have ensured robustness of the conclusions I derive from what follows.

[52] The average factor price for a given market is calculated as the average prices of that factor paid by the plants sourcing that market (weighted by the sourcing plants' shipments to that market). The price effect of substitute kiln fuels (fuel oil and coal) are interactions of the average price of the fuel and the average use of that fuel in the production of cement shipped to the market (i.e. given the location of coal mines in the South of the country, coal prices have a larger effect on the cost of cement plants located in the South). A market's average plant-to-market freight price is modelled as the interaction of the average distance to market across the plants sourcing that market (again weighted by shipments) and a transport price index (based heavily on the price of diesel oil).

a dummy is included to account for price controls in the first ten months of 1991: this supply-shifter may be viewed as an additional element of Z_{lt}.) The market-level pricing equation is thus

$$p_{lt} = -\theta_l \frac{p_{lt}}{\hat{\eta}_{lt}} + W_{lt}\beta^1 + Z_{lt}\beta^2 + \nu_l + \varepsilon^s_{lt} \quad (14)$$

where ν_l is a market-specific fixed effect and the market-specific conduct parameter θ_l is time-invariant (other specifications I have fitted allow θ_l to vary over time, such as upon stabilisation). Equation (14) is fitted using fixed-effects instrumental variables panel data estimation, where the endogenous regressor $\frac{p_{lt}}{\hat{\eta}_{lt}}$ is instrumented using excluded exogenous demand variables Y_{lt}, and thus the orthogonality condition $E(Y'\varepsilon^s) = 0$ *is imposed*. Since the elasticity $\hat{\eta}_{lt}$ is an estimate based on the demand estimates from Section 4.2, I compute bootstrapped (heteroskedasticity-robust) standard errors (with 1000 repetitions, reestimating demand in the first stage for each bootstrap sample) for the fitted coefficients $\hat{\theta}_l$ and $\hat{\beta}$ (and $\hat{\nu}_l$). Notice that though knowledge of the nature of technology is used when specifying marginal cost to be linear in factor prices, *marginal cost is assumed to be unknown*: this is estimated from the observed supply-shifters (W_{lt}, Z_{lt}) and the estimates of the fixed coefficients (β, ν) as $W_{lt}\hat{\beta}^1 + Z_{lt}\hat{\beta}^2 + \hat{\nu}_l$.

Figure 15 reports estimation results. The comments that follow refer to estimation (I), based on the entire period, though estimates based only on observations from the post-stabilisation period (i.e. from July 1994) are provided to demonstrate robustness of the conclusion that follows. The coefficients on the prices of fuel oil, coal, electricity and freight are all positive and significant. The coefficient on the average size (age) of plants is negative (positive), as expected, though not significant. On the other hand, contrary to intuition, the price of labour is significantly negative[53]. The price-cost margins are estimated to be very low; these are pictured in Figure 16, along with 95% confidence intervals, for the state of Rio de Janeiro (*RJ*), for example. The dual to these cost estimates are the low estimated conduct parameters $\hat{\theta}_l$, not significantly different from 0, suggesting competition[54]. For the state of *RJ*, a $\hat{\theta}$ of 0.0079 would correspond to the equilibrium price-cost margins of a static symmetric 130-firm Cournot industry (1/0.0079). Dividing $\hat{\theta}_{RJ}$ by the (negative of the) estimated elasticity $\hat{\eta}_{RJ}$ of -0.48 from Figure 14, the estimated (average) price-cost margin as a proportion of price is only $0.0079/0.48 \approx 1.6\%$ (recall expression (2)).

It is clear from our knowledge of marginal cost and price-cost margins in the industry that these estimates are inconsistent. Figure 16 also depicts the (much higher) direct measures of (average) price-cost margins on sales to the state of *RJ*. What lies behind the market price elasticities of demand of the order of only -0.5 in equilibrium, *is not the prevalence of competition, as suggested by* $\hat{\theta}$, *but the constraining effect of imports on prices at the industry equilibrium.* Econometrically, as argued in Section 2.2, this constrained equilibrium translates into the correlation between the exogenous demand

[53]Interestingly, this counter-intuitive estimate is also obtained by Jans and Rosenbaum (1996), who estimate a market-level structural model of the US cement industry (it must be pointed out that, despite their penetration into US markets, a price-constraining role for imports is not considered in Jans and Rosenbaum's model). In attempting to explain the negative coefficient on wages, the authors cite Clark (1980), who suggests that plants that pay higher wages may do so because their labour force is more productive (and possibly more unionised, as Clark finds the more productive US cement plants to be).

[54]It is worth mentioning that the estimated confidence intervals for $\hat{\theta}_l$ vary considerably according to the specification (such as the functional form for demand), though low (absolute) values do seem to be a robust result.

	(I) IV Full sample		(II) IV Post-stabilisation subsample	
	coef	bootstrap s.e.	coef	bootstrap s.e.
No. obs.	2652		1938	
Market-specific conduct parameters				
20 *SP*	0.0167	(0.0194)	0.0021	(0.0152)
17 *MG*	0.0194	(0.0127)	-0.0049	(0.0163)
19 *RJ*	0.0079	(0.0206)	-0.0112	(0.0120)
16 *BA*	0.0004	(0.0100)	-0.0268 *	(0.0142)
(Parameters for 13 other markets not shown)				
Factor prices				
Fuel oil (interacted with fuel use)	18.1368 ***	(2.7773)	20.1344 ***	(2.7119)
Coal (interacted with fuel use)	0.0906 ***	(0.0343)	0.0447	(0.0430)
Electricity	0.0343 ***	(0.0125)	0.0494 ***	(0.0169)
Labour	-7.7850 ***	(1.2287)	-3.9898 ***	(1.1363)
Freight (distance interacted with price of diesel oil)	0.0065 **	(0.0028)	0.0066 **	(0.0026)
Other supply-shifters				
Size of sourcing plants	-9.38E-08	(5.84E-07)	4.56E-08	(6.64E-07)
Age of sourcing plants	0.0191	(0.0316)	0.0188	(0.0321)
Price controls (Jan 91 to Oct 91)	-4.4828 ***	(0.8479)		
Intercept (*SP*)	12.1986 ***	(2.6814)	6.9360 **	(2.8436)
(Other market-specific fixed effects included but not shown)				

Note: Heteroskedasticity-robust standard errors with bootstrapping to account for demand estimation in the first stage. 1000 repetitions, clustered by month (e.g. in (I) a bootstrap sample consists of 156 month draws, and for every month in the bootstrap sample there are 17 markets).
Demand estimates from the first stage of (II) also based on post-stabilisation subsample.
*** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level
Dependent variable is the price of cement in units of local currency per bag (at Dec 1999 prices)

Figure 15: Estimation of a static pricing equation, assuming cost is not known. Instrumented with exogenous demand variables.

variables being used to instrument pricing equation (14) and its residual. The identifying assumption's failure to hold results in the overestimation of the degree of competition. (Indeed, the p-values of overidentification tests à la Sargan and Hansen – where the null is that the set of instruments is valid – is 0.0000 for any overidentifying set.) The finding that the coefficients on factor prices and other supply-shifters are of the expected sign (bar wages) and mostly significant may lead one to misjudge that the econometric model is appropriately specified. But the estimated coefficients are only picking up the expected correlation between cement prices and factor prices. They are not consistent estimates of the structural cost parameters β. The general point is that because the *threat* of entry is not observed, it is only natural that a researcher overlook its role in restraining prices, inadvertently taking the lack of price variation to exogenous movements in demand as evidence in the direction of price-taking behaviour and zero price-cost margins[55].

[55] A comment on this particular industry where conditions (i.e. the steepness of the market demand curve and the marginal cost of imports) are such that demand is so inelastic at the equilibrium. Assume

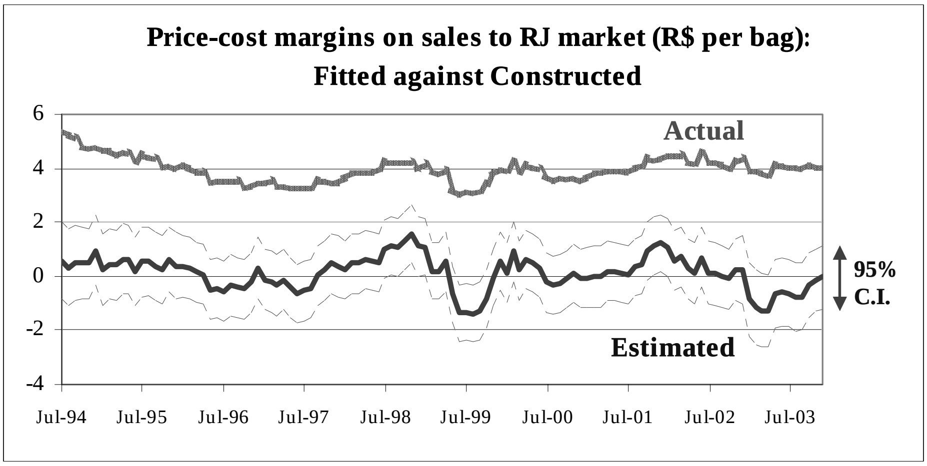


Figure 16: Estimated (average) price-cost margin on sales to RJ market, as estimated by the static pricing equation, against Actual (constructed) price-cost margin. In constant R$ per bag (December 1999 terms).

4.4 Inferring conduct in a constrained equilibrium

So far I have argued that what lies behind the very low market price elasticities of demand in equilibrium is the threat of imports restraining prices. As laid out in the theoretical framework of Section 2, the competitive supply of high-cost imports sets an upper limit to prices. 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. The evidence in support of this claim can be summarised as follows:

1. Demand is estimated to be inelastic in all 17 local markets. This is so irrespective of the number and concentration of sellers, ranging from states where the one-firm concentration (C_1) is around 25% to states where C_1 is as high as 80%.

2. In attempting to unravel the low equilibrium elasticities, one must consider price-taking behaviour on the part of cement producers as an alternative explanation to the binding presence of imports. By this alternative explanation – plausible *a*

one does not realise that the imports constraint binds at the equilibrium and thus considers the class of behavioural models nested in the static pricing equation $p + \theta_f \frac{p}{\eta} = c_f$ (i.e. the theoretical counterpart to the firm-level pricing equation (13), suppressing the error and writing it in the form marginal revenue = marginal cost). It is clear that a η of -0.5 is not consistent with cartel behaviour ($\theta = 1$). Profit maximisation would lead the cartel to cut output until the cartel's marginal revenue were equal (and thus positive) to marginal cost. Nor will such a low value of η be consistent with a Cournot industry, unless all firms have small market shares. To see this, notice that if the largest firm has a market share of 50%, then $\max_f\{\theta_f\} = 0.5$ and thus this firm's marginal revenue, to be equated to its marginal cost, is zero. Small market shares across local markets are clearly not the case in the Brazilian cement industry. Any statistical model selection exercise à la Gasmi, Laffont and Vuong (1990, 1992) will thus result in, say, both the cartel model and the Cournot model being rejected in favour of price-taking behaviour by firms ($\theta = 0$). Though misguided in the present case, the high correlation between factor prices and cement prices ensure that the OLS regression of cement prices on factor prices (and other supply-shifters, along with a set of market dummies) – i.e. under the hypothesis of price-taking behaviour – displays good fit: $R^2 = 54\%$. Again, by misspecifying the set of alternative models generating outcomes in the industry, a researcher would mistakenly conclude in favour of price-taking behaviour, not realising that his estimates are simply picking up correlation between cement prices and factor prices.

priori – an industry facing such inelastic demand would not be able to cut output to raise prices because competition among producers drives prices down toward marginal cost. However, I reject competition on the basis of the large observed price-cost margins. Producers enjoy considerable market power.

This dynamic story where the threat of entry restrains prices is further supported by a wealth of anecdotal and interview-based evidence. It is also consistent, as argued in Section 3.2, with the high correlation observed between cement prices and the exchange rate, the latter having varied considerably over the time period.

I have also shown – and illustrated empirically – that in such a setting the identification of a standard pricing equation from the comparative statics of demand fails. I now turn to the test of conduct spelled out in Proposition 3 to cast light on the pattern of behaviour in the Brazilian cement industry. Admittedly, this test provides only a *sufficient* statistic to reject Cournot conduct in favour of more collusive behaviour and the data requirements are large: one must observe both marginal cost and firm-level quantity data. But the value of the test resides in uncovering firm-level behaviour when market outcomes are constrained by the threat of entry. I show that the data rejects Cournot as a benchmark for conduct in the cement industry, in favour of market division. I finalise in Section 4.4.2 by illustrating the rationality of such a strategy in an industry where firms meet in different markets.

4.4.1 Rejecting Cournot behaviour in favour of collusion

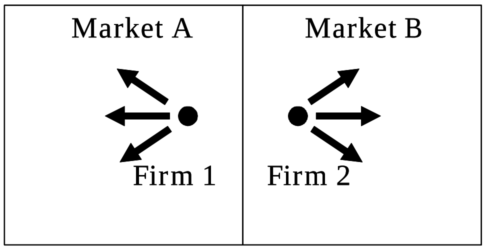
Prior to stating the results of the test of Proposition 3 as it applies to the Brazilian cement industry, I provide a flavour of why the data leads to the rejection of Cournot behaviour by considering a specific example extracted from the data. This serves only as an example of a broader trend in the data. As shown subsequently, there are many instances in the data where firms undersupply local markets as compared to the supply decisions of a Cournot firm[56]. In other words, there are many instances where the marginal revenue of a firm in a given market were it adopting the Cournot conjecture – taking its rivals' output as given – significantly exceeds the marginal cost in supplying that market.

A case in point Consider the two adjacent states of Alagoas (AL) and Sergipe (SE), located in the northeast of Brazil (see Figure 6). These states are equally small both in terms of market size and geography. Up until 1996 each also had only one plant located within its borders: 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)[57]. Consider the year 1996. While firm 1 commands an 83% share in market A, it does not supply to neighbouring market B, right next door to its plant located in market A. Equally striking, firm 2 commands an 89% share in market B, while attaining only a 7% share in the neighbouring market A, next door to its plant in market B. Thus while in market A firm 2's share pales in comparison to firm 1's share, in the

[56] As in the empirical literature on conduct, the Cournot assumption serves as a benchmark (e.g. Parker and Röller 1997).

[57] 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.

neighbouring market B the former firm dwarfs the latter rival (the latter rival in actual fact does not supply to market B!) Average consumer prices in markets A and B are almost identical, respectively R$ 9.47 (per bag) and R$ 9.46. As explained previously, 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$ 5.17.[58] This is illustrated in the following picture and table, where I take the price elasticity of demand in equilibrium for both markets to be -0.5:[59]



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

(Year 1996)	Price, p	Share, $\frac{q_f}{q}$	MR Cournot, $p+\frac{p}{\eta}\frac{q_f}{q}$	MC, c	Can reject Cournot?
Local market $l = A$ (AL)					
Firm $f = 1$ (Bren)	9.47	0.83	$9.47-\frac{9.47}{0.5}0.83 = -6.25$	5.20	$\varphi_{1A} < 0$: No
Firm $f = 2$ (Voto)	9.47	0.07	$9.47-\frac{9.47}{0.5}0.07 = 8.14$	5.30	$\varphi_{2A} > 0$: **Yes**
Local market $l = B$ (SE)					
Firm $f = 1$ (Bren)	9.46	0	$9.46-\frac{9.46}{0.5}0 = 9.46$	5.47	$\varphi_{1B} > 0$: **Yes**
Firm $f = 2$ (Voto)	9.46	0.89	$9.46-\frac{9.46}{0.5}0.89 = -7.38$	5.17	$\varphi_{2B} < 0$: No

One is thus able to reject the hypothesis of firm 1 behaving in Cournot fashion towards market B in 1996, since (perceived) marginal revenue $p+\frac{p}{\eta}.\frac{q_f}{q} = 9.46$ considerably exceeds marginal cost 5.47, i.e. $\varphi_{1B} = 9.46 - 5.47 = 3.99$, amounting to 42% of consumer price. Likewise, I reject Cournot behaviour for firm 2 towards market B in 1996: marginal revenue 8.14 considerably exceeds marginal cost 5.30, i.e. $\varphi_{2A} = 2.84$, or 30% of consumer price. Recalling the right panel of Figure 5 in the theoretical framework of Section 2, firm 1's (firm 2's) supply decision toward market B (market A) can be illustrated as firm f.

Thus Cournot behaviour can in these instances be rejected in favour of more collusive conduct. A story where Votorantim tacitly agrees to give Brennand the upper hand in AL in exchange for the latter staying away from SE would help explain the observed shipments. As noted previously, with a view to testing conduct, the marginal costs I construct in this study are conservative, i.e. they err on the high side. (This understates φ, working against the rejection of Cournot conduct.) In spite of this, the φ are not only positive but sizeable: of the order of 30 - 40% of consumer price! Interestingly, note

[58]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$ 0.13. 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 penalised 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.

[59]The subsequent test takes the estimation of η in Section 4.2 into account. Also for simplicity, in this illustration I compute an average φ for the year (for each firm-market combination).

that Brennand (firm 1) ships from its plant in *AL* (market A) to the states of *PB*, *PE* and *BA*, located at further distances than *SE* (market B) and where prices are similar to those in *SE*.

I now compute the test statistic of Proposition 3 for each active firm-market-month combination, indexed as before by f, l and t respectively. A firm is active in a given month if it owns a plant which is active in that month; that is, firm f is active iff $\sum_l \sum_{i \in \mathcal{O}_{ft}} q_{ilt} > 0$ (recall that i indexes plant and $\mathcal{O}_{ft}$ is the set of plants owned by firm f in month t). For every month t in which a firm f is active, there are 17 (f, l, t) combinations, one for each of the 17 markets, irrespective of the markets to which firm f *actually* ships in month t. Now at each month t 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. $c_{flt} := \min_{i \in \mathcal{O}_{ft}} c_{ilt}$. From the Cournot pricing condition (10), compute the test statistic

$$\hat{\varphi}_{flt} = p_{lt} + \frac{p_{lt}}{\hat{\eta}_{lt}} \frac{q_{flt}}{q_{lt}} - c_{flt} \tag{15}$$

where $\hat{\eta}_{lt}$ is based on the demand estimates of Section 4.2. 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 month t, in favour of more collusive behaviour; a Cournot firm perceiving marginal revenue to exceed marginal cost would expand output beyond the observed output (and, importantly, recall that this statistic allows for the constraining effect of imports). Notice that p, q and c are observed (or constructed: it is clear from (15) that the construction of c as an upper bound to the true marginal cost conservatively tilts the test statistic against rejection of Cournot), such that the randomness in $\hat{\varphi}$ stems from the randomness of the estimated price elasticity $\hat{\eta}_{lt}$.

Total number of active firm-market-month combinations, (f, l, t)	37536	
Number of (f, l, t) combinations for which:		
The upper limit to the 95% confidence interval for η_{lt} is negative	24696	100%
$\hat{\varphi}_{flt}$ is greater than zero	16806	
$\hat{\varphi}_{flt}$ is significantly greater than zero at the 5% level	**14849**	60%
$\hat{\varphi}_{flt}$ is positive and greater than 10% of consumer price	13197	
$\hat{\varphi}_{flt}$ is positive and greater than 20% of consumer price	**8035**	33%
$\hat{\varphi}_{flt}$ is positive and greater than 30% of consumer price	3258	
$\hat{\varphi}_{flt}$ is positive and greater than 40% of consumer price	504	

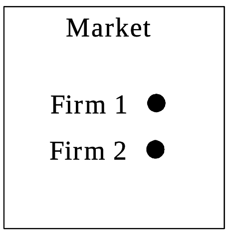
Total number of active firm-market-month combinations, (f, l, t)	37536	
Number of (f, l, t) combinations for which:		$\mid \hat{\varphi}_{flt} > 0.2 p_{lt}$
$\hat{\varphi}_{flt}$ is positive when $\hat{\eta}_{lt}$ is taken as -0.3	25335	12757
$\hat{\varphi}_{flt}$ is positive when $\hat{\eta}_{lt}$ is taken as -0.5	27270	14237
$\hat{\varphi}_{flt}$ is positive when $\hat{\eta}_{lt}$ is taken as -0.7	28665	15575

The table above summarises the results. There are 37536 active firm-market-month combinations (corresponding, therefore, to an average of $37536/17/156 \approx 14$ active firms across the country in any given month). Since I calculate the 95% confidence interval (C.I.) for φ_{flt} from the 95% C.I. for the price elasticity η_{lt}, I choose to drop 12840 observations for which the upper limit to the C.I. for η_{lt} is positive. In other words, I conservatively consider only the 24696 combinations for which the C.I. for the price elasticity lies in the interval $(-\infty, 0)$. I find that the null hypothesis of Cournot behaviour allowing for the constraining effect of imports, $\varphi_{flt} \leq 0$, can be *rejected at the 5% level of significance in 14849 of these 24696 combinations.* Put differently, under the Cournot conjecture, one would expect firms to expand their supply to local markets in $14849/24696 \simeq 60\%$ of monthly supply decisions vis-à-vis observed outputs – these firms are choosing output to the left of their Cournot reaction functions. As in the earlier illustration, 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 8035 supply decisions! To check robustness, the table also provides the number of supply decisions for which $\hat{\varphi}_{flt} > 0$ when $\hat{\varphi}$ is calculated using elasticities of -0.3, -0.5 or -0.7. The rejection of Cournot behaviour in favour of more collusive conduct is robust. It is clear from (15) and from the table that a market price elasticity of demand greater (in absolute value) than the estimated -0.5 on average reinforces this result. I further comment on the robustness of this conclusion in Appendix B.

4.4.2 Collusion and market division

The cement industry is commonly used to illustrate industry characteristics that the literature on tacit collusion has deemed to enhance the likelihood of collusion[60]: see Appendix B.3 for a summary. Unsurprisingly, the cement industry has a long history of anticompetitive behaviour and antitrust litigation across several jurisdictions[61]. Tacit collusion in the Brazilian cement industry, orchestrated for instance via market division, is a concrete possibility in that the characteristics of the industry are consistent with the characteristics which are understood to make tacit collusion more likely. For the sake of illustration, I now turn to some simple collusive arrangements – relevant to the case at hand – which may be supported in equilibrium.

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 cost c facing a competitive fringe of imports with marginal cost c_I such that $c < c_I < p^M$, where p^M is the monopoly price as in the theoretical framework of Section 2. Recall that in such a setup the most collusive price, which maximises aggregate (domestic) industry profit, is $p = c_I$, where the aggregate industry profit (per period) is $\Pi := (c_I - c)p^{-1}(c_I)$ and $p^{-1}(.)$ denotes the demand function. As is standard in the literature on supergames, the most collusive price

[60] As before, I refer to collusion in prices (or quantities), though I later comment on collusion in capacity investments.

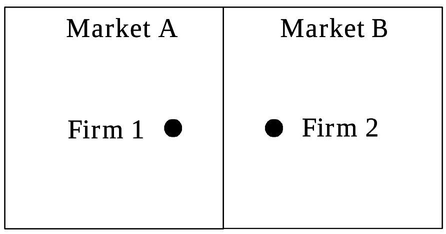
[61] See, for example, Dumez and Jeunemaître (2000). Ghemawat and Thomas (2004) cite the fines imposed by the European Court of First Instance in 1994 on 42 cement-related undertakings across Europe, in what has been one of the EU's largest competition cases to date.

may be supported in equilibrium by each firm adopting, say, the following symmetric "grim" strategy in prices: set the collusive price $p = c_I$ 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 $p = c_I$ (or any other price p such that $c < p \leq c_I$) may be supported in equilibrium.

Illustration 2: two firms and two neighbouring 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 neighbouring states of Sergipe (*SE*) and Alagoas (*AL*), equally small in terms of market size and geography. As stated previously, 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 serving the neighbouring 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 $c' = c + t$ (e.g. firm 1 in market B), where $c < c' < c_I$ (c_I as before). Demand is identical in each market, given as before by $p^{-1}(.)$. Denoting $\Pi := (c_I - c)p^{-1}(c_I)$ as before, let $\Pi' := (c_I - c')p^{-1}(c_I)$. (This corresponds to firm 1's maximal profit in neighbouring market B were it to act as a monopolist in the supply of that market[62]. Clearly $\Pi > \Pi'$.) It is easy to see that the collusive arrangement that maximises 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 $p = c_I$: firm 1 supplies quantity $p^{-1}(c_I)$ to market A (i.e. shares $s_{1A} = 1$, $s_{2A} = 1 - s_{1A} = 0$) and firm 2 supplies quantity $p^{-1}(c_I)$ to market B (i.e. $s_{2B} = 1$, $s_{1B} = 1 - s_{2B} = 0$). But can this arrangement be supported in equilibrium?

[62] Realise that implicit in this statement is the regularity assumption that the monopoly price $p^M(c) := \arg\max_p (p - c)p^{-1}(p)$ is an increasing function of marginal cost c. Thus $p^M(c') > p^M(c) > c_I$, where $p^M(c) > c_I$ is as before, such that firm 1 acting as a domestic monopolist in the supply of neighbouring market B and facing the fringe of imports, would set $p = c_I$.

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 $p = c_I$ (or any collusive price p above the competitive price, equal to the high-cost firm's cost c', but lower than c_I, i.e. $c' < p \leq c_I$) 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[63]:

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

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

where $\Pi^{war} := (c' - c)p^{-1}(c')$ denotes industry profit under retaliation (price war, when $p = c'$), 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 c') in *both* markets should any firm undercut the collusive price in any market in a previous period, the collusive arrangement that maximises aggregate industry profits across markets – i.e. setting $p = c_I$ with complete 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

$$s_{1A}\Pi\frac{1}{1-\delta} + (1-s_{2B})\,\Pi'\frac{1}{1-\delta} \geq \Pi + \Pi' + \Pi^{war}\frac{\delta}{1-\delta} \qquad \text{firm 1's pooled IC} \tag{16}$$

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. $s_{1A} = s_{2B} = s$) (16) can be rearranged to yield firm f's ($f = 1, 2$) incentive constraint:

$$\delta \geq \frac{(1-s)\,\Pi + s\Pi'}{\Pi + \Pi' - \Pi^{war}} \tag{17}$$

The collusive arrangement can now involve complete market division, $s = 1$. Indeed, for $p = c_I$, setting $s = 1$ in (17) minimises the discount factor threshold above which collusion is sustainable[64]:

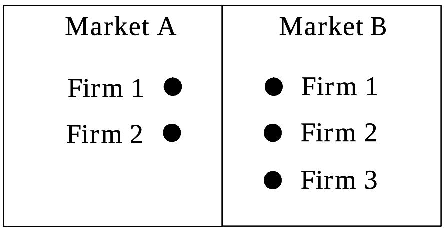
$$\delta \geq \frac{\Pi'}{\Pi + \Pi' - \Pi^{war}} \tag{18}$$

[63] Note that firm 1 and firm 2's shipments are then respectively $q_{1A} = s_{1A}p^{-1}(c_I)$ and $q_{2A} = (1-s_{1A})\,p^{-1}(c_I)$.

[64] Recall that $\Pi > \Pi'$. Intuitively, when $s = 1$ the short-term gain from cheating (equal to $(1-s)\Pi$ in the own market plus $s\Pi'$ in the neighbouring market) is lowest (and equal to Π'). 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' 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-

Thus for a high enough discount factor, the collusive scheme that maximises aggregate industry profit in each market, setting $p = c_I$ 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 neighbouring market where that firm has high cost, low share and low profit[65].

Illustration 3: three firms and two neighbouring 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 neighbouring 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 neighbouring* RJ*, while Soeicom had a 9% share in its home market* MG *and a (somewhat) lower 6% share in neighbouring* RJ.)



As before, assume that the cost of supplying a market from a plant located in that market is c but rises to $c' = c+t$ when supplying from a plant located in the neighbouring market. Demand $p^{-1}(.)$ is again identical in each market, recall $p^M(c') > p^M(c) > c_I$ and denote Π' 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 $p = c_I$; 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 $p = c_I$.[66] The (pooled) incentive constraint for

constraint more stringent (for $s = 1$). However, as mentioned in the footnotes to the table on industry characteristics in Appendix B.3, the *profitability* of collusion may be increasing in t, since the effect of eliminating wasteful cross-hauling, through market division, on profits may now be larger. 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). Second, when $t = 0$, then $c' = c$, $\Pi' = \Pi$ and $\Pi^{war} = 0$, implying that incentive constraints (17) and thus (18) collapse to the familiar $\delta \geq \frac{1}{2}$ of Illustration 1.

[65] Notice that I have assumed Bertrand behaviour should collusion break down, but could just as well have assumed Cournot competition. In this case, the right-hand side of incentive constraint (16) would have to be modified as follows: (i) a deviant firm would now earn less than $\Pi + \Pi'$ 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 5, thus expanding output in the neighbouring market where it has a low share), and (ii) upon retaliation either firm would also earn positive payoffs in its neighbouring market, where it incurs a higher cost (and, as Figure 5 makes clear, the Cournot equilibrium outcome would not necessarily be unique).

[66] In market A, firms 1 and 2 will then supply $q_{1A} = q_{2A} = s_A p^{-1}(c_I)$ and firm 3 will supply $q_{3A} = (1 - 2s_A)\, p^{-1}(c_I)$. In market B, firm 3 will supply $q_{3B} = s_B p^{-1}(c_I)$ and firms 1 and 2 will each supply $q_{1B} = q_{2B} = \frac{1}{2}(1 - s_B)\, p^{-1}(c_I)$.

each of firms 1 and 2, that operate plants in both markets, becomes:

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

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

$$\delta \geq \frac{3 - 2s_A + s_B}{4} \tag{19}$$

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

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

which is equivalent to

$$\delta \geq \frac{(1-s_B)\Pi + 2s_A\Pi'}{\Pi + \Pi'} \tag{20}$$

As in illustration 2, the collusive arrangement that maximises 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 $p = c_I$. Plugging $s_A = 1/2$ and, say, $s_B = 2/3$ such that all three firms produce the same quantity, sustainability constraints (19) and (20) become $\delta \geq \frac{2}{3}$ and $\delta \geq \frac{\Pi/3+\Pi'}{\Pi+\Pi'}$ respectively.

Capacity and collusion Some remarks about the role of capacity in the Brazilian cement industry. As noted in Section 3.3, capacity significantly exceeds production, and this (low) *capacity utilisation* appears to be fairly symmetric across plants and firms, despite the asymmetric capacities across these plants and firms. Thus, for instance, plant 1 with a capacity of 2 mtpa may be running at a 65% capacity utilisation while plant 2, owned by a rival firm, with a capacity of 1 mtpa may be operating at the same 65% capacity utilisation. This observation is consistent with a situation where *all* domestic producers adhere to the collusive arrangement, with no producer "free riding". (This is reinforced by the fact that all producers are long-time members of the cement producers' trade association (SNIC), an active lobbying outfit for the industry.) The corollary to this observation is that there appears to be no relevant fringe to the (tacit) cartel[67]. Further, evenly-distributed idle capacity across firms would serve the important purpose

[67] More recently, an entrant, Mizú, has successfully managed to establish a foothold in local markets in and around the state of Espírito Santo (*ES*), where it is based. Set up in 1998 by a large independent ready-mixed concrete firm, Mizú signed a long-term contract with a steel producer (Companhia Siderúrgica de Tubarão) to supply it with steel slag, which it grinds and mixes with ground clinker, imported from as far as Japan, producing slag cement. Mizú's (grinding-only) plant is located conveniently next door to the steelworks and to the port of Vitória. In contrast to established cement producers, by 2003 Mizú was selling up to capacity (0.7 mtpa). It would appear that the established producers have accommodated Mizú's entry, given its limited capacity and the irreversibility of its investment. (As noted in Appendix A, consumption and shipment figures compiled by the cement producers' trade association, and used in this paper, do not consider Mizú. The distortion nevertheless is small in view of Mizú's (to date) limited capacity, limited geographic scope and recent entry.)

of disciplining the cartel: the threat of punishment would not be credible were capacity to be tight[68] [69].

5 Concluding remarks

In this paper, I show that when an industry faces potential entry and this threat of entry constrains pre-entry prices, cost and conduct will not be identified from the comparative statics of equilibrium. The well-established technique of relying on the jumping around (i.e. shifting *and* rotating) of the demand curve to empirically distinguish between the hypothesis of a high-cost competitive industry and the alternative of a low-cost oligopoly with market power fails in the event that the low-cost oligopoly is constrained by potential entry. Because the extent to which the no-entry constraint binds may be unobserved to the researcher, since in equilibrium entry is *not* observed, some studies of market power claiming to consistently estimate structural parameters of the data generating process may actually be underestimating the degree of market power. A typical situation of such limit pricing is that where a domestic oligopoly faces a competitive fringe of foreign suppliers.

This is negative news to enthusiasts of the estimation of market power when cost data is lacking, and has important implications for antitrust practitioners, particularly in a world where trade barriers are being pulled down. My paper provides an additional theoretical setting to a criticism advanced by Corts (1999) regarding the non-robust performance of static structural estimation in the absence of cost when applied to a dynamic model. In an imports-constrained setting, I show one way in which a researcher, equipped with cost and firm-level data may delve deeper into the pattern of conduct in an industry where firms meet in different markets.

The Brazilian cement industry provides a clear-cut illustration. An elastically-supplied fringe of imports restrains domestic prices and the market price elasticities of demand are of the order of -0.5 in equilibrium. Despite this binding constraint, the behavioural model generating outcomes in the industry is identified from the observed data. While the estimation of a static pricing equation incorrectly points to competition, I show that conduct is more collusive than the Cournot benchmark, characterised by (tacit) market division. I illustrate with examples of simple dynamic multimarket games which give rise to such equilibrium behaviour. The existence of a price limit provided by the delivered cost of imports would seem to provide a natural focal price; market division would further enhance collusive pay-offs by limiting cross-hauling.

A clear policy recommendation emanating from the illustration is the finding that producers possess substantial market power and that imports (in the form of cement or the intermediate product clinker) have an important role to play in curbing the ability of domestic producers to raise prices above marginal cost. To the extent that investments

[68] A further strategic role may be that of helping deter entry, as studied in the literature (e.g. Dixit 1980).

[69] A final comment regarding the possibility that producers collude in capacity investments, in addition to colluding in product market outcomes. Rather than restricting capacity and hence output, producers overinvest in capacity, as just discussed. Other characteristics of the cement industry, such as the lumpiness, infrequency, long life and irreversibility of investment, would further suggest that the scope for collusion in capacities is limited. See Ivaldi et al (2003) for a discussion.

may be made to reduce transaction (entry) costs of imports, one should not necessarily expect to observe an increased share of imports but certainly expect higher consumer welfare in the form of lower prices. Such a recommendation stands in direct contrast to recent policy experience, whereby the cement industry successfully managed to lobby the government into enacting "antidumping" measures against foreign producers who were attempting to make inroads into Brazil's local markets.

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A Appendix: Data

This appendix comments on the sources of data and how I treat the data. I also perform robustness checks on my direct computations of marginal cost.

Anonymous acknowledgement I wish to express my gratitude to all the people related to the cement industry whom I have interviewed during the course of this project. This project would not have been possible without their help, particularly in regard to the data collection and validation effort. I do not name them in order to preserve their confidentiality but hereby acknowledge them by citing their professional relationship with the cement supply chain: representatives for various state-level construction sector trade associations (SINDUSCONs); representatives for the cement industry's trade association (SNIC); representatives for the technical arm of the cement industry's trade association (ABCP); sales representatives, engineers and executives of cement producers; representatives of cement buyers (resellers, ready-mixed concrete firms, construction firms and producers of construction aggregates); representatives for equipment suppliers to the cement industry; representatives for factor suppliers to the cement industry; Confederation of National Industry (CNI); Brazilian Institute for Geography and Statistics (IGBE); officials of regulatory agencies; officials of government ministries; investment bank analysts; international traders in cement; academics.

A.1 Sources and treatment of data

Cement consumption by state (i.e. demand by local market) Monthly series by state, in 1000 tonnes of cement, are obtained from the annual reports (and other reports) of the Brazilian cement industry's trade association, the National Syndicate of the Cement Industry (SNIC). This body has played a leading role in the history of the Brazilian cement industry and represents almost the entirety of the set of producers[70]. To compile consumption figures for a given state, SNIC aggregates reported shipments by its members to that state. Thus I observe shipments by cement producers to buyers broken out by destination state. Four possible sources of distortion, each deemed to be small, are: (i) Consumption figures do not include shipments by non-members to the association (namely Mizú and Davi: see footnote 70). The distortion is small given the limited capacity, limited geographic scope and recent entry dates attached to these non-members; (ii) Consumption figures do not include imports. Again the distortion is small in view of the limited penetration of imports (see Section 3.3); (iii) Consumption figures do not account for any cross-state shipping *at the reseller level* (i.e. shipments by resellers in state l shipping across to buyers further downstream located in state $n \neq l$). In compiling consumption by state, a shipment by a cement producer to a buyer located in a given state counts towards consumption in that state. This distortion is considered small in that the high cost of transporting cement and the fact that the industry takes into account the possibility of trade arbitrage when setting commercial

[70] Up until 2003 only two recent entrants were not members of the trade association: (i) Cimento Mizú, set up in 1998 by a large independent ready-mixed concrete firm, Polimix, and (ii) Cimento Davi, set up in 2001. Both concerns consist of relatively small-scale grinding operations (respectively 0.7 mtpa and 0.4 mtpa to date), importing clinker from as far as Asia and producing slag cement (both are located in close proximity to steel producers, from whom they purchase blast furnace slag, based respectively in the states of Espirito Santo, *ES*, and Minas Gerais, *MG*.) See footnote 67.

terms make the scope for cross-state shipping by resellers limited. Further, the bulkiness, fast turn and short shelf life of cement leads producers to reach far "down the trade", via direct-from-plant deliveries and own distribution terminals: in spatial terms, reselling is largely a local business. In any case, shipments by resellers into a state ought to approximately cancel shipments by resellers out of that state; and (iv) Variation in inventories downstream are not accounted for. Again the distortion is small given that the characteristics of cement (e.g. short shelf life) means inventory levels and their time-series variation to be limited.

Flow of cement from plants to states Annual shipments of cement from each plant to each state is obtained from SNIC, from the same database from which the monthly consumption series by state are extracted. Thus I observe, for each year T, an $I \times L$ shipment matrix with element q_{ilT} denoting the shipments from plant i to state (local market) l in year T. To obtain the flow of cement from plants to states on a monthly basis, I assume that the distribution of shipments to market l across sourcing plants is invariant over the 12 months in each year. Thus I take plant i's shipments to market l in month $t \in T$ to be $q_{ilt} = \frac{q_{ilT}}{\sum_i q_{ilT}} q_{lt}$ where q_{lt} denotes the consumption in market (state) l in month t, as detailed above.

Cement prices by state Current retail cement prices in units of local currency for the standard 50 kg bag are provided by the Brazilian office of national statistics, the Brazilian Institute for Geography and Statistics (IGBE). This office is one of Brazil's two main providers of economic statistics, charged with carrying out population censuses, compiling the national accounts and publishing price indices. In effect, the cement price series I use is collected to compute the latter. Monthly series by state are available on the median price for a sample of retail stores (commonly referred to as resellers) located in each state. (Producer prices are not observed; these are backed out from retail prices as explained below.) Owing to the high levels of inflation prevailing in the first *one-quarter* of the time period I consider[71], particular attention has been paid to the conversion of current cement prices to constant prices (in December 1999 terms). While this is done using a General Price Index (GPI), I also convert cement prices using other (economy-wide) price indices, such as a Consumer Price Index (CPI) or a Wholesale Price Index (WPI), to check the robustness of the estimation results (these are, respectively, the "IGP-DI", the "IPC-br" and the "IPA-DI", all published by the Fundação Getúlio Vargas). Further, where possible, I compare the constant price series I calculate for each state with reports on cement prices to be found in trade publications or the press. For example, the constant cement price series I calculate indicate a sharp increase in real terms in 1992; this is confirmed by aggregate real cement price indices and accounts published in trade reports at the time. One must also point out that despite the high level of inflation in the first half of the 1990s, the economic environment was far from chaotic; economic agents had learned how to cope with a chronic and fast-changing price level, and to anticipate it reasonably well in the short term. It is thus possible for the researcher to filter (upward and downward) variation in real prices from the much larger (upward) variation in nominal prices in the pre-stabilisation phase of the time period I cover.

[71] That is, the pre-stabilisation phase, or the 42 monthly observations between January 1991 and June 1994, out of a total of 156 observations (up to December 2003).

Exogenous demand variables Several alternative series of economic activity, either in the construction and building sector or aggregated across sectors of the economy, are available as proxies for the exogenous demand for cement. The favoured series, issued by the Brazilian office of statistics (IBGE), reports the real index of activity in the construction sector for each of the 27 states, on an annual basis. Importantly, this series follows from a *volume* decomposition of Value Added in the construction sector (from the National Accounts) and should thus be a good proxy for exogenous demand. I blow up the index series for each state using the relative size of the construction sector between states, also obtained from the National Accounts; these can then be compared cross-sectionally (i.e. across states). Alternative quarterly series are available, which I use in checking the robustness of my estimation results.

Taking states to represent local markets As mentioned in footnote 33, the constraints imposed by data availability require that I take each state to represent a market (i.e. I do not observe data at the "SMSA" or city level). However, I believe that this is sound, as follows. As the econometrician, I observe the flow of cement from each plant to buyers (resellers and consumers) in any given state. As explained above, the scope for cross-state shipping by resellers is limited. Thus price and consumption observations – obtained from different sources, as explained above – can reasonably be paired. A potential distortion arises from the possibility that the larger states may contain more than one local market with heterogeneous demand conditions, and that therefore identifying states with markets may hide important variation at a more local level where agents interact. To my defence, however, I discard the largest northern states, albeit for another reason as I explain in Section 4.2. Further, in the data I observe that cement *can* travel over significantly large distances from plants located in a state to buyers located in another state. Several field interviews and price data obtained directly from a sample of producers suggest that the spatial variation of prices within a state is minimal: prices are mostly uniform within a state. Of note, several studies in the literature have taken US states (of sizes similar to and as diverse as their Brazilian counterparts) to represent markets, such as Sutton (1998), FTC (1966) and Newmark (1998).

Factor prices Factor prices are either observed in the form of current prices, in which case they are converted to constant prices as explained above, or already reported in the form of constant prices. Though alternative series proxying each factor price are available – which I use as alternative instruments in the demand estimation or to check the robustness of the supply-side estimation – the main series are:

- Fuel oil: country-wide delivered prices from refineries in units of local currency per kg (excluding sales taxes) are obtained, on a monthly basis, from the oil industry regulator, the National Agency for Oil. I add sales taxes to these prices according to legislation. (Owing to policy in the oil sector, price variation across regions during the time period of the study, has been minimal.)

- Diesel oil: country-wide delivered prices from refineries in units of local currency per litre are obtained, on a monthly basis, from the oil industry regulator, the National Agency for Oil.

- Coal: FOB prices of coal in local currency units per tonne are obtained, on an annual basis, averaged across mining firms, from the Ministry for Mining and Energy. Price lists are also obtained from a sample of mining firms. Of note, coal mines are located in the South of the country; freight to cement plants employing coal as kiln fuel (largely located in the South) is added accordingly (see comments on freight cost below).
- Electricity: state-level delivered prices to (high-voltage) industrial consumers in local currency units per MWh are obtained, on a monthly basis, from the electricity industry regulator, the National Agency for Electrical Energy.
- Labour: manufacturing-industry real wage indices in the 12 states with the largest industrial output, in addition to a country-wide index, are obtained, on a monthly basis, from the Confederation of National Industry.

Plant characteristics Plant characteristics such as ownership, capacity (i.e. kiln pyroprocessing capacity and grinding capacity), number of kilns, age, technology (i.e. the type of equipment and process, whether dry or wet, whether a preheater is employed) and the fuel mix employed by kilns (largely either fuel oil, coal, or more recently pet coke or natural gas) is available from the Brazilian trade association[72] and from different editions of the World Cement Directory, published by the European Cement Association (Cembureau) every three years, compiling information on cement producers across the world. Data is complemented by or confirmed against information from (i) industry publications, (ii) investment banking reports, (iii) the press, (iv) companies' websites, (v) academic publications, and/or (vi) field interviews (see below). Of note, capacity and technology data may contain significant measurement error. The shortest distance by road from each plant to the main metropolitan areas in each state is available from the Ministry of Transport.

Computing plant marginal cost: an upper bound Using the fixed-coefficient nature of cement production technology, I can directly calculate marginal cost from observed factor prices, the observed plant characteristics and engineering estimates of the fixed coefficients. I employ the term "calculate" rather than "estimate" since obtaining marginal cost does not involve statistical inference; however, calculated marginal costs are indeed estimates – in fact they are estimated upper bounds to the true marginal costs – in the sense that there inevitably are unobserved plant characteristics, as I explain below. In view of the fixed-coefficient technology and my understanding of the industry, I model plant marginal cost as flat in quantity up to capacity. To the extent that marginal cost varies across kilns within the same plant complex, this will be an approximation to the true plant marginal cost which would then be a step function in quantity. (For example, if a plant consists of two kilns, labelled 1 and 2 in order of most

[72] Plenty of other information is available, such as stock levels by plant, or the form shipments from each plant take, in terms of packaging (in bags or in bulk) or in terms of means of transportation (by road, rail or water). Aggregating across all plants, between 1997 and 1999 81% of shipments were in bags, and 91% of shipments were by road. The breakdown of shipments among different buyer channels is also available, with resellers accounting for 76% and ready-mixed concrete firms accounting for 11%, in this same period.

efficient first, with kiln marginal costs denoted c_1 and $c_2 > c_1$, denoting other marginal cost by c, and denoting kiln capacities by K_1 and K_2, then marginal cost would be $MC(q) = c + c_1$ if $q \leq K_1$ or $c + c_2$ if $K_1 \leq q \leq K_2$.) Clearly, this will be of relevance only if plant capacity utilisation varies sufficiently over time that the *marginal kiln* in operation differs (e.g. a less efficient kiln is fired up and shut down for months at a time according to demand). I thus mitigate any distortion stemming from my approximation of plant marginal cost as being flat in quantity by taking capacity utilisation (see below) and the characteristics of the marginal kiln into account when computing marginal cost. (It should also be noted that in recent decades the trend for cement plants has been to favour large single-kiln production lines as against multiple small lines, in view of the economies of scale.) It is also worth clarifying the way a kiln works. A kiln, when in operation, must run at close to full capacity; it cannot be operated at any given moment at, say, 50% capacity. Further, firing up a kiln is costly so when in operation a kiln typically runs for at least several days or weeks. As for plant marginal costs, it is clear that these will vary across plants according to the technology, capacity and age of the equipment and the fuel employed by the kiln; these are accounted for to the best of my knowledge as I explain below[73]. Plant marginal costs fall into four main categories – kiln fuel, electricity, mineral extraction royalties, and labour/packaging/other costs – as follows:

1. Kiln fuel: This is the main component of plant marginal cost. Based on engineering estimates, the heat content required to produce 1 kg of clinker using the dry process (see Section 3.1) will typically fall in the 650 - 850 kcal range (e.g. see World Cement, January 2000 issue). (The wet process consumes over double this.) A kiln's (thermal) energy efficiency will depend on the capacity, technology (including the specifications of preheating, cooling and waste heat recovery systems used) and age of the kiln. (The kiln's brick lining has to be changed periodically, and the time since the last relining will also impact the energy efficiency of the kiln.) Interview-based evidence, however, indicates that the energy efficiency of kilns in operation in the Brazilian cement industry is (i) high relative to its global peers (including the US industry), with producers having shifted to the dry process chiefly over the 1980s, (ii) has continued to improve over the 1990s, and (iii) presents low variation across producers (with perhaps two exceptions, both with lower productivity). Based on observed plant characteristics and interviews, I classify the energy efficiency of each plant as "above average", "average" and "below average", assuming energy contents of 690, 730 and 800 kcal/kg of clinker respectively. (For example, with respect to kiln capacity, a kiln with capacity in excess of 1 mtpa will require a heat content approximately 6% below that of a kiln with capacity of 0.25 mtpa, controlling for other characteristics.)[74] To arrive at the marginal cost relating to kiln fuel, I consider two types of fuel – fuel oil and coal – for which I observe prices, as explained above. I then use the observed fuel mix for each plant and the properties of each fuel to obtain fuel cost. (For example, an

[73]To this end I have met with engineers working in cement plants or working for the technical arm of the cement producers' trade association (the Brazilian Association for Portland Cement, ABCP), as well as meeting executives of equipment suppliers to the cement industry.

[74]In addition to the above, I use other sources of information such as a report compiled by the industry's trade association in 1993 on plant productivity with respect to energy inputs (stating the amount of hydrocarbon equivalent burned by tonne of clinker produced by plant). Note further that I neglect time-series variation in plant-specific energy efficiency given that this has been low over the time period of the study.

average-efficiency kiln burning a certain grade of fuel oil – with inferior calorific power of 9750 kcal/kg of fuel oil – will require $730/9750 \times 1000 = 75$ kg of fuel oil per tonne of clinker.)

2. Electricity: While thermal energy is required to produce clinker in the kiln, electricity is used mostly for grinding raw material, solid kiln fuel (such as coal) and clinker – a process known as comminution – and to a lesser extent to operate conveyor belts and packaging lines. Considerations here are similar to those made for kiln fuel. For example, in terms of technology, the more modern vertical roller mills tend to consume less power than the ball mill system. Again based on engineering estimates, the total plant electricity content required to produce 1 tonne of cement typically falls in the region of 90 - 105 kWh.

3. Mineral extraction royalties: The marginal cost component arising from the extraction of raw material (limestone and clay), from a quarry usually located within the plant complex, follows from legislation. The "Financial Compensation for the Extraction of Mineral Resources" (CFEM) requires that the cement producer collect 2% of its revenues from the sale of cement, net of sales taxes and freight, in the way of compensation to the government (see below for producer prices and sales taxes). Exceptions to this requirement, where negotiated between producers and the government, are not observed (see comment below on unobservables).

4. Labour/packaging/other costs: As mentioned in Section 3.1, labour essentially performs a supervisory role. One may argue that a certain proportion of a plant's labour cost is fixed. The variable proportion of labour would correspond to quarrying personnel and possibly workers involved with the packaging and distribution centre operations. I refrain from discussion, given the relatively low cost of these plant operations and the fact any bias in the direction of overstating marginal cost reinforces the results of this study. Packaging costs will vary according to the proportion of a plant's production that is shipped in bags (largely in the form of the standard 50 kg bag) as opposed to bulk shipments; recall that I observe this proportion. As such, based on information at hand, I take this component of marginal cost to amount to around 5% of net producer price.

A final comment relates to unobservables. Despite a researcher calculating marginal cost to the best of his ability from observables, there will always be an unobserved (to the researcher) component to productivity across plants. In view of this, in computing marginal cost I choose to "err on the side of conservatism", in this case by overstating marginal cost. I claim the calculated marginal cost is thus an upper bound to the true marginal cost, thus leading to an understated price-cost margin. The reason behind this choice is that, when I turn to the testing of conduct in Section 4.4, such a bias reinforces the results of this study. There are several potential sources of bias (in the direction of overstating marginal cost). One source of unobserved plant heterogeneity may be the quantity discount enjoyed by Votorantim, the largest producer on a nationwide basis, in acquiring fuel oil, electricity or trucking services vis-à-vis the smaller producers. To the extent that producers manage to acquire factors on different terms (controlling for location), the marginal cost I compute may be overstated for the firms with greater bargaining power over suppliers. Another possibility is that producers substitute away from traditional kiln fuels such as fuel oil and coal in favour of cheaper alternatives[75]. Yet another bias stems from the formulation I use to compute the marginal cost of cement (see footnote 24). For simplicity I take 1 kg of cement to correspond to 1 kg of clinker. Now clinker is the most expensive input to the grinding process and even "pure" cement (referred to commonly as type I cement, or simply ordinary cement) is comprised of 96% clinker and 4% gypsum by weight. To the extent that different formulations of cement are produced, with a lower proportion of clinker (and higher content of lower-cost additives, such as slag, pozzolane and/or filler), the bias in the direction of overstating marginal cost will be higher. For example, composite (type II) cement, with a clinker content in the region of 70 - 80%, accounted for 78% of the Brazilian industry's total production between 1999 and 2001. Finally, note that *fixed cost* heterogeneities across plants, stemming for example from decreasing unit capital costs as a function of capacity (i.e. economies of scale), are not relevant for the computation of marginal cost and the resulting price-cost margins.

Computing plant-to-market freight cost This is the first component to ex-plant marginal cost that I consider (the other two are the reseller mark-up and producers' sales taxes). In the cement industry, as seen in Section 3.1, 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 soyabean 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)[76]. 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[77]. Figure 17 summarises 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 constant prices as

[75] Indeed, since 2000 the use of pet coke (imported by some producers themselves from the Mexican Gulf) and natural gas (to the extent that a plant is located in proximity to a pipeline) is on the rise. A clinker kiln will in principle burn any material with a sufficiently high energy content, such as used rubber tyres, solvents and hazardous waste materials. The equipment supplier FLSmidth speculates that in the long term the cost of kiln fuel could fall to zero, or even turn negative, with cement producers being paid to dispose of waste materials.

[76] For example, an interview with a cement industry executive revealed that during the soyabean 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 soyabean 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.

[77] 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 soyabean, maize and (the mineral) limestone was kindly made available.

explained earlier[78]) 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 soyabean), in addition to interaction variables. It is clear from the R^2 of the OLS regressions that the fit is very high; 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 litre for the price of diesel oil), the predicted price of freight for a tonne of soyabean 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.

Backing out net producer prices from retail prices The other components to ex-plant marginal cost, apart from plant-to-consumer freight, are the reseller (retailer) mark-up and producers' sales taxes. Recall that the lion's share of the Brazilian cement business consists of producers shipping bagged cement to resellers, who then sell directly to the end user (a small-scale consumer); I only observe the prices set by these resellers, not the prices set by producers. However, I back out producer prices as follows. Based on several field interviews[79], I model the reseller as competitive. I thus avoid the issue of double marginalisation. A reseller's cost consists largely of (i) two forms of sales tax ("PIS" and "COFINS", not to be confused with the sales taxes collected by the producer), which are proportional to the retail price (varying from 2.65 to 3.65% over the time period), and (ii) labour costs (for unloading the truck, storage handling and

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

[79] These interviews include cement producers' field representatives and sales executives, buyers of cement and representatives of the construction sector's trade associations across a sample of local markets. Information provided in these interviews was also consistent with a report on the supply chain prepared by a consulting firm for the cement industry trade association (Booz Allen & Hamilton 1990).

	(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 17: Auxiliary OLS regressions for plant-to-market freight cost

stocking shelves). While sales tax will be perfectly correlated with cement prices, this is not the case for labour costs. In any case, based again on the field interviews, I assume that resellers apply a fixed proportional mark-up over the producer price (namely in the region of 13%) and can then back out producer prices from observed retail prices. To the extent that (i) labour costs vary across markets, or (ii) some resellers evade taxes, or (iii) some resellers occasionally choose to price cement as a "loss leader" to lure consumers into their stores, the reseller mark-up may vary across resellers. This variation, however, should be small (and the bias, again, is in the direction of overstating marginal cost). Further, price discrimination by producers on the basis of customer size (i.e. quantity discounts) is very limited across resellers[80]. A 5-10% discount may be offered to large buyers who buy in bulk (ready-mix concrete firms and large construction firms) yet again this corresponds to a small share of the business compared to that flowing through resellers. Among the robustness checks I perform, I compare *observed* producer prices that I was fortunate to obtain from a subset of producers to the backed-out producer prices. Finally, to calculate producers' sales taxes and thus arrive at net producer prices, I consider federal and state-level tax legislation. Despite the awkwardness of

[80]As mentioned earlier, in view of the bulkiness, fast turn and short shelf life of cement, producers reach far "down the trade", via direct-from-plant deliveries and own distribution terminals. They resort to distributors for a minor share of their business. Even a relatively small retailer (reseller) will be able to place an order directly with the producer; recall that a 15 ton (25 ton) truckload corresponds to only 300 (500) bags.

Brazil's sales tax system (one needs to compute five different sales taxes, namely "ICMS-normal", "ICMS-ST", "IPI", in addition to the producer's own collection of "PIS" and "COFINS"; note further that tax rates vary according to the origin and destination of the shipment) the total sales tax collected by a producer upon selling to a buyer is conveniently proportional to the (net or gross) price set. Despite sales taxes on cement (and on other products in general) being high (e.g. towards the end of the time period of study, sales taxes owed by a producer located in the state of São Paulo selling to a buyer located in the same state amounted to 28% of the gross producer price), sales tax evasion on the part of producers is considered to be minimal. However, to the extent that producers manage to negotiate reductions in their tax liabilities with state governments eager to attract investments – negotiations which I do not observe – the marginal cost I calculate will again be overstated (see the earlier paragraph on unobservables).

A glance at margins Figure 18 displays the by-market evolution of consumer prices, marginal costs and price-cost margins since July 1994 for nationwide leading firm Votorantim (Figure 18 is the by-state counterpart to Figure 11 in Section 3.3, where these series are aggregated across the 25 states where Votorantim is present).

Capacity utilisation As mentioned above, among other plant characteristics I observe capacity. As is usually the case with capacity figures, these are admittedly prone to considerable measurement error. Nevertheless, I proceed to analysing the evolution of plant capacity utilisation, including the three years post stabilisation of steep consumption growth (1995 to 1997). Throughout the time period, capacity outstrips production (*including* the growth years, although the slack is lower[81]), with capacity utilisation hovering around an average 65%. As discussed in Section 4.4.2, capacity seems to play a strategic role in the industry. Of particular interest, capacity utilisation appears to be similar across firms and plants, with firms' capacity utilisation rates being correlated over time, as firms' market shares are fairly stable, with some exceptions. This finding further supports my modelling of marginal cost as being flat in quantity (up to capacity). To the extent that as capacity utilisation rises, older, smaller and energy-inefficient kilns may be put back into use, marginal costs may rise as capacity becomes tight.

A.2 Robustness checks on direct measures of marginal cost

In addition to checking my calculation of the reseller's mark-up on a subset of the data where I *do* observe producer prices – thus enabling these to be compared to the producer prices I back out from observed consumer prices, as explained above – I perform two other robustness checks of the constructed marginal costs. The first check is centred on the Portugal-based multinational Cimpor, which in 1997 bought its way into Brazil and in 1999 became the third largest firm in the country upon acquiring Brennand. This firm is of particular interest in that it is listed on the Lisbon stock exchange and

[81] Note therefore that the post-stabilisation boom in demand did not catch the cement industry unprepared in terms of capacity. Other industries with tighter capacity facing the same boom in demand saw either entry (such as imports) or an increase in prices, which clearly was not the experience of the cement industry (recall that imports were largely kept at bay and, not unrelatedly as I argue in this paper, prices fell).

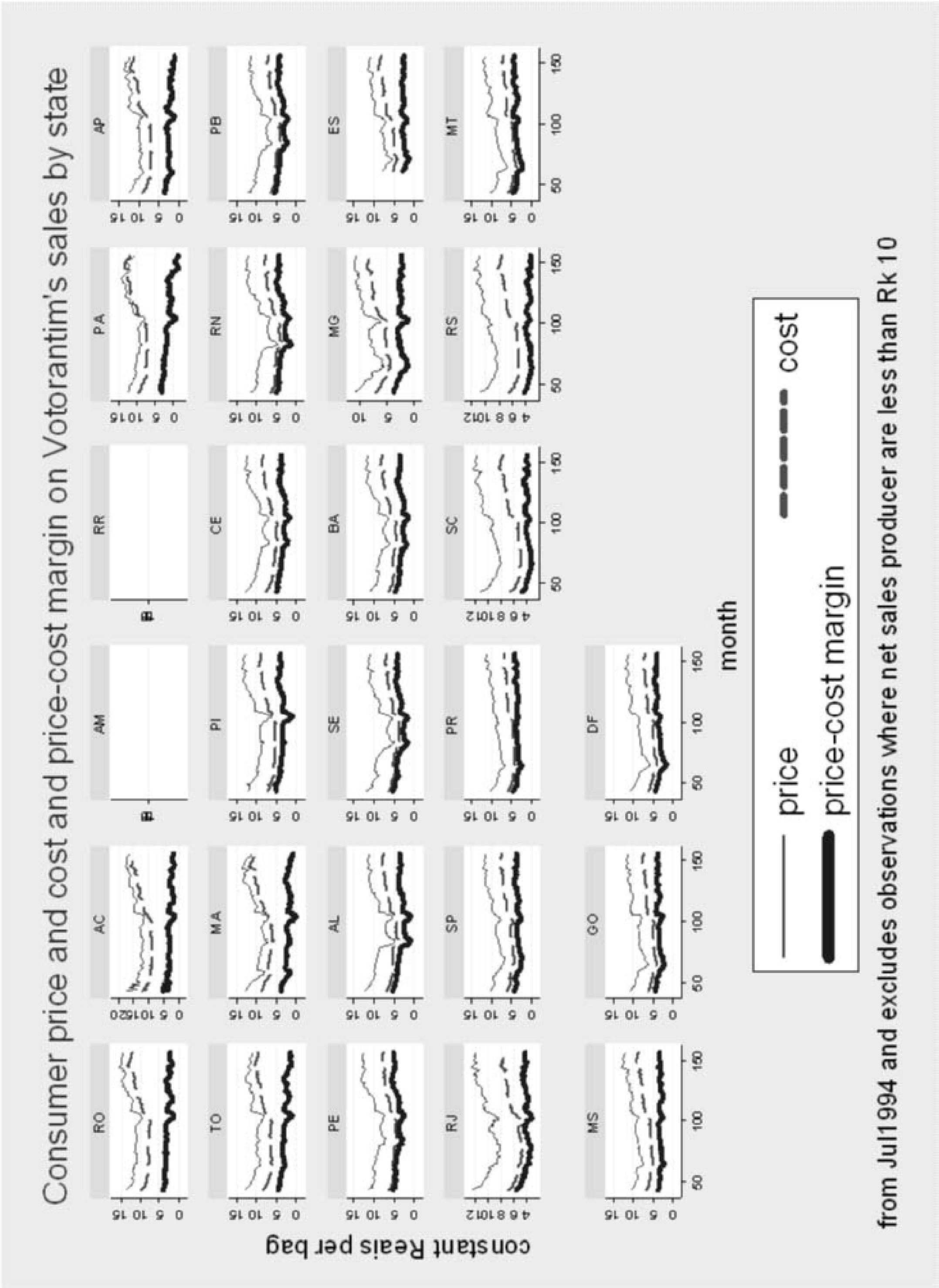

Figure 18: By-market evolution of consumer prices, marginal costs and price-cost margins since July 1994 (post-stabilisation phase) on Votorantim's sales. In constant Reais per bag (at December 1999 values).

chooses to report its financial results broken out by country of operation (and line of business). I can thus use their reported results for Brazil as a robustness check for my calculated price-cost margins. The evolution of the calculated price-cost margin, as a percentage of net producer sales (i.e. net of sales taxes), is graphed in Figure 19. This evolution is compared to Cimpor's reported EBITDA (earnings before income tax and depreciation allowance, also known as operating cash flow) as a percentage of net sales, over the period 1998 to 2003. (I can further check my estimates of resellers' mark-ups and sales taxes by comparing my calculated net producer sales, backed out from observed consumer prices, to their reported net sales.) The time series fit between constructed and reported figures is good. For example, I estimate Cimpor's average price-cost margins as a percentage of net producer sales rising from around 47% in 2000 to 56% in 2002. Cimpor reports a similar rise in this period, from 44% to 55%.[82] If anything, my calculated price-cost margins are slightly higher than the EBITDA figures Cimpor reports. This is to be expected, for while my cost estimates include only (constant) marginal cost, Cimpor's EBITDA figures are net of other costs such as plant overhead and sales and administrative expenses. Indeed, my price-cost margins appear to be conservative (on the low side), as expected from the discussion above regarding the directional bias in the construction of marginal cost owing to unobservables (in the way of overstating marginal cost).

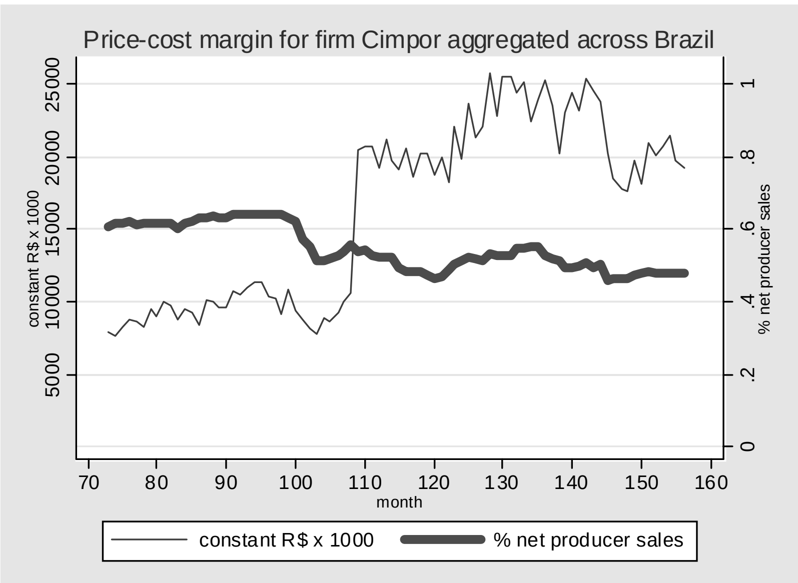

Figure 19: Evolution of the average price-cost margin for firm Cimpor. In constant Reais x 1000 per month (at December 1999 values) and as a percentage of net producer sales. Aggregated across all states.

The second additional robustness check is based on accounting data of the cement industry surveyed annually by the Brazilian Institute for Geography and Statistics (IBGE) as part of their Annual Industry Survey (PIA) series. Figure 20 depicts the average accounting gross margin (defined as producers' Net Sales minus Cost of Goods Sold) as

[82] Comparing operating cash flow (EBITDA) margins across the 9 countries (in Iberia, Africa and South America) where Cimpor is active, Brazil's cement operations are the most profitable: a 55.5% EBITDA margin in Brazil compared to an average 39.2% across all countries.

a percentage of net sales for a sample of establishments over the 1990s; the number of establishments varies between 33 and 55 and only aggregate data is published. The accounting gross margin is high, hovering around 50%. Note that the accounting definition of Cost of Goods Sold does not include freight expenses but does includes accounting depreciation, so the accounting gross margin cannot be immediately compared to my constructed price-cost margin (which does consider freight but not depreciation). Further, I do not know the identity of the surveyed establishments. However, the magnitude of both series appears to be consistent. Of perhaps greater importance, the variation in the surveyed accounting gross margin is consistent with the observed fall in prices beginning in 1992 and the rise in prices commencing in 1997. (Notice the capital-intensive nature of the industry: on average payroll – corresponding not only to plant but also to sales and administrative employees – accounts for less than 10% of a producer's net sales.)

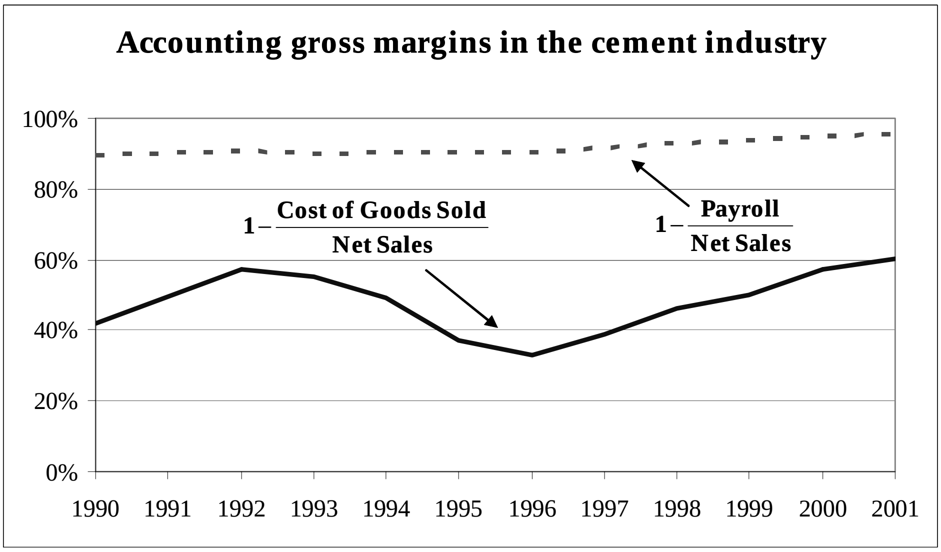

Figure 20: Accounting gross margins in the cement industry, from surveys conducted by the Brazilian Institute for Geography and Statistics (IBGE)

B Appendix: Robustness of the structural estimation

B.1 Robustness checks in the demand estimation

It is possible that the estimated market price elasticities of demand, of the order of -0.5, underestimate the "true" elasticities. I thus proceed to performing some robustness checks.

Estimating demand across states simultaneously One would expect that unobserved demand shocks across states should be correlated. In this case, the residuals ϵ_{lt}^{d} of the market-level equations would be correlated across markets l. Estimating the

17 state-level demand equations simultaneously should thus yield similar estimated coefficients but somewhat lower standard errors: while one would hope that both 3SLS estimates and (equation-by-equation) 2SLS estimates are consistent, the former procedure should improve efficiency over the latter[83]. Though omitted here, I indeed find 3SLS estimates to be somewhat similar to those obtained under 2SLS, and the standard errors are smaller. To take an example, consider again the largest market, São Paulo (*SP*). Evaluating exogenous demand at the mean of the post-stabilisation phase, the price elasticity of demand is -0.366 (standard error 0.038). This compares to an elasticity of -0.333 (standard error 0.060) under 2SLS (Figure 12). The average 3SLS-estimated intercept in the post-stabilisation phase is 7.61 (standard error 0.09), compared to 7.54 (standard error 0.14) under 2SLS[84].

Rather than specifying a demand function for each state, an alternative approach is to specify only one demand function for the population of states and to run fixed effects instrumental-variables panel data estimation, treating each state as a unit and calculating clustered standard errors (i.e. clustering the observations pertaining to a given state). Compared to specification (12), one would estimate, for example,

$$\log q_{lt} = \alpha^1 + \alpha^2 Y_{lt} + \alpha^3 \log p_{lt} + \alpha_l^4 Y_{lt} \log p_{lt} + \nu_l + \epsilon_{lt}^d \tag{21}$$

where α_l^4 and ν_l are the market-specific parameters. Notice that, given the vastly larger number of observations (156 months $\times$ 17 states as opposed to 156 months for each market-level regression) relative to parameters to be estimated, this specification increases efficiency at the expense of cross-unit restrictions $\alpha_l^j = \alpha^j \ \forall l, \forall j \neq 4$. Estimation results – not shown – again point to very low market price elasticities of demand.

Functional form and reversion of dependent variable It could be that the elasticity estimates are inconsistent and/or biased (downward) due to functional form misspecification. To investigate this possibility, I fit alternative functional forms, namely semi-log-linear and linear, as opposed to the log-linear specification (12), and obtain similarly low elasticity estimates. For example, I estimate the linear demand equation

$$q_{lt} = \alpha_l^1 + \alpha_l^2 Y_{lt} + \alpha_l^3 p_{lt} + \alpha_l^4 Y_{lt} p_{lt} + \epsilon_{lt}^d \tag{22}$$

Though again not shown, the fitted (linear) demand curves in 16 out of the 17 states rotate anticlockwise upon stabilisation: the coefficient on the interaction term is negative for these 16 states and significantly so at the 5% level in 13 of them[85]. The average

[83] In 3SLS a GLS approach is used to account for the correlation structure in the residuals across the equations.

[84] Across states, the (average) post-stabilisation price elasticity seems to be smaller under 3SLS: the previous mean value across states of -0.41 is now -0.36.

[85] Recall that $\bar{Y}_{l,post} > \bar{Y}_{l,pre}$ across all states l and realise that with linear demand $\frac{dq_{lt}}{dp_{lt}} = \alpha_l^3 + \alpha_l^4 Y_{lt}$; thus the fitted demand curve rotates anticlockwise upon stabilisation iff $\hat{\alpha}_l^4 < 0$, since the estimated $\frac{dq_{lt}}{dp_{lt}} |_{\bar{Y}_{l,post}} - \frac{dq_{lt}}{dp_{lt}} |_{\bar{Y}_{l,pre}}$ is then $\hat{\alpha}_l^4(\bar{Y}_{l,post} - \bar{Y}_{l,pre}) < 0$. The mean elasticity in the pre-stabilisation period is computed at the means of the variables as $(\hat{\alpha}_l^3 + \hat{\alpha}_l^4 \bar{Y}_{l,pre}) \frac{\bar{P}_{l,pre}}{\bar{Q}_{l,pre}}$ (similarly for the post-stabilisation period). That demand becomes more elastic as the general price level in the economy stabilises from a high rate of inflation makes for interesting reading. How can one interpret such a finding? Intuitively, as the rate of change of the prices of goods and services falls, prices become more meaningful to consumers, carrying greater signal as opposed to noise, making demand more sensitive to variation in prices. Given

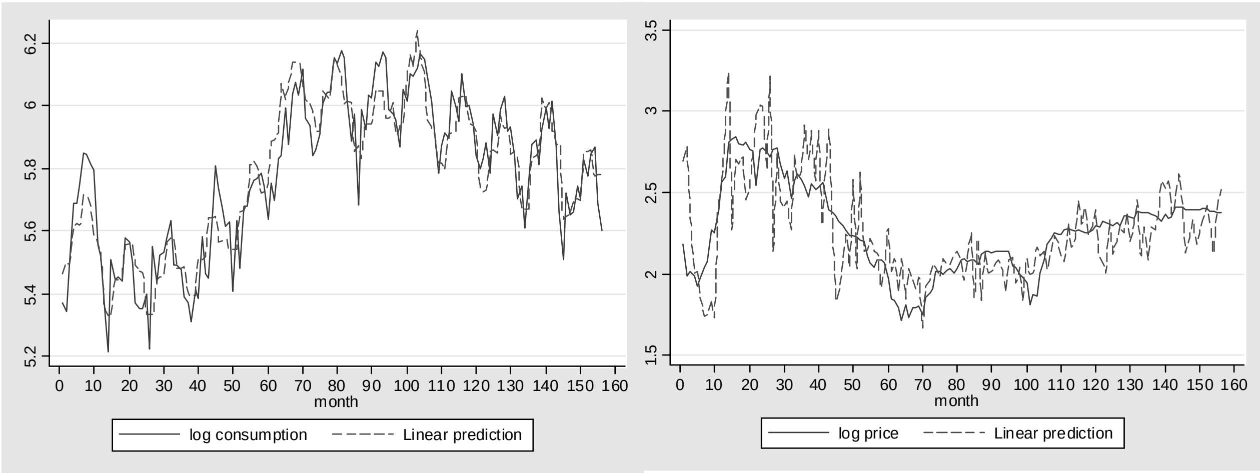

Figure 21: Goodness of fit in the estimation of demand for the state of Minas Gerais (*MG*). Left panel: Fit of a 2SLS regression of log consumption on log exogenous demand, log price and an interaction variable, as in (12). Right panel: Fit of a 2SLS regression of log price on log exogenous demand, log consumption and an interaction variable.

price elasticity across states, computed for each state at the means for the two subsamples, again almost doubles from -0.20 in the pre-stabilisation phase to -0.39 upon stabilisation, varying in the latter post-stabilisation phase from a minimum (in absolute) of -0.10 to a maximum of -0.67.

Thus when consumption (or its log) is taken as the dependent variable, market price elasticities of demand are estimated in each case at around -0.4 to -0.5. On the other hand, when *prices* are taken as the dependent variable, the elasticity is estimated to be higher, at around -0.7 to -0.8. However, the fit suffers significantly and the choice of prices as the dependent variable appears to be forcing the estimation of a higher elasticity. Figure 21 plots the fit of regression (12) – i.e. a log-linear regression of consumption on prices – and compares this to the fit of the reverse regression – i.e. a log-linear regression of prices on consumption[86]. (Indeed, Carlton (forthcoming) comments that “it seems to be an empirical regularity that one can often obtain a high elasticity simply by estimating price on quantity rather than the reverse!” (p. 8))

the potential error associated with the measurement of prices in an inflationary environment, one must cautiously interpret the empirical finding that the price elasticity of demand for cement increased upon stabilisation; however, the estimate that it almost doubled on average across states seems to be a strong result. Much research has been conducted about the economic effects of general price stabilisation, but the hypothesis that stabilisation may lead to increased elasticity of demand has not been tested extensively in the empirical literature. My results provide some evidence in favour of this hypothesis. Notice that such an anticlockwise demand rotation would, in the presence of market power on the part of producers, put downward pressure on prices in equilibrium. In the case at hand, cement prices did indeed fall concomitant with stabilisation, but I have argued earlier that, because of the binding imports constraint, this was due to a reduction in the marginal cost of imports (brought about by an appreciation of the local currency and the trade liberalising reforms of the early 1990s), rather than a change in the slope of market demand.

[86]Of note, prices are taken as the dependent variable in the demand estimation of Röller and Steen (2002) and Parker and Röller (1997); no mention is made regarding the fit of the chosen parametric form compared to alternatives.

Weak instruments As for the possibility that demand is not being identified due to weak instruments, the strong (partial) correlation of the instruments with cement prices, informed by the structural-theoretic framework, suggests otherwise. As discussed in Section 4.2, overidentifying restrictions are tested and only a small subset of the set of available instruments is used (Staiger and Stock 1997). In any case I carry out the following specification test. I consider only observations from 1991 and 1992 and use the fact that price controls were dropped in November 1991, leading to a large and immediate increase in prices, to identify the demand curve (I assume that demand conditions in this period were largely unchanged.) Estimated elasticities are again of the order of -0.2 to -0.3, in line with the estimates in Figure 14 for the pre-stabilisation phase.

Dynamics Another possibility is that while in the "short-run" the elasticity amounts to around -0.5, the "long-run" elasticity is higher. Using an autoregressive distributed lag (ADL) demand specification, where prices are regressed on consumption, lagged consumption and lagged prices, Röller and Steen (2002) estimate a long-run elasticity of -1.47, compared to the short-run elasticity of -0.46. The authors argue that "(t)his is in line with intuition, as other materials like wood and metal can be substituted for cement in the long run" (p.10). While intuitive, it is not clear why the difference between the short-run and the long-run elasticities should be this large, particularly in the Brazilian context, where cement is sold primarily to small-scale consumers who in reality do not have substitutes available and, if facing a shortfall, would rather tend to postpone their construction activities. (Note, for example, that the use of cement in highway construction, has to date been minimal, and large-scale buyers, who purchase cement in bulk as opposed to bags, account for only 20% of shipments. One can argue that dynamic effects of demand by Brazil's small-scale consumers, to the extent that they matter at all, may be present in the direction of yielding a *lower* price elasticity of demand in the long-term, the reverse of what Röller and Steen estimate for Norway.) Nor is it clear what is meant by "long-run" and which lags should be included in the ADL demand specification, particularly to the extent that observations in the present study are frequent (monthly rather than annual). Further, even if one could theoretically argue, and empirically demonstrate, that the long-run elasticity were significantly higher, it is not clear either why producers going about making their supply decisions should consider a long-term slope for the demand curve as opposed to a short-term one[87].

B.2 Other robustness checks: spatial competition

In the cement industry, transportation assumes a significant proportion of cost and firms' offerings are spatially differentiated. I thus review in Salvo (2004) the literature on spatial competition[88] to check whether a plausible substitute (or complement) to my theoretical framework – the presence of a competitive fringe of imports – can be found. Any plausible theory should satisfactorily reconcile the low market price elasticity of demand with the presence of market power by firms. My motivation stems from the equilibrium in a well-known example of spatial competition, the Hotelling-type circular

[87]Despite these reservations, I have attempted to estimate an ADL specification à la Röller and Steen (2002), including 6 to 12 month lags, with no success.

[88]Examples include Thisse and Vives (1988) on price-setting games and Greenhut and Greenhut (1975) – applied to the cement industry by McBride (1983) – on quantity-setting games.

road model. In this model, inelastic market demand does not imply low price-cost margins (since inelastic market demand does not translate into inelastic demand for the firm). As I show, however, this result of positive price-cost margins even at local markets where spatially-differentiated firms' market boundaries meet owes to a very special class of spatial pricing policy assumed in the model, that a firm is restricted to set only a "mill" price, with delivered prices to consumers who are distributed over space being equal to the sum of this mill price and the transportation cost. This is not the case in the Brazilian cement industry, where firms set prices at the local market level (and these are observed to be quite uniform over space, including those local markets where many firms meet). I conclude in Salvo (2004) that models of spatial competition do not provide further insight over the theoretical framework proposed presently[89].

B.3 Characteristics of the cement industry and their relation to the literature on collusion

The table below, based on Ivaldi et al (2003), lists industry characteristics that are understood to facilitate collusion, summarising the extent to which they characterise the cement industry[90]. The purpose of this section is to show that tacit collusion in the Brazilian cement industry, orchestrated for instance via market division, is a concrete possibility in that the characteristics of the industry are consistent with those characteristics that the literature suggests make tacit collusion more likely.

Characteristics facilitating collusion	Characterise the cement industry?
Few competitors (in a given local market)	Yes
Entry barriers	Yes
Frequent interaction among firms	Yes
Market transparency (1)	Yes
Growing demand	Yes in some local markets
Mild business cycles (intensity and length)	Yes in some local markets
Low innovation	Yes
Homogeneous product (low differentiation)	Yes
Low cost asymmetry (2)	Yes in some local markets
Low capacity asymmetry	No
Evenly-distributed idle capacity	Yes in some local markets
Multimarket contact (3)	Yes
Low price elasticity of demand in equilibrium (4)	Yes
Absence of countervailing buyer power	Yes
Structural links between firms (e.g. cross-ownership)	Yes in some cases
Small competitors on the fringe	Yes
Absence of network effects or learning effects	Yes

Notes to the table: (1) Market transparency. Of note is the (potential) monitoring role played by the cement producers' trade association in compiling and sharing data on firm-level

[89] Salvo (2004) also estimates a gravity model (a tobit specification) to statistically analyse the flow of cement between plants and markets, "detecting" outliers in the data, in the spirit of the trade literature.

[90] A discussion of each characteristic and how it relates to the cement industry is beyond the present scope. The purpose of the table is to convey a simple message with which most academics and analysts would agree, stated loosely as follows: cement is an archetypal example of an industry whose characteristics make it *more* collusion-prone than *less*.

quantities, prices and/or capacity utilisation. (2) Low cost asymmetry. Scherer et al (1975) report very low economies from multiplant operation in the cement industry. (3) Multimarket contact. It is worth reflecting on the changes to market structure across time. As mentioned earlier, of the 19 producers operating in Brazil in 1991, the industry had consolidated to 12 firms by 1999. Yet this came about not in the form of increased concentration at the local market level, but largely in the form of firms making acquisitions in markets where they did not previously operate. Thus despite the changes to asset ownership, the number of firms shipping to any given market has not changed significantly. It is rather multimarket contact which has increased, in the sense that the number of local markets in which any two producers meet has gone up considerably over the decade. See Bernheim and Whinston (1990) and the discussion in Section 4.4.2. (4) Low price elasticity. Ivaldi et al (2003) argue that rather than enhancing the sustainability of collusion, in the sense of increasing the range of discount factors at which a collusive equilibrium can be supported, the effect of inelastic demand may be to increase the profitability of collusion by raising the optimal collusive price. A similar point may be made regarding market division, by which firms concentrate shipments to those markets where their plants are located and reduce cross-hauling to neighbouring markets (i.e. to other firms' backyards). To the extent that under competition one may observe cross-hauling (e.g. under Cournot competition), the effect of high transport costs, as is the case for cement, may then be to raise the profitability of a collusive agreement that prescribes large shares in a given local market to those firms with plants located in that market. While the effect of inelastic demand works via demand (higher collusive prices increasing the profitability from collusion), the effect of high transport cost operates via cost (the reduction of cross-hauling increasing the profitability from collusion). See Section 4.4.2.