# The Tip of the Iceberg: Actual Trade Flows Understate the Extent of Globalization

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**PRELIMINARY AND INCOMPLETE**

**Abstract**

The United States and Brazil both have many local consumer markets which imported cement can access by waterway. Despite this similarity, the degree of import penetration is strikingly different. While imports from around the world have accounted for as much as 30% of U.S. cement consumption, Brazil hardly imports cement. U.S. cement producers, facing lower inbound trade costs and higher marginal costs compared to their Brazilian counterparts, not only compete (on the margin) with foreign capacity but actually welcome it (on the inframargin) as an extension of their own capacity. This paper provides evidence to support that import competition in Brazil, though latent, is already present in the form of an entry threat which sets a price ceiling that binds on domestic outcomes. In explaining domestic prices, I show that mixture models that allow for an imports price ceiling outperform models where a foreign sector is absent. The unique institutional setting vividly illustrates how actual trade flows may represent only the "tip of the iceberg" when it comes to inferring the extent of trade integration: only in the U.S. does one see imports, but the threat of foreign entry in Brazil already restricts the exercise of market power. Such latent international competition is not captured by traditional models of comparative advantage, and helps explain why product prices and wages appear to be increasingly determined by global forces of demand and supply.

*Keywords*: Import competition; international competition; imports discipline; trade arbitrage; price ceiling; threat of entry; contestability; mixture models; non-nested model selection tests

*JEL classification*:

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"Consider the example of U.S. trade in petroleum products. It is not especially large as a percentage of total U.S. output or consumption of petroleum products. And yet arbitrage ties the price of oil within the United States closely to the price in the world market. Even a pair of countries that records no bilateral oil trade whatsoever will find that their prices move closely together. It is the absence of barriers and the *potential* for large-scale trade that keeps prices in line and makes the markets integrated in the most meaningful sense, not the magnitude of trade that takes place." Jeffrey Frankel (2000, p.51), on Globalization of the Economy

# 1 Introduction

To the lay observer of globalization, it is the first arrival of foreign goods at the local store or dealer that signals tougher times ahead for domestic producers. However, in the presence of market power, gradually falling trade costs may already have been making life harder for the domestic industry, having forced it to successively lower prices and tighten margins to keep imports at bay. In labor markets, while it is the "offshoring" of jobs to China, India or Mexico that grabs the headlines, (organized) workers might accept lower real wages (surplus) when credibly threatened with the closure of factories or offices from either the offshoring of tasks or the advance of international competitors.[1] As these product and labor competition examples suggest, the first margin of adjustment as a local market integrates into the world economy may well be price, rather than the market share of local suppliers.

This paper examines the cement industry in two similar yet different countries over the past 15 years to offer a vivid illustration of how international competition can strike. The United States and Brazil both have many local consumer markets which imported cement can access by waterway. Despite this similarity, the degree of import penetration is strikingly different. While imports from around the world have accounted for as much as 30% of cement consumption in the United States (with Asia being the largest exporting continent in several years), Brazil hardly imports cement. In the face of such facts, few would dispute that imports play an important role in the U.S. cement industry, whereas many would naturally assume away any such role in Brazil.

Nonetheless, I uncover substantial empirical evidence which suggests that international competition also plays an important role in the Brazilian cement industry, despite

[1] Leamer (2007) describes the "possibility that manufacturing jobs may be contested by low-wage foreign workers but still stay right here in the US. That global contest may be met by a deterioration of wages and working conditions in the US, not a movement of jobs to low-wage countries... The real bottom line: we do not know the breadth and intensity of global contestability of US jobs, and until we do, we will not have a real handle on the impact of global competition on the US workforce." (p.117)

the virtual absence of import flows. This manifests itself, I posit, in the form of a fluctuating price ceiling, determined by the landed price of imports, which binds on the domestic oligopoly in many local (time-and-region) markets. The hypothesis is that, at prevailing supply and demand conditions, the Brazilian industry finds it optimal to limit price to stave off foreign entry. In contrast, the U.S. industry—conceivably due to lower inbound trade costs and higher domestic marginal cost (i.e., kilns of older vintage and more stringent environmental restrictions)—acquiesces to the entry of foreign cement; this is exported (on the margin) by highly competitive "independent" producers located in coastal areas around the world who are eager to keep their high fixed-cost plants running at close to capacity. The choice of industry is made all the more interesting in view of the fact that as recently as the 1970s, prior to the development of specialized seaborne handling and transportation technologies, international trade in cement was restricted to neighboring areas.

A simple static open-economy model of a local oligopoly—monopoly, say—helps frame the hypothesis. Relative to the local market, production capacity lying in the hands of competitive foreign "swing" producers is assumed to be large enough, and entry (and exit) costless, that the supply of imports is modeled as perfectly elastic at the delivered marginal cost of imports. There are three outcomes to consider depending on this imports price ceiling (relative to domestic conditions). When trade costs are sufficiently high, the competitive foreign sector has no bearing on the local market and the monopolist sets the monopoly price. I label this autarkic setting as a "type 1" market, exemplified by local cement markets up to the 1970s. At the other extreme, when trade costs are sufficiently low, the imports price determines the domestic price *and* the local monopolist chooses to supply up to the point where (rising) domestic marginal cost equals the imports price, with the excess demand in the local market being met by foreign capacity. I denote this a "type 3" market, exemplified by coastal cement markets in the United States today. For intermediate trade costs, the imports price already determines the domestic price but at this price it is still profitable for the local monopolist to supply the entire market. These "type 2" markets would describe most coastal cement markets in Brazil today, a hypothesis that Levinsohn (1993) might have referred to as the "*latent*-imports-as-market-discipline" hypothesis, in that the role of import competition is not visible to the naked eye. Price-cost margins in such type 2 markets are tighter than in autarkic type 1 markets but, unlike competitive type 3 markets, they are still positive.

A careful analysis of cement institutions in the United States and in Brazil hopes to convince the reader about the *plausibility* of the latent import competition hypothesis (for Brazil). I make the best use I can of comparable data available in the two countries though, perhaps surprisingly, data for Brazil is considerably richer relative to that for the U.S. Take prices, for example: while for Brazil I observe a monthly state-level panel of cement prices, in the U.S. I observe either annual prices in 26 "districts" or monthly prices in 20 cities. Nonetheless, price variation across and within the two countries is consistent with the import price ceiling hypothesis.[2] Brazilian cement prices to buyers are highly correlated with U.S. imported cement prices (i.e., actual CIF prices at U.S. ports of entry).[3] Brazilian cement prices along the many coastal markets are nearly uniform, despite large variations in domestic market structure; for example, the mean price in the coastal state of Santa Catarina, where one firm commands an 80% share of the market, is about the same as the price in the also coastal state of Rio de Janeiro, where the market leader has a 24% share. Also, higher cement prices in inland markets are consistent with the import price ceiling increasing in the distance from the coast. (For what they are worth, I briefly state some anecdotes—underscoring the threat posed by imports—that were revealed to me during interviews.)[4]

I then provide two pieces of structural econometric evidence for Brazil. First, I estimate demand across Brazil's many local markets. I systematically obtain very low market price elasticities of demand, of the order of $-0.5$, including the quasi-monopolistic Santa Catarina. Why does a (quasi) monopolist, facing such inelastic *market* demand, not cut output to raise prices to a point where demand is more elastic? I interpret this finding as evidence of a binding price ceiling, i.e., a kink in the *residual* demand curve that the domestic oligopoly faces.

Second, I fit alternative behavioral models of the Brazilian industry and use likelihood ratio tests for non-nested models (Vuong 1989) to select among these candidate data generation processes. In explaining the observed data, switching-regime models of a domestic oligopoly constrained by the threat of import competition (namely "constrained monopoly" and "constrained Cournot") outperform behavioral models where no foreign sector is modeled (namely, "autarkic monopoly", "autarkic Cournot" and "autarkic perfect competition"). Under "constrained monopoly" or "constrained Cournot", the estimated implied probability that the imports-constraint binds, averaged across region-and-time markets in the sample, is a very high 98%. Intuitively, variables that move the marginal cost of imports—chiefly the exchange rate (for which huge swings have occurred over the sample period, only somewhat correlated with domestic factor prices)—explain much of the variation in domestic cement prices, in a way that domestic conditions (domestic factor prices, domestic demand shocks) are unable to beat. I conclude that

[2]I employ "consistent with" in the sense that other (domestic) behavioral models, which I allow for in the subsequent formal tests, can also explain such observed prices.

[3]In terms of levels, an average relative price of 1.57 (i.e., producer prices delivered to buyers net of sales tax in Brazil's coastal states, divided by U.S. CIF prices in East and Gulf Coast ports of entry), between 1992 and 2006, is also consistent with the hypothesis.

[4]Elsewhere, for Brazil, I have used the very detailed spatial supply data and simple production technology to document: (i) very large price-cost margins enjoyed by cement producers (about 50% of producer prices; see Salvo 2010a); and (ii) evidence of spatial collusion (Salvo 2010b).

empirical evidence of latent import competition is strong. The example vividly illustrates how one needs to look beyond the "tip of the iceberg" when it comes to inferring the extent of globalization.

The bigger picture is that the cross-border movement of goods, capital and tasks alone might understate the extent of world integration. In spite of this, trade research has typically taken measures of actual trade flows, such as import penetration, to proxy for the extent of international competition.

[NOTICE TO YALE SEMINAR PARTICIPANTS: A literature review is still missing. This will probably include the literature on pricing-to-market and exchange-rate pass-through, including surveys such as Anderson and van Wincoop (2004), Goldberg and Knetter (1997). Also, trade—Engel and Rogers (1996), empirical IO/trade—Goldberg and Verboven (2001, 2005). In historical context, supply-price elasticity of exports—Goldstein and Khan (1985). Need to cite recent applied macro/international finance literature, such as research at the BIS. Any other citations that are missing at this point are most welcome!]

# 2 Actual and latent import competition

## 2.1 Historical motivation

Consider an initially protected domestic industry that exercises market power in its local markets. High international trade costs shield the oligopoly—a local monopolist, say—from a competitive foreign sector. Thanks to its large size relative to the domestic market, the foreign sector exhibits perfectly-elastic supply, over a relevant range, at the delivered price (equal to cost) of imports defined by a world price plus the inbound trade cost, i.e., $p^I := P^W + T$.[5] In this autarkic (or "high $T$") setting, the local monopolist is free to set the domestic monopoly price $p^*$, since the high price ceiling $p^I$ does not bind, and the equilibrium price is $p = p^* \leq p^I$.

Trade reforms then occur and trade costs fall. For sufficiently low trade costs $T < p^* - P^W$ (or, equivalently, for $p^I < p^*$), the autarkic price $p^*$ can no longer be sustained, as the foreign sector now puts downward pressure on domestic prices. In this imports-constrained regime, two outcomes can be distinguished. In one outcome, labeled as "low $T$" in the left panel of Figure 1, import competition is observed in the form of strictly positive trade flows. Here, the drop in $T$ is large enough that the local monopolist finds it optimal to allow foreign entry, since the delivered price of imports falls below $p^c$,

[5] This is a simple static model and I assume costless entry (and exit). The model can, in principle, be adapted to allow for hysteresis (see, e.g., Dixit 1989 and, for an empirical study of foreign entry decisions, Roberts and Tybout 1997).

i.e., $p^I$ drops below the price that would obtain in a hypothetical perfectly competitive autarkic domestic industry. In equilibrium, the import price determines the domestic price, $p = p^I << p^*$. In the other outcome, labeled as "intermediate $T$" in the right panel of the figure, import competition is not visible; rather, it is "latent". In contrast to the first outcome, equilibrium trade flows are zero, yet the effect of trade on the local market is qualitatively similar. Under the implicit assumption that entry (and exit) costs are low, at this intermediate trade cost the threat of foreign entry already arbitrages away the monopolist's power over price, with price again determined by the price of imports $p = p^I < p^*$.

Denoting the market's (downward-sloping) demand and the local monopolist's (upward-sloping) marginal cost functions respectively by $q = D(p, .)$ and $c = c(q, .)$, the market price is given formally by

$$p = \min\left(p^*, p^I\right) = \begin{cases} p^* = \arg\max D(p)\left(p - c\left(D(p)\right)\right) & \text{if } p^* \leq p^I \text{ ("autarky/high } T\text{")} \\ p^I = P^W + T & \text{otherwise ("intermediate } T\text{" and "low } T\text{")} \end{cases}$$

Noting the hypothetical competitive price $p^c = \arg\text{solve}\left\{D(p, .) = c^{-1}(p, .)\right\}$, the quantity of imports $q^I$ is

$$q^I = \max\left(0, D\left(p^I\right) - c^{-1}\left(p^I\right)\right) = \begin{cases} 0 & \text{if } p^* \leq p^I \quad \text{("autarky/high } T\text{")} \\ 0 & \text{if } p^c \leq p^I < p^* \quad \text{("intermediate } T\text{")} \\ D\left(p^I\right) - c^{-1}\left(p^I\right) & \text{otherwise ("low } T\text{")} \end{cases} \tag{1}$$

and the quantity supplied domestically $q^s$ is the difference between market demand $q = D(p, .)$ and this import quantity, i.e., $q^s := q - q^I$.[6]

## 2.2 Fitting a structural model from observed price and quantity data

Let $Y$, $W$ and $W^I$ denote exogenous covariates that are observed by the econometrician and that respectively move demand, domestic cost and import cost, while the mean-zero error terms $\varepsilon^d$, $\varepsilon^s$ and $\varepsilon^I$ denote the corresponding unobserved exogenous components

[6] Three comments are in order: (i) I ignore exports for simplicity, implicitly assuming that the export price $P^W - T$ (where here $T$ is the outbound trade cost), which sets a floor on the domestic industry's marginal revenue, is low enough that it does not put upward pressure on domestic prices (in the autarkic setting of course). (ii) Were inbound trade costs to monotonically fall over time, the model would predict that domestic supply $q^s$ would first rise (latent import competition) and then fall (actual import competition). (iii) Were the monopolist able to complement domestic production with foreign production, this would feature in the "domestic" cost schedule $c(q)$; i.e., any imports by the incumbent are inframarginal and lie to the left of $c^{-1}\left(p^I\right)$ in the left panel of Figure 1.

to demand, domestic supply and import supply. Local market demand is

$$q = D(p, Y, \varepsilon^d; \alpha) \tag{2}$$

The autarkic monopoly price and output $(p^*, q^*)$ are then the solution to the system given by the market demand function (2) and the pricing equation

$$p = -q\frac{\partial p\left(q, Y, \varepsilon^d; \alpha\right)}{\partial q} + c\left(q, W; \beta\right) + \varepsilon^s \tag{3}$$

where $p\left(q, .\right) \equiv D^{-1}\left(q, .\right)$ is inverse demand, and $\varepsilon^s$ enters additively. (Notice that the autarkic oligopoly solution—local monopoly in the example here—can easily be modified, as I do in the application.) The hypothetical perfectly competitive autarkic outcome $(p^c, q^c)$ is the solution to (2) and the pricing equation

$$p = c\left(q, W; \beta\right) + \varepsilon^s \tag{4}$$

Finally, the price ceiling set by the delivered marginal cost of imports, which analogously to domestic marginal cost is generally not observed by the econometrician,[7] is specified as

$$p^I = P^W + T = c^I\left(W^I; \beta^I\right) + \varepsilon^I \tag{5}$$

In addition to demand and supply shifters $Y$, $W$ and $W^I$, the econometrician observes the limited dependent variable

$$p = \min\left(p^*, p^I\right) = \min\left(-q^*\frac{\partial p\left(q^*, Y, \varepsilon^d; \alpha\right)}{\partial q} + c\left(q^*, W; \beta\right) + \varepsilon^s, c^I\left(W^I; \beta^I\right) + \varepsilon^I\right) \tag{6}$$

and the aggregate quantity consumed in the local market $q = D\left(p, Y, \varepsilon^d; \alpha\right)$ (in the more general situation, for now, the breakdown between domestic supply $q^s$ and foreign supply $q^I$ is not observed). To be clear, $p^*$ and $p^I$ are latent; a market observation is thus given by the censored price $p$ and the corresponding quantity on the demand curve $q = D\left(p, Y, \varepsilon^d; \alpha\right)$. From (1), as demand and supply conditions fluctuate (over time and across regions), markets can be of three types:

- "Type 1" market: Imports-unconstrained regime ("autarky/high $T$"), characterized by $p^* \leq p^I$, or equivalently

$$-q^*\frac{\partial p\left(q^*, Y, \varepsilon^d; \alpha\right)}{\partial q} + c\left(q^*, W; \beta\right) + \varepsilon^s \leq c^I\left(W^I; \beta^I\right) + \varepsilon^I$$

[7] In markets where imports do occur, it may be that the econometrician observes the price at the port of entry (e.g., the CIF price). This price, however, is only a component of $p^I$, the import price with delivery to the consumer, which by assumption is not observed.

(Note that $q^*$ also depends on $\varepsilon^s$ so I do not collect $\varepsilon^I - \varepsilon^s$ on the same side of the inequality.)

- "Type 2" market: Imports-constrained regime where imports do not occur ("intermediate $T$"), characterized by $p^c \leq p^I < p^*$, or equivalently

$$c\left(q^c, W; \beta\right) + \varepsilon^s \leq c^I\left(W^I; \beta^I\right) + \varepsilon^I < -q^* \frac{\partial p\left(q^*, Y, \varepsilon^d; \alpha\right)}{\partial q} + c\left(q^*, W; \beta\right) + \varepsilon^s$$

- "Type 3" market: Imports-constrained regime where imports do occur ("low $T$"), characterized by $p^I < p^c$, or equivalently

$$c^I\left(W^I; \beta^I\right) + \varepsilon^I < c\left(q^c, W; \beta\right) + \varepsilon^s$$

The model can be estimated by Maximum Likelihood, given structural assumptions regarding supply behavior (e.g., domestic monopoly), functional form and the distribution of the errors. Let the subscript $t = 1, ..., N$ index market observations. In what follows, I condition the likelihood of observing the limited dependent variable $p = p_t$ on the (inferred) curvature of demand. A consistent estimate of $\partial p/\partial q$ can be obtained by 2SLS in an earlier stage, and then bootstrapped standard errors can be calculated for the supply estimates to account for the sampling variation in demand. (An alternative to this two-step procedure is to estimate demand along with supply by ML.) Make the distributional assumption that the mean-zero supply shocks $\varepsilon^s, \varepsilon^I$ are i.i.d. normal, with respective variance $\sigma_s^2, \sigma_I^2$. Let $\omega := \left\{\beta, \sigma_s, \beta^I, \sigma_I\right\}$ denote the vector of supply parameters to be estimated, and write[8]

$$\begin{array}{rrcl} \text{[unconstrained regime]} & \varepsilon^s & = & p + q\widehat{\partial p/\partial q} - c(q, W; \beta) \equiv S\left(p, q, \widehat{\partial p/\partial q}, W; \beta\right) \\ \text{[constrained regime]} & \varepsilon^I & = & p - c^I(W^I; \beta^I) \equiv I\left(p, W^I; \beta^I\right) \end{array}$$

Since the unconstrained regime (i.e., a type 1 market where $p = p^* = p_t \leq p^I$) and the constrained regime (a type 2 or type 3 market where $p = p^I = p_t < p^*$) are mutually exclusive events, the conditional likelihood is the sum of two terms:

$$L(p = p_t | \, q_t, \widehat{\partial p/\partial q}_t, W_t, W_t^I; \omega) = \Pr(\text{unconstrained} \cap p = p_t) + \Pr(\text{constrained} \cap p = p_t)$$

where, denoting the determinants of the appropriate Jacobians by $|J^s|$ and $\left|J^I\right|$ (to

[8] Thus $S\left(.\right)$ provides the $\varepsilon^s$ that explains $p$ conditional on the regime being unconstrained (i.e., a type 1 market) and the domestic supply parameters (besides data and demand). Similarly, $I\left(.\right)$ conditions on the regime being constrained (a type 2 or type 3 market).

account for the transformation in random variables[9]),

$$\begin{aligned}\Pr\left(\text{unconstrained} \cap p = p_t\right) &= \Pr\left(p^I \geq p_t\right)\Pr\left(p^* = p_t\right)\\ &= \Phi\left(\frac{-I\left(p_t, W_t^I; \beta^I\right)}{\sigma_I}\right)\phi\left(\frac{S(p_t, q_t, \widehat{\partial p/\partial q_t}, W_t; \beta)}{\sigma_s}\right)\frac{1}{\sigma_s}\left|J^s\right|\end{aligned}$$

and

$$\begin{aligned}\Pr\left(\text{constrained} \cap p = p_t\right) &= \Pr\left(p^* > p_t\right)\Pr\left(p^I = p_t\right)\\ &= \Phi\left(\frac{-S(p_t, q_t, \widehat{\partial p/\partial q_t}, W_t; \beta)}{\sigma_s}\right)\phi\left(\frac{I\left(p_t, W_t^I; \beta^I\right)}{\sigma_I}\right)\frac{1}{\sigma_I}\left|J^I\right|\end{aligned}$$

The implied probability that a market $t$ is unconstrained is given by the relative contribution of the first term to the likelihood, i.e., $\Pr\left(\text{unconstrained} \cap p = p_t\right)/L(p = p_t|\,.)$. The log likelihood function is then given by

$$\log L = \log\left(\prod_{t=1}^{N} L(p = p_t|\, q_t, \widehat{\partial p/\partial q_t}, W_t, W_t^I; \omega)\right) = \sum_{t=1}^{N} \log L\left(p = p_t|\, q_t, \widehat{\partial p/\partial q_t}, W_t, W_t^I; \omega\right) \tag{7}$$

Salvo (2010a) reports results from Monte Carlo experiments indicating that the structural model can be consistently estimated by this procedure. The present context is reminiscent of disequilibrium models à la Goldfeld and Quandt (1975) and Kiefer (1979), where observed quantity is given by min(Demand($p, X^d, \varepsilon^d$), Supply($p, X^s, \varepsilon^s$)), and covariates $X$ and prices $p$ are observed while $\varepsilon$ is unobserved (a setup to be compared to the present data generating process (6).) Unlike Lee and Porter (1984) and Ellison (1994), the regime switch here is endogenous, i.e., the regime (unconstrained, constrained) depends on the realization of $\varepsilon^s, \varepsilon^I$. Also, unlike models of the tobit kind, the threshold here fluctuates and is unobserved, i.e., $p^*$ and $p^I$ are latent.

Finally, notice that in the specific situation where the econometrician observes the breakdown of local consumption $q$ among domestic supply $q^s$ and foreign supply $q^I$, the observable distinction between type 2 markets (where $q^I = 0$ is observed) and type 3 markets ($q^I > 0$ observed), conditional on the constrained regime, can be reflected in the likelihood function to improve estimation efficiency.

## 2.3 Testing alternative structural models

Non-nested model selection tests can then be applied to select among candidate data generating processes, with Vuong's (1989) likelihood ratio tests being a natural choice

[9] In the imports pricing equation (5), since $c^I(.)$ is exogenous and thus $\partial\varepsilon^I/\partial p^I = 1$, $\left|J^I\right| = 1$.

in the above ML framework. In light of the subsequent empirical example, consider a setting where a researcher observes a domestic industry in which foreign entry has not actually occurred, yet he suspects that the threat of foreign entry constrains a subset of market outcomes. That is, by observing zero import quantities the researcher can rule out type 3 markets (over time or in geographic space), but wants to allow for the presence of type 2 markets in addition to type 1 markets. In a highly concentrated industry, the researcher might want to test the hypothesis of, say, a local monopoly (or Cournot oligopoly) that is shielded from foreign competition—i.e., DGP (3)—against the alternative and more general model of a local monopoly (or Cournot oligopoly) that faces latent import competition—i.e., DGP (6).

Should both domestic and foreign producers purchase some key inputs that are traded internationally (e.g., oil), or should they incur some common costs (e.g., inland distribution, incurred beyond plant or port), it is likely that domestic cost-shifters $W$ and imports cost-shifters $W^I$ will be correlated. In this case, data generated by a domestic monopoly where the import price ceiling binds in many markets—and thus $p = c^I\left(W^I; \beta^I\right) + \varepsilon^I$—may appear, to the naked eye, to have been generated by a competitive domestic industry—where $p = c\left(q, W; \beta\right) + \varepsilon^s$. For this reason, the researcher would want to formally test the constrained monopoly (or oligopoly) hypothesis (6) against the alternative non-nested model of a competitive domestic industry, given by DGP (4). I return to this in Section 3.4.

# 3 An empirical cross-country example

## 3.1 Comparing the United States and Brazilian cement industries: Similarities and differences

U.S. cement consumption is more than twice that in Brazil.[10] In 1999, for example, consumption of portland cement amounted to 104 million tons (mt) in the U.S. (midyear resident population 273 m) and 40 mt in Brazil (population 169 m), translating into per capita consumption levels of 382 kg and 237 kg respectively. Several features are common across both countries' cement industries. They sell essentially the same homogeneous good,[11] whose bulkiness relative to value makes transport a key component of cost.

[10] See the appendix for data sources and treatment. Quantity data are obtained mainly from the U.S. Geological Survey (Department of the Interior) and the Brazilian cement producers' trade association (SNIC)—the latter data being considerably richer, as I subsequently explain. Ryan (2006), Hortaçsu and Syverson (2007) and Salvo (2010a) provide further institutional details of the cement industries in either country.

[11] This is true down to the level of the specific type or formulation of cement: in 1999, for example, ordinary (defined as "general use and moderate heat, types I and II") cement's share of total portland cement shipments to domestic customers amounted to 90% in the U.S. and 82% in Brazil.

Both industries operate in countries of continental dimensions—the U.S.'s land mass being slightly larger than that of the Brazil. For historical reasons, a large proportion of each country's consumers are located in close proximity to waterways: in states along the East, West and Gulf Coasts and the Mississippi Basin in the case of the U.S., and in states along a vast 4,655 mile-long Atlantic coastline in the case of Brazil (Brazil's northwestern states remain largely covered with jungle and are sparsely populated, despite several being somewhat accessible by river). This similar prevalence of "coastal" local markets in the two countries is important since transporting cement by water is substantially cheaper than by road or by rail. These markets are thus the natural candidates for imports to penetrate. (See Maps 1 and 2.)

Several differences are noteworthy. In the U.S., the representative buyer is a ready-mix concrete firm that acquires cement in bulk form. In 1999, for example, ready-mix operations accounted for 73% of the country's cement purchases. By contrast, cement in Brazil is typically distributed in 50 kg bags through several hundred thousand resellers. In aggregate, these local neighborhood stores accounted for 77% of Brazil's cement purchases in 1999, with only 11% accruing to ready-mix concrete firms. The U.S. also exhibits lower concentration of ownership of production assets, with the top 5 firms concentrating 41% of U.S. production in 1999, to be compared to Brazil where the leading firm alone accounted for this high a share of nationwide production. That year, as the maps indicate, 115 plants in the U.S. were owned by 40 firms, while 57 plants in Brazil were owned by 12 firms.

Consistent with the strikingly different levels of import penetration, as I detail next, there are several reasons to suggest that the ratio of domestic plant marginal cost to inbound trade costs is considerably higher in the U.S. than in Brazil. First, having developed earlier, the U.S. industry tends to use more dated technology relative to the more youthful Brazilian industry, which has enjoyed access to modern equipment thanks to this being an industry where technology is mostly purchased off-the-shelf rather than developed inside the firm. For example, in 1999, the average age of kilns in operation was 33 years in the U.S. and 21 years in Brazil; the average annual capacity per kiln in operation was 0.40 mt in the U.S. and 0.56 mt in Brazil.[12] That year, a large 25% of total U.S. kiln capacity still employed the obsolete "wet" process—which consumes more than double the energy required by the modern "dry" process—compared to only 6% for Brazilian capacity. Second, the U.S. industry faces more stringent environmental restrictions relative to its Brazilian counterpart, not least by local communities which resist the industry's plans to expand capacity, fearful of its poor environmental record, such as regarding emissions of cement kiln dust (CKD). Third,

[12] Owing to scale economies, technology over the past decades has been advancing in the direction of bigger and more energy efficient kilns; new plants have been moving away from multiple small (kiln) lines toward single large lines.

despite marked improvements in recent years, Brazil is notorious for the inefficiency of its ports, adding to import trade costs relative to that in the U.S.[13] Fourth, less competition among international shippers on trade routes to Latin America relative to routes to the U.S. should again lead to higher inbound trade costs for Brazil (Hummels et al 2009). The widespread distribution of cement in bags via resellers rather than in bulk to ready-mix concrete firms also contributes to higher import costs in Brazil compared to import costs in the U.S.

**Starkly different levels of import penetration** In terms of traded cement (and the high-value intermediate product clinker), a small share of each country's production is exported—typically less than 1%. While this share remains stable in the U.S., Brazil's exports have recently been growing, reaching 4% of production in 2006 (primarily on the back of exports from Brazil's northeastern region to southern U.S. markets). Most striking is the difference in the imported quantity of cement and clinker across the two countries. The top panel of Figure 2 reports how the U.S. imports a large share of its cement needs, recently reaching almost 30% of domestic consumption.[14] Though import quantity data by local market destination are not available, this average figure probably masks considerably higher import shares in several U.S. coastal markets. In sharp contrast, Brazil barely imports cement, as the bottom panel of the figure indicates (scales are comparable to the U.S.). In Brazil, cement and clinker imports have hovered around 1% of domestic consumption (even after adjusting Brazil's import quantities upward relative to official figures, to reflect the fact that imported clinker has predominantly been used to produce slag cement[15]).

Over the years, neighboring Canada has naturally been a key cement supplier to the U.S., with imports from Mexico and Venezuela having been somewhat held back by

[13] In a cross-country study ($N = 150$) on trade logistics which includes the efficiency of customs procedures, costs, and the quality of infrastructure, the World Bank (2007) ranks Brazil as 61st. Revealingly, South Africa ranks 24th, China 30th and India 39th. See, also, the Economist (2006).

[14] In fact, imports have hovered around 10-20% of U.S. cement consumption since the 1980s (Carlsson 2001). The development of specialized seaborne handling and transportation in the 1970s gave rise to global trade in cement (Dumez and Jeunemaître 2000). U.S. Geological Survey (2000), for example, describes "both clinker and cement (as) widely traded" (p.2). Industry analyst Roy (2002) describes the costless entry and exit nature of imports: "...self-unloading ocean-going cement silo ships have made international trade in cement far more economical... International cement trade is not only intracompany... Independent contracting is also widely used... Few US ports ALWAYS receive significant cement imports. It is far more typical to receive imports only in peak demand periods when local supply cannot meet cement demand" (pp.76-77; original emphasis). Citing "hundreds of independents...in place", the Economist (1999) argues that the wave of global acquisitions by large multinationals is partly aimed at reducing the "risk (of) having to compete with cheap imported cement in their home markets".

[15] Unlike the U.S. where clinker has accounted for only about 15% of total imports, Brazil's clinker imports exceeded cement imports in certain years. For Brazil I consider that four-fifths of imported clinker was used to produce a blend of 60% blast furnace slag and 40% clinker, rather than ordinary cement (with a much higher 96% clinker content). I thus add (upward-adjusted) clinker imports to cement imports, inflating Brazil's import penetration.

persistent antidumping protection. But in the past decade Asia has become a major supplier, accounting for 40% of U.S. imports by the turn of the century. In 1999, for example, Asia (e.g., China, Thailand and Korea) accounted for 38% of U.S. cement imports, the Americas 34% and Europe 27% (e.g., Greece, Spain and Turkey). Map 1 indicates the U.S. ports through which cement and clinker have actually been imported in the period 1994 to 2005.

At a much lower level, actual imports of ordinary cement in Brazil in the period 1996-2006 have occurred primarily in the northern jungle state of Amazonas (AM, by river from Venezuela and Cuba to the north), in the southeastern state of São Paulo (SP, by water from Europe) and in the southern state of Rio Grande do Sul (RS, by road from Uruguai to the south). (See Map 2.) As for Brazil's actual imports of clinker, the two main ports of entry have been the southeastern states of Espírito Santo (ES) and SP, importing mainly from Asia. Clinker has primarily been imported by a handful of independent grinders who were deftly able to enter into long-term contracts with steel producers for the provision of blast furnace slag, at a time in which slag was considered worthless. To lower their clinker requirement, these grinders then mix slag with ground clinker to produce slag cement, a close substitute for the predominant ordinary cement in most types of user applications. Intriguingly, the two largest independents—Cimento Mizú set up in 1998 in the state of ES with slag cement capacity of 0.7 mtpa, and Cimento Davi set up in 2001 in the southeastern state of Minas Gerais (MG) with capacity of 0.4 mtpa—were simultaneously acquired in 2006 by leading incumbents in the southeast—Votorantim and Lafarge respectively. The acquisitions followed a period in which cement prices in local markets served by these independents (the southeastern states of ES, MG and Rio de Janeiro, RJ) fell relative to cement prices in other local markets, suggesting that a price war may have occurred.

Much anecdotal evidence suggests that despite the very low level of actual foreign entry relative to the U.S., the *threat* of foreign entry restrains prices in Brazil's local cement markets. Interviews by the author[16] revealed stories about how incumbents have so far largely managed to keep imports at bay, including buying up and scrapping (with the support of local government, on "work safety" grounds) floating cement handling terminals that had been shipped from Europe, or warning large customers who had been approached by cement traders seeking to consolidate import orders that in future periods of "probable" tight capacity the domestic industry would favor those customers who had stayed loyal to them. Equity analyst Zaghen (1997), for example, writes: "(a)lthough imports accounted for only 1.6% of total Brazilian consumption in 1995, reaching 451

[16]These included representatives of: (i) the domestic cement industry (executives, salespeople); (ii) the industry's trade association (SNIC and its technical arm ABCP); (iii) importers (executives at independent imported clinker grinders Mizú, Davi and Cimec, as well as an international trader who actually imported cement); (iv) cement buyers (ready-mix concrete firms, construction firms, concrete product manufacturers, resellers); and (v) local construction sector trade associations (SINDUSCONs).

thousand tons, they represent a constant threat to domestic producers, pressing down domestic prices and imposing a price ceiling of US$ 70 per ton" (p. 24). (The author refers to the CIF price—see below. See also Gazeta Mercantil 1998.) An interview with a top executive for a leading cement producer in 2003 revealed that the industry was concerned about "lots of import start-ups being planned"; on being asked why "in contrast to the U.S., the Brazilian industry had been able to keep imports at bay", the executive added "well, until the present time". Less anecdotal evidence that domestic producers were threatened by imports is their successful lobbying of federal government in passing antidumping measures—namely a 23% import tariff—in the late 1990s against Venezuelan and Mexican cement producers who were starting to make inroads into local markets particularly in the north and northeast of the country.

While certainly valuable, this paper does not take the anecdotal route. Rather, I offer strong econometric evidence that supports the latent imports-as-market-discipline hypothesis in Brazil. Before that, however, I provide some stylized facts about price variation across and within the two countries.

**Price variation across and within the United States and Brazil** Figure 3 reports the evolution of cement prices in the U.S. and in Brazil, at varying points of the supply chain as per data availability. (Prices are in constant Dec-1999 U.S. CPI US$ per ton: see the data appendix for details.) For the U.S., I observe (in descending order of average price) (i) the producer price delivered to the buyer (for some cities), (ii) the producer price ex-plant (for cement-producing districts), and (iii) the actual CIF (cost, insurance and freight) import price (for ports of entry through which cement or clinker has been imported). To roughly control for differences in data availability, the figure depicts average prices for cities, districts or ports located in East and Gulf Coast states only. The three time series are somewhat correlated, with means (1992 to 2006) of US$ 76 producer delivered, US$ 70 producer ex-plant and US$ 53 importer CIF port. A lower delivered producer price relative to ex-plant price in two of the years is odd, and probably owes to differences in aggregation or measurement error. For example, the delivered price, provided by a construction trade publication, is quoted from a single buyer. The lower import prices are to be expected since the CIF data do not include unloading costs nor customs duties (the latter being mildly positive due to antidumping duties that were in effect); further, the import prices include clinker—15% of total imports—which still needs to be ground into cement.

For Brazil, I observe a rich monthly state-level panel of retail prices (i.e. shelf price at resellers), but do not observe producer prices. However, assuming that producers do not evade sales tax (which is included in the producer's invoice to the reseller but collected by the producer) and a plausible assumption (based on field interviews) on the reseller's gross margin, I can back out the delivered producer price (net of sales tax). In so doing, a high mean retail price of US$ 128 (for 17 coastline states) reduces to a mean delivered producer price of US$ 84. Relative to producer prices in the U.S. (a mean of US$ 76, as above), producer prices in Brazil were higher until 1997, similar or somewhat lower over the next 5 years, and higher thereafter. The temporary dip in the Brazilian cement price in US$ in 1999 owes to a large bout of devaluation—the Brazilian currency crisis—that the domestic industry chose not to pass through immediately onto prices. As I argue below, though the import price ceiling in local currency Reais (R$) would have risen in line with the exchange rate, the industry may have been wary that marking domestic prices up immediately—as opposed to gradually—would attract negative publicity. It is noteworthy that, even at this level of aggregation and including the temporary dip in 1999, producer prices in Brazil correlate well with actual import prices in the U.S.: the correlation coefficient is 0.79. This is consistent with the imports discipline hypothesis for Brazil, to the extent that the actual U.S. import price is a good proxy for the world price of cement and thus for the latent price ceiling in Brazil.[17]

Finally, Figures 4 and 5 provide a sense of within-country spatial price variation for the U.S. and for Brazil respectively (Brazil prices are now in constant Dec-1999 Brazil GPI R$ per bag). In neither country, using the data available, is there a clear (unconditional) correlation between the price of cement and seller concentration at the local market level—see the top panel of each of Figures 4 and 5. (In the U.S. case, I do not observe plant-to-market shipments, so I cannot calculate local HHIs based on firms' quantity shares. Instead I use the capacities of firms' plants located within each district in 1999: this is at best a rough approximation for seller concentration as it assumes away cross-district flows including imports and assumes equal capacity utilization.) At the observed market aggregation, cement prices are no higher in the more concentrated markets—e.g. districts OR/WA and OH in the U.S. and states AM and Roraima (RR) in Brazil—relative to the less concentrated ones—e.g. districts TX and CA in the U.S. and states MG and RJ in Brazil. This is consistent with the hypothesis of an import price ceiling binding in each of the two countries.

The bottom panels of Figures 4 and 5 indicate how the price of cement varies in the market's road distance from a port of entry. In the U.S. case, I group the 20 cities for which I observe (delivered producer) prices into (i) 13 port cities through which imports have entered, and (ii) 7 cities located at a distance (255 miles on average) from a port of entry.[18] The two series are tightly correlated, with prices in the latter remote cities being

[17]For the reasons mentioned above (e.g., less competitive maritime freight), I would expect the latent CIF prices for Brazil to exceed the observed CIF prices for the U.S.

[18]Port cities (the first group) are Baltimore MD, Boston MA, Chicago IL, Cleveland OH, Detroit MI, Los Angeles CA, Minneapolis MN, New Orleans LA, New York NY, Philadelphia PA, St Louis MO, San Francisco CA and Seattle WA. Non-port cities (the second group) are Atlanta GA, Birmingham AL, Cincinnati OH, Dallas TX, Denver CO, Kansas City KS and Pittsburgh PA.

somewhat higher (in the period Jan-1992 to Dec-2006, a mean of US$ 79 per ton against US$ 76). I interpret this as again being consistent with the price ceiling hypothesis—it may be that the more removed cities include a greater proportion of type 2 (constrained regime in which imports do not occur) relative to type 3 markets. In the case of Brazil, (retail) prices are also higher in the market's distance from a border port—witness the states of Rondônia (RO) and Acre (AC) (further west of RO, not even shown in Map 2). Take the average annual prices between 1991 to 2006 for each of Brazil's 27 states: a regression of these 432 market-year prices on distance from the nearest port of entry (in 1000 miles) and a set of year dummies yields a distance coefficient of 0.94 with standard error of 0.07. It is noteworthy that prices are quite uniform along the many coastal states—in Figure 5, witness the agglomeration of points around a distance of zero, including quasi-monopolistic states such as Santa Catarina (SC) and Sergipe (SE) where the one-firm sales concentration ratio is 80%. I again interpret these stylized facts as being consistent with the latent import competition hypothesis.[19]

## 3.2 Demand analysis in the United States and in Brazil: Low elasticities in equilibrium

The first piece of econometric evidence that offers support for the latent imports-as-market-discipline hypothesis in Brazilian cement stems from the estimation of market demand. As I discuss, the very low equilibrium price elasticities of demand that are estimated across Brazil's local markets, including markets where the supply of cement is quasi-monopolistic, can be rationalized by reference to a binding price limit in the industry. Demand estimation is also the first stage in fitting alternative models of supply behavior in Section 3.4.I thus also estimate demand elasticities across local U.S. markets (using the best data available[20]).

**Setup** There are $L$ geographic markets, indexed by $l = 1, ..., L$. Scattered across these $L$ markets are $I$ plants, indexed by $i = 1, ..., I$. Let $i = 0$ index the aggregate fringe of foreign suppliers. The flow of cement is contained 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 $i$ to market $l$ in that time period. Given cement's short shelf life (relative to

[19] These facts are also consistent with other behavioral models, e.g., domestic competition might generate uniform prices along coastal states regardless of concentration, as well as prices that increase in the distance from the coast (assuming some inputs might be imported or shipped over from the populated coastal states). But I will allow for these other models when testing for the data generating process.

[20] To be clear, it is the unusually supplier-disaggregated plant-$i$-to-market-$l$ shipment panel data $q_{ilt}$ that are available only for Brazil. As such, supply can be estimated *without* requiring restrictive assumptions on the spatial flow of cement, such as assuming that each local market is served only by plants located within its borders.

the time period), I take total period $t$ shipments to market $l$, $q_{lt} = \sum_{i=0}^{I} q_{ilt}$, to equal the market's consumption that period. The market demand function can be written:

$$q_{lt} = D(p_{lt}, Y_{lt}, \varepsilon_{lt}^{d}; \alpha_l) \tag{8}$$

where $p_{lt}$ is the price of cement to the buyer, $Y_{lt}$ are exogenous variables moving demand (i.e. construction activity, including seasonality), $\varepsilon_{lt}^{d}$ is the econometric error term and $\alpha_l$ are market-specific parameters.

As detailed in the data appendix, I observe $q_{lt}$ and $p_{lt}$ for both countries. However, while I observe monthly consumption and prices for each of Brazil's 27 states over the period Jan-1991 to Dec-2006, such panel data for the U.S. are not as rich. In particular, U.S. cement prices (since 1994) are available either at an aggregated annual frequency for 26 districts, or at a monthly frequency for only 20 cities. Depending on the richness of the data for each country, I can estimate different specifications for (8). I adopt a linear fixed-effects panel specification as the baseline

$$q_{lt} = \alpha_{1l} + \alpha_2 Y_{lt} + \alpha_3 p_{lt} + \alpha_4 Y_{lt} p_{lt} + \varepsilon_{lt}^{d} \tag{9}$$

I can further restrict (9) in a theoretically-plausible way. Say that the "nature" of cement demand is similar across local markets such that the (linear) demand curve for local market $l$ swivels round a common price intercept—determined by a common highest-valuation buyer—according to the local market's construction activity (or population) $Y_{lt}$. As demand changes multiplicatively with $Y_{lt}$, i.e., $p_{lt} = \tilde{\alpha}_1 + \tilde{\alpha}_2 Y_{lt}^{-1} q_{lt}$, this "restricted panel" demand function becomes

$$q_{lt} = \bar{\alpha}_1 Y_{lt} + \bar{\alpha}_2 Y_{lt} p_{lt} + \varepsilon_{lt}^{d} \tag{10}$$

where the quantity intercept and the coefficient on the price level term have been restricted to zero. Intuitively, the inverse demand curve $p(q)$ for a local market $l$ that is twice the size of market $l'$ would have the same price intercept but half the slope. Additionally, I can estimate (as I do for Brazil) the less restrictive market-specific version of (9), where coefficients vary by local market $\alpha_i = \alpha_{il}$, $\forall i = 1, ..., 4$, as well as test whether estimates are robust to different functional forms (e.g., loglinear rather than linear demand).

Since prices are endogenous, (8) is instrumented with supply shifters, namely domestic factor prices $W$ and/or import factor prices $W^I$. As explained previously, $W$ and $W^I$ are correlated either because some inputs are tradable (e.g., domestic kiln fuel prices following world energy prices to a large extent in the U.S. or to some extent in Brazil) or because domestic and imported cement delivered to the buyer have a common cost component (e.g. inland freight prices).

**Estimates for the United States** [TO BE COMPLETED]

Result: Inelastic demand in equilibrium. Compare to Jans and Rosenbaum (1996) who report an average $-0.81$ across 25 regional U.S. markets.

**Estimates for Brazil** Price elasticities of demand across Brazil's local markets (identified with states), estimated by 2SLS, are reported in Table 1. Column I reports elasticities for the linear panel specification (9) with market fixed effects, and column II restricts the specification according to (10). Owing to possible measurement error (in prices mainly), specification I considers the 17 essentially coastal markets as panel units, dropping the 10 sparsely populated jungle states that together account for 60% of the country's land mass but only 12% of its cement consumption.[21] Elasticities are significantly low, economically and statistically, in the order of $-0.1$ to $-0.2$ (and insignificant for the smaller states). To check robustness, the restricted specification II considers all 27 states: elasticities are higher (in absolute value), but still in the order of $-0.2$ to $-0.4$. Columns III and IV report estimates for the flexible individual state regressions, using linear and loglinear functional forms respectively. Elasticities are no higher than $-0.5$ with two interesting exceptions: the remote and higher price states of RO and AC (recall Map 2 and Figure 5), with elasticities of $-0.6$ and $-1.2$ respectively. While the higher elasticities in the remote states of RO and AC are certainly suggestive of a higher price ceiling, I note that any evidence from jungle states should be counterbalanced by the possibility of measurement error.[22]

**Discussion: Evidence of a binding price ceiling** Other studies of the cement industry have found low market price elasticities of demand. For example, Jans and Rosenbaum (1996) report an average $-0.81$ across 25 regional U.S. markets (and Röller and Steen 2006 find an elasticity of $-0.46$ for Norway). The (inverse) demand curve for cement is well known to be steep, owing to the product's typically low share of construction budgets and the absence of close substitutes (except in highway construction, where asphalt is a substitute). But while necessary, a steep demand curve is not sufficient to explain why demand is inelastic *at the equilibrium*. Why does an industry facing such inelastic demand not cut output to raise prices to a point where demand is more elastic? One possibility is that there is tough competition among incumbents such that the

[21] For example, price auditors working for the country's statistical agency may limit their coverage to a few more-acessible locations in these states. As a point of comparison, despite being long established in Brazil, the global market research firm Nielsen does not audit jungle states due to their unusual geodemographic characteristics. (On compiling a state's consumption quantities, however, I still consider sourcing from anywhere.)

[22] For example, the estimated elasticity for the state of AP is positive and large (+0.6). This may be due to measurement error in prices (as explained), in construction activity (its very small market size: 0.2% of nationwide consumption) or in consumption (the possibility of cement smuggled in from French Guiana or Suriname to the north, given its remote location and dense jungle).

residual demand each *individual firm* faces is elastic. For example, low concentration would imply that any firm internalizes only a small fraction of the aggregate benefit (of the large price rise) that would result from a (small) reduction in output; in equilibrium the price then remains at a level consistent with aggregate demand being inelastic.

This possibility that competition among incumbent sellers drives prices down to their marginal cost is more plausible in the U.S. case than it is in the case of Brazil. In the U.S., cement producers not only compete with independent cement importers but also import cement to distribute it themselves, thus seeing foreign capacity as a cheaper alternative to their own high-cost marginal capacity. The combination of imports by (plausibly competitive) independents and imports by U.S. producers suggests that the marginal cost of swing U.S. plant capacity may be similar to domestic prices—recall the left panel of Figure 1. In contrast, the hypothesis of competition among incumbents to explain inelastic market demand in equilibrium in Brazil is hard to square with the higher seller concentration. Though I will formally test—and reject—this hypothesis of domestic competition in Section 3.4, for now I note that market elasticities are systematically low across local markets, including quasi-monopolistic markets such as Santa Catarina (SC) and Sergipe (SE) where the one-firm sales concentration ratio is as high as 80%. Further, Salvo (2010a) combines the disaggregated plant-to-market shipment data with engineering parameters of the simple production technology and factor prices (including transport costs), finding price-cost margins that amount to around 50% of delivered producer prices (net of sales tax). Salvo (2010b) analyzes the spatial supply decisions of domestic cement producers, uncovering evidence of a collusive geographic market division ("market swapping") scheme.[23]

Another possibility, which I subsequently test directly, and do not reject, is the occurrence of limit pricing. While market demand at the price ceiling happens to be inelastic, the residual demand which the *domestic industry* faces at the ceiling is highly elastic. Attempts by the domestic industry, already enjoying a large price-cost margin, to raise prices above this ceiling would only invite foreign entry.[24]

## 3.3 Domestic versus import competition in Brazil

[NOTE: ESTIMATES FOR THE US WILL BE ADDED IN THE NEXT VERSION]

[23] In 2007, Brazil's Antitrust Authorities brought a high-profile case against the cement industry, on charges of explicitly forming a cartel to divide regional markets and fix prices. The authorities claimed to have gathered "conclusive" direct evidence, including company documents seized during police raids, records of private meetings, and testimonies by whistleblowers (Agência Estado 2007). As of early 2010, the case had not yet been taken to court.

[24] A third possibility hinges on a very special class of models of spatial competition, à la Hotelling-Salop, where a firm sets only a "mill" price and cannot price discriminate over space. The restrictive nature of pricing then ensures that a low *market* price elasticity of demand does not translate into a low price elasticity of demand faced by the *firm*.

In the remainder of the paper, I use the detailed supply data that I observe for Brazil to examine the data generating process. As a preview to the final section's testing of the hypothesis of latent import competition, this section provides an intuitive sense of how well variables that move the marginal cost of imports explain domestic cement prices, and contrast this to how well cement prices are explained by variables that move the domestic industry's marginal cost.

Table 2 reports estimates of OLS regressions and their $R^2$. Columns I and II adopt fixed effects panel regressions and columns III and IV summarize their individual state-level counterparts (i.e. a separate regression for each state). (I consider all 27 states and 192 months between Jan-1991 and Dec-2006.) Column I (column III), which may be viewed as a benchmark, assumes that the Brazilian cement industry is perfectly competitive and that prices are driven down to the domestic industry's marginal cost. Here I implement a behavioral model where domestic marginal cost is constant in output and linear in domestic factor prices, i.e. the regression equation is $p = W\beta + \varepsilon^s$. Column II (column IV) takes import competition as the behavioral model, assuming that the import price ceiling binds in all markets and, as such, that cement prices are determined by the import marginal cost. I implement the linear model $p = W^I\beta^I + \varepsilon^I$.

In column I, the explanatory power of domestic cost-shifters $W$ is quite high, with an $R^2$ of 46%. $W$ includes domestic factor prices and other supply-shifters, namely (see the data appendix for further details; all prices in constant Dec-1999 Brazil GPI R$): (i) the price of oil-based kiln fuel (an index that tracks the domestic price of fuel oil until 1999 and green pet coke thereafter, given the domestic industry's energy usage); (ii) the price of coal-based kiln fuel; (iii) the price of electricity for grinding raw material and clinker; (iv) manufacturing wages; (v) the price of diesel oil for road transport (the predominant mode of shipment to buyers); (vi) a dummy variable to account for price controls in the first ten months of 1991; and (vii) a set of state fixed effects.

Estimated coefficients are significantly different from zero at the 1% level, though signs on wages and diesel are negative.[25] The fact that the $R^2$ remains quite high at 31% when the state fixed effects are dropped is consistent with prices being quite uniform across Brazil's local markets, most of which are located along or in proximity to waterways. Column III indicates the $R^2$ of the same regression equation taken to the data for each panel unit separately. To illustrate, the top panel of Figure 6 plots the actual cement price in the state of SP alongside its projection onto $W$, revealing that the fit is quite good (an $R^2$ of 51% from column III of Table 2).

In column II, the explanatory power of imports cost-shifters $W^I$ is considerably

[25] The negative sign on the price of diesel owes to the high correlation with kiln fuel: the sign on the former turns positive and significant on dropping the latter from the regression. The negative sign on wages is harder to rationalize, though one could try a rent-sharing story, as in Clark (1980).

higher, with an $R^2$ of 71%. $W^I$ includes (i) the local currency R$ exchange rate against the US dollar; (ii) the world crude oil price proxied by the West Texas Intermediate (converted to R$); (iii) the price of maritime bulk freight proxied by the Baltic Dry Index (converted to R$); (iv) the (domestic) price of diesel oil for inland distribution interacted with the market's distance from the nearest port of entry; (v) the cost of import finance/bank letter of credit proxied by the (real) yield on Brazilian Treasury bills; (vi) a dummy variable to control for short periods (9 months each) following three large unexpected bouts of devaluation during which the domestic industry would be wary that suddenly matching a higher limit price might be politically unpalatable (see below); (vii) the Jan-to-Oct-1991 price control dummy (common to $W$); and (viii) a set of state fixed effects (also common to $W$).

Estimated coefficients are highly significant and the signs are intuitive, with one exception: the diesel×distance interaction is negative, as it correlates with the world oil price and maritime freight.[26] Again, the approximate uniformity of spatial prices implies that the $R^2$ remains very high at 60% on dropping state fixed effects from the regression. This is illustrated in the bottom panel of Figure 6, where cement prices in the state of SP are projected onto $W^I$. The fit is very good. In fact, column IV of Table 2 indicates that the $R^2$ for separate regressions for the four largest consumer markets—the states of SP, MG, RJ and PR accounting for 58% of nationwide cement consumption—reaches 80%, to be compared to 51-64% using domestic cost-shifters.

Conditioning on the latent import competition hypothesis which I subsequently test, it is not surprising that domestic cost-shifters perform quite well, given their correlation with imports cost-shifters. For example, in addition to $W^I$ and $W$ having common components such as the price of diesel oil for inland distribution, world oil prices and domestic oil prices are highly correlated (e.g., the correlation coefficient between world crude and domestic diesel is 0.88, and that between world crude and domestic kiln fuel is 0.50). What is surprising is the very high predictive power of imports cost-shifters $W^I$ in explaining cement prices, suggesting that a very high proportion of (time-and geographic) markets may be constrained by the threat of imports. In particular, the predictive power of the single most important component of $W^I$, the exchange rate, is striking. The $R^2$ of a panel regression of cement prices on the exchange rate *alone* (but including state fixed effects) amounts to 48% (and 31% without the state fixed effects). This is comparable to the $R^2$ of the regression of cement prices on the *full* set

[26] Given the inclusion of market fixed effects, the diesel×distance coefficient is estimated off the time series variation in diesel prices. The coefficient becomes significantly positive on dropping the correlated world oil and maritime freight prices from the regression (and other coefficients hardly change, with the $R^2$ falling only slightly to 69%). Also, had I included the diesel price without the distance interaction, its coefficient would be significantly positive but now the world oil price would be significantly negative and maritime freight would be insignificant. As I explain below, what essentially drives the predictive power of $W^I$ is the exchange rate. Alternatively, dropping the market fixed effects makes the diesel×distance interaction significantly positive (recall the cross-section variation).

of domestic cost-shifters $W$! In terms of economic magnitude, the estimated coefficient on the exchange rate (5.11) multiplied by this covariate's mean value in the sample (1.72 R$/US$) accounts for 81% of the mean cement price in the sample (10.87 R$/bag), indicating a very high rate of pass-through.

To drive the point home, the bottom panel of Figure 7 plots the evolution of the cement price (again in the state of SP) alongside that of the exchange rate (notice that, being in constant R$, this series depicts the relative variation between the domestic price of the U.S. dollar and the average price of goods in the economy). The two series move closely in step despite large swings in Brazil's exchange rate. Notice that as the exchange rate has unexpectedly plummeted on three different occasions (the "Brazil crisis" in 1999, the "Argentina crisis" in 2001, and the run-up to the presidential elections of 2002), the pass-through into higher cement prices has been more gradual, suggesting that marking cement prices up to the exchange rate in the wake of devaluation is not friction free. For perspective, the evolution of the cement price alongside that of the domestic price of fuel oil (the largest cost component, burned in the kiln) is reported in the top panel. In recent years, as the local currency has been appreciating on the back of booming commodity exports, cement prices have been falling—consistent with the latent import competition hypothesis—whereas domestic oil prices (and world oil prices for that matter) have been rising or flat at best.

## 3.4 Selecting among behavioral models in Brazil

[NOTE: ESTIMATES FOR THE US WILL BE ADDED IN THE NEXT VERSION]

I now follow Section 2.3 to test among alternative non-nested models of the Brazilian cement industry (see, e.g., Bresnahan 1987, Gasmi, Laffont and Vuong 1992, and Villas-Boas 2007). I begin by outlining the baseline specification—"specification B"—and then specify the different behavioral models that, conditional on a choice of specification, I take to the data. Vuong (1989) tests are then used to statistically discriminate between each pair of structural models.

Let *specification* denote a choice over (i) functional form and exogenous covariates for demand; (ii) functional form and exogenous covariates for domestic marginal cost; (iii) functional form and exogenous covariates for import marginal cost; and (iv) the set of observations (i.e whether to include all local markets as panel units or exclude the sparsely-populated jungle states where measurement error may be higher, whether to include all months for which I have shipment data or exclude the early pre-stabilization period up to mid 1994 where inflation was high and thus measurement error may be higher—see the data appendix and the bottom panel of Figure 7). Given that demand is estimated in a first stage via 2SLS, a specification further includes a choice over (v) instruments for demand.

For example, specification B is chosen as follows: (i) demand is given by (10), the linear panel specification with the additional theoretically-plausible restriction that the coefficients on the intercept and the price level are zero, as in specification II of Table 1; (ii) domestic marginal cost is flat in output (and again coefficients do not vary cross-sectionally), as in specification I of Table 2:

$$c(q_{lt}, W_{lt}; \beta) = c(W_{lt}; \beta) = W_{lt}\beta$$

where $W_{lt}$ includes domestic factor prices (similar to Section 3.3: fuel oil and coal interacted with respective usage in the kilns supplying each market, electricity for grinding, manufacturing wages, diesel oil for delivery interacted with the market's average distance from sourcing plants) and other supply-shifters (size and age of sourcing plants, a dummy to account for price controls in the first ten months of 1991, a set of state fixed effects); (iii) import marginal cost follows specification II of Table 2:

$$c^I\left(W^I_{lt}; \beta^I\right) = W^I_{lt}\beta^I$$

where $W^I_{lt}$ includes import factor prices (the exchange rate, the world oil price, the price of maritime bulk freight, the domestic diesel oil price interacted with the market's road distance from the nearest port of entry, the cost of import finance/bank letter of credit, a dummy to account for gradual and thus politically palatable pass-through rates after three unexpected bouts of devaluation) and other supply-shifters (a dummy to account for price controls in the first ten months of 1991, a set of state fixed effects); (iv) all 27 states including the jungle states and all 156 months between Jan-1991 and Dec-2003, i.e. the period over which I observe plant-to-market shipments[27]; and, finally, (v) a combination of $W_{lt}$ and $W^I_{lt}$ as demand instruments (domestic prices for fuel oil, coal, labor and transportation, the price control dummy and the exchange rate).

Given a specification, and conditional on the 2SLS estimation of demand in a first stage, I separately fit the following five *behavioral models* for the domestic industry:

Model 1 [Mixture model of constrained monopoly] A domestic monopoly that is partially constrained by import competition, where the DGP is given by (6). This structural model is estimated by ML, as explained above. The reduced-form function for the

[27] Thus, unfortunately, I cannot include Jan-2004 to Dec-2006. From the preceding section, I conjecture that including these markets would only reinforce my subsequent finding of latent import competition (recall Figure 6, with cement prices falling in tandem with the appreciation of the exchange rate, while domestic oil prices are rising or at best flat).

autarkic monopoly price $p^*$ for the example of specification B is given by

$$2p^* = -\left(\frac{\alpha_1 Y + \varepsilon^d}{\alpha_2 Y}\right) + W\beta + \varepsilon^s$$

(where time-and-geographic market subscripts $lt$ are omitted for simplicity)

Model 2 [Mixture model of constrained Cournot oligopoly] A domestic (symmetric) Cournot oligopoly that is partially constrained by import competition, where DGP (6) is modified to

$$p = \min\left(p^*, p^I\right) = \min\left(-\frac{1}{F}q^*\frac{\partial p(q^*, Y, \varepsilon^d; \alpha)}{\partial q} + c(q^*, W; \beta) + \varepsilon^s, W^I\beta^I + \varepsilon^I)\right)$$

(again omitting market subscripts for simplicity) where now the asterisk denotes the autarkic Cournot oligopoly solution for the given specification, and where the observed number of firms selling (from any plant $i$) to market $l$ in month $t$ is

$$F_{lt} = \left|\left\{f \mid \textstyle\sum_{i\in\mathcal{O}_{ft}} q_{ilt} > 0\right\}\right|$$

$f$ indexing firms and $\mathcal{O}_{ft}$ denoting the set of plants owned by firm $f$ in month $t$. Estimation is again by ML. The reduced-form function for the autarkic Cournot price $p^*$ for the example of specification B is given by

$$p^*\frac{F+1}{F} = -\frac{1}{F}\left(\frac{\alpha_1 Y + \varepsilon^d}{\alpha_2 Y}\right) + W\beta + \varepsilon^s$$

Model 3 [Unconstrained monopoly, a particular case of mixture model 1] A domestic monopoly that is fully shielded from import competition, where the DGP is given by (3). Conditional on the demand estimates from the first stage, this can be estimated by 2SLS as follows

$$p + q\widehat{\partial p/\partial q} = c(q, W; \beta) + \varepsilon^s$$

where excluded exogenous demand covariates $Y$ (construction activity) instrument for any included endogenous marginal cost covariates. In the example of specification B, the dependent variable becomes $p + q\widehat{\partial p/\partial q} = p + q\left(\hat{\alpha}_2 Y\right)^{-1}$ and the model is estimated by OLS (since marginal cost is flat in output).

Model 4 [Unconstrained Cournot oligopoly, a particular case of mixture model 2] A domestic (symmetric) Cournot oligopoly that is fully shielded from import competition. The estimated model is similarly

$$p + \frac{1}{F}q\widehat{\partial p/\partial q} = c(q, W; \beta) + \varepsilon^s$$

and, in the example of specification B, the dependent variable is $p+(F)^{-1} q (\hat{\alpha}_2 Y)^{-1}$ and, because marginal cost is flat in output, the model can be implemented by OLS.

Model 5 [Competitive domestic industry, not nested in any previous model] A price-taking domestic industry (and protected from imports, since imports into Brazil hardly occur), where the DGP is given by (4), as in specification I of Table 2. The model can similarly be estimated by 2SLS, with excluded exogenous demand covariates $Y$ (construction activity) instrumenting for any included endogenous marginal cost covariates.

Model 6 [Fully constrained domestic industry, a particular case of mixture models 1 or 2] Domestic markets are always contested by imports, where the DGP is given by

$$p = c^I \left(W^I; \beta^I\right) + \varepsilon^I$$

as in specification II of Table 2. The model can be estimated by OLS.

Table 3 reports estimates for each one of the six behavioral models, conditional on specification B and the estimation of demand in a first stage. (Standard errors for behavioral models that are conditional on demand are estimated by bootstrapping, to account for demand estimation in the first stage—see the notes to the table.) Correspondingly, Table 4 reports the results for the pairwise Vuong selection tests.

[TO BE COMPLETED—discussion of estimates and tests, robustness of conclusion to specification changes]

# 4 Concluding remarks

[TO BE COMPLETED]

# A Appendix: Data sources and treatment

**United States**

Cement consumption: Portland cement consumption, including blended cement but excluding masonry cement. Level of aggregation: Each of the 51 states (excluding Puerto Rico and Foreign Possessions and Territories), by month in the period Jan-94 through Dec-06. Equals domestic production of cement (including cement produced from imported clinker) plus imports of cement minus exports of cement minus change in yearend cement stocks (at domestic producers and importers). Source: Electronic data obtained from the US Geological Survey (through consolidated monthly surveys of shipments by producers and importers), validated against Tables 1 and 9 of the USGS Minerals Yearbooks. The vast majority of Portland cement is General use (gray) Types I and II.

Cement and clinker imports: Imported Portland cement and imported clinker (for production of cement). Excludes Puerto Rico and Foreign Possessions and Territories. Source: Tables 1, 9 and 17 of the USGS Minerals Yearbook (through the U.S. Census Bureau). Portland cement imports are equated to reported hydraulic cement imports since masonry cement imports are negligible. Also, imported clinker is low relative to imported cement so, unlike the case of Brazil, I make no upward adjustment for clinker in summing with cement.

Domestic cement prices: Two series are available: (i) Annual producer prices for Portland cement at the factory gate (mill) for 26 "districts", in the period 1994 through 2005, available from the USGS Minerals Yearbooks (average realized prices are obtained from an annual survey of plants and importers; district is the location of the reporting facility, not the location of sales). Includes cement produced from imported clinker, and both bag and bulk shipments. The data are ex-terminal for independent terminals. (ii) Monthly producer prices for Portland cement delivered to the buyer for 20 cities, in the period Jan-92 through Dec-06, available from Engineering News Record (ENR), a construction trade publication (prices are quoted spot for a truckload quantity). For both series, current prices are in US$ per ton and are converted to constant prices (base December 1999) using the Consumer Price Index (averaged across U.S. cities and all items) from the Bureau of Labor Statistics (U.S. Department of Labor). (All other current prices in US$ are similarly converted to constant US$ prices.)

[In computing average prices reported in Figure 3, the 10 U.S. districts along the East and Gulf coasts (as classified by the US GS) are NY+ME, PA eastern, PA western, FL, GA+SC, MD+VA+WV, AL, KY+MS+TN, TX northern, TX southern. The 9 U.S. cities in East and Gulf coast states are Atlanta GA, Baltimore MD, Birmingham AL, Boston MA, Dallas TX, New Orleans LA, New York NY, Philadelphia PA, Pittsburgh PA.]

Imported cement prices: Calculated by dividing import CIF (cost, insurance and freight) values in US$ by import quantities. Available for total hydraulic cement and clinker by customs district and by year. Source: USGS Minerals Yearbook (through the U.S. Census Bureau). [In preparing Figure 3, the U.S. ports along the East and Gulf coasts include: Baltimore MD, Boston MA, Buffalo NY, Charleston SC, Houston-Galveston TX, Miami FL, Mobile AL, New Orleans LA, New York NY, Norfolk VA, Philadelphia PA, Port Arthur TX, Portland ME, Providence RI, Savannah GA, Tampa FL, Washington DC, Wilmington NC.]

Plant-to-local-market shipments: **This is not available, restricting the analysis**

**of U.S. firm behavior relative to the case of Brazil.**

Building and construction activity: [TO BE COMPLETED]

Plant-level characteristics: Kiln number, age, technology and capacity, as well as plant ownership, obtained from the 1999 U.S. Plant Information Summary prepared by the U.S. Portland Cement Association

Domestic cost-shifters: [TO BE COMPLETED]

Import cost-shifters: These include (i) World crude oil prices: monthly spot prices of West Texas Intermediate crude oil at Cushing, OK, in US$ per barrel (source: Energy Information Administration, U.S. Department of Energy); (ii) Maritime bulk freight: the Baltic Dry Index of US$ per day charter prices (source: London Baltic Exchange) [TO BE COMPLETED]

Other: Buyer characteristics obtained from the USGS Minerals Yearbooks

**Brazil**

Cement consumption: Portland cement consumption, including blended cement. Level of aggregation: each of the 27 states, by month in the period Jan-91 through Dec-06. Equals domestic production of cement (including cement produced from imported clinker) plus imports of cement minus exports of cement minus change in yearend cement stocks (at domestic producers and importers). Source: Brazilian cement trade association's Yearbooks (SNIC). Vast majority of Portland cement is General use (gray) Types I and II.

Cement and clinker imports: Imported Portland cement and imported clinker (for production of cement). Source: Web-based system (ALICE-Web) of the Secretariat for Foreign Trade (SECEX) of the Ministry for Development, Industry and Foreign Trade (MDIC). In summing with imported cement, I adjust imported clinker tonnage upward to reflect its use in clinker-light slag cement, as explained in the text.

Domestic cement prices: Retail (reseller) price for the standard 50 kg bag of Portland cement in units of local currency (Reais, R$). Level of aggregation: each of the 27 states, by month in the period Jan-91 through Dec-06. Source: Brazilian Institute for Geography and Statistics (IBGE). (The median price for a sample of retail stores in each state is reported, and is used by the institute to prepare economywide price indices.) Current prices are converted to constant prices (base December 1999) using an economywide General Price Index (GPI), the "IGP-DI" published by the Fundação Getúlio Vargas. Owing to the high level of inflation that prevailed over the first one-quarter or one-fifth of the time period I consider[28], particular attention has been paid to the conversion of current cement prices to constant prices, such as checking robustness with respect to other price indices and validating the resulting real price variation against reports from historical trade publications. (All other current prices in R$ are similarly

[28] That is, the pre-stabilization phase, or the 42 monthly periods between Jan-1991 and Jun-1994, out of a total of 156 periods (up to Dec-2003) or 192 periods (up to Dec-2006).

converted to constant R$ prices.)

[In computing average prices reported in Figure 3, the 17 coastal states of Brazil are: AP, PA, MA, PI, CE, RN, PB, PE, AL, SE, BA, ES, RJ, SP, PR, SC, RS. To back out delivered producer prices net of sales tax as reported in the figure, I subtract the (assumed) reseller mark-up and the (observed) producer sales tax from the (observed) retail price. Based on field interviews[29], I assume resellers are competitive, and that their gross margin amounts to around 13% of the producer price. Producer sales tax is calculated according to the observed proportional (ad valorem) plant-to-market rates for different federal and state-level taxes, namely "PIS", "COFINS", "ICMS-normal", "ICMS-ST" and "IPI". Sales tax is large: for example, by the end of the time period, sales tax owed by a producer located in the state of SP selling to a within-state buyer amounted to 28% of the gross producer price. I cross-validate the backed-out net producer prices by comparing them to net producer prices that I was able to obtain directly from some producers.]

Plant-to-local-market shipments: Annual cement shipments from each producer plant to each state is obtained from the Brazilian cement trade association, for the period 1991 to 1999. For each year $T$, I observe an $I \times L$ shipment matrix with element $q_{ilT}$ denoting 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.

Building and construction activity: Different data series are available from the Brazilian Institute for Geography and Statistics (IBGE). The main series is real construction activity, obtained from the National Accounts (a volume decomposition of Value Added in the construction sector). Level of aggregation: each of the 27 states, by year in the period 1991 through 2005. I extrapolate the data to 2006 using time series variation from a quarterly nationwide construction activity index. To account for seasonality in construction activity (more pronounced in the south where winters are colder), I either include quarterly dummy variables in my specifications, or embed seasonality directly in the annual construction activity data by combining these with the quarterly construction activity index.

Plant-level characteristics: Kiln number, age, technology, capacity and fuel type obtained from the World Cement Directory (several issues) prepared by Cembureau (the European cement trade association). Plant ownership, inventories, form of packaging (in bags or in bulk) and modal choice (shipments by road, rail or water) are obtained from

[29] These interviews include salespeople at producers, buyers at resellers and representatives of the construction sector 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).

the Brazilian cement trade association's Yearbooks. The shortest distance by road from each plant to the main metropolitan areas in each state is available from the Ministry of Transport.

Domestic cost-shifters: Domestic factor prices are observed either in the form of current prices, in which case they are converted to constant prices as explained above, or already in the form of constant prices. Though alternative series proxying for each factor price are available—these can be used to test robustness—the main series are: (i) Fuel oil: monthly countrywide delivered prices from refineries in R$ per kg[30] (source: National Agency for Oil, ANP); (ii) Green pet coke: (starting in 2000 the domestic cement industry began switching away from fuel oil and into imported green pet coke) quarterly countrywide FOB import prices in US$ per kg, converted into R$ per kg using the current R$/US$ exchange rate as explained below (source: SECEX); (iii) Diesel oil: monthly countrywide delivered prices from refineries in R$ per liter (source: National Agency for Oil); (iv) Coal: annual ex-plant prices in R$ per ton, averaged across mining firms with delivery cost then added (source: Ministry for Mining and Energy); (v) Electricity: monthly state-level delivered prices to (high-voltage) industrial buyers in R$ per MWh (source: National Agency for Electrical Energy, ANEEL); (vi) Labor: monthly real manufacturing wage indices in selected large industrial states or by region of Brazil (sources: Confederation of National Industry, CNI until 2003, followed by the Monthly Survey of Industrial Employment and Wages of the Brazilian Institute for Geography and Statistics, IBGE).

Import cost-shifters: See import cost-shifters for the U.S. Additionally, the exchange rate in current R$/US$ is obtained from the Central Bank of Brazil. I convert import cost-shifters in current US$ into current R$ using the current R$/US$ exchange rate. Prices in current R$ are then converted into constant R$ as explained above. The nominal yield on Brazilian Treasury bills is available from Gazeta Mercantil; I then similarly deflate the series using the GPI to obtain a proxy for the cost of import finance/bank letter of credit.

Other: Buyer characteristics obtained from the Brazilian cement trade association's Yearbooks

[30]Since these prices exclude sales tax I add tax back according to legislation. Also, owing to policy in the oil sector, price variation across regions during the time period of the study, has been low.

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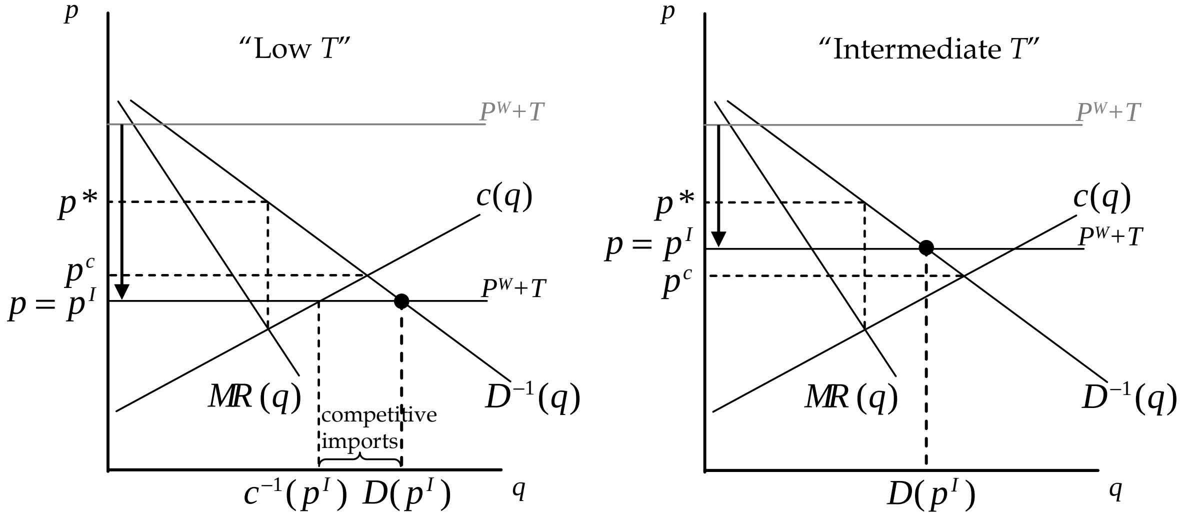


Figure 1: Trade liberalization affects a local market. Left panel: ("Low $T$") Actual foreign entry constrains domestic prices. Right panel: ("Intermediate $T$") Threatened foreign entry constrains domestic prices.


Figure 2: Penetration of cement and clinker imports in the United States (top panel) and in Brazil (bottom panel). Yellow area depicts country's cement imports as a proportion of domestic cement consumption. Red area depicts country's clinker imports as a proportion of domestic cement consumption. Vertical axes are drawn to the same scale for both countries. Sources: US GS, SECEX, SNIC. (For Brazil, clinker quantities are conservatively adjusted upward to reflect usage in the production of "clinker-light" slag cement.)

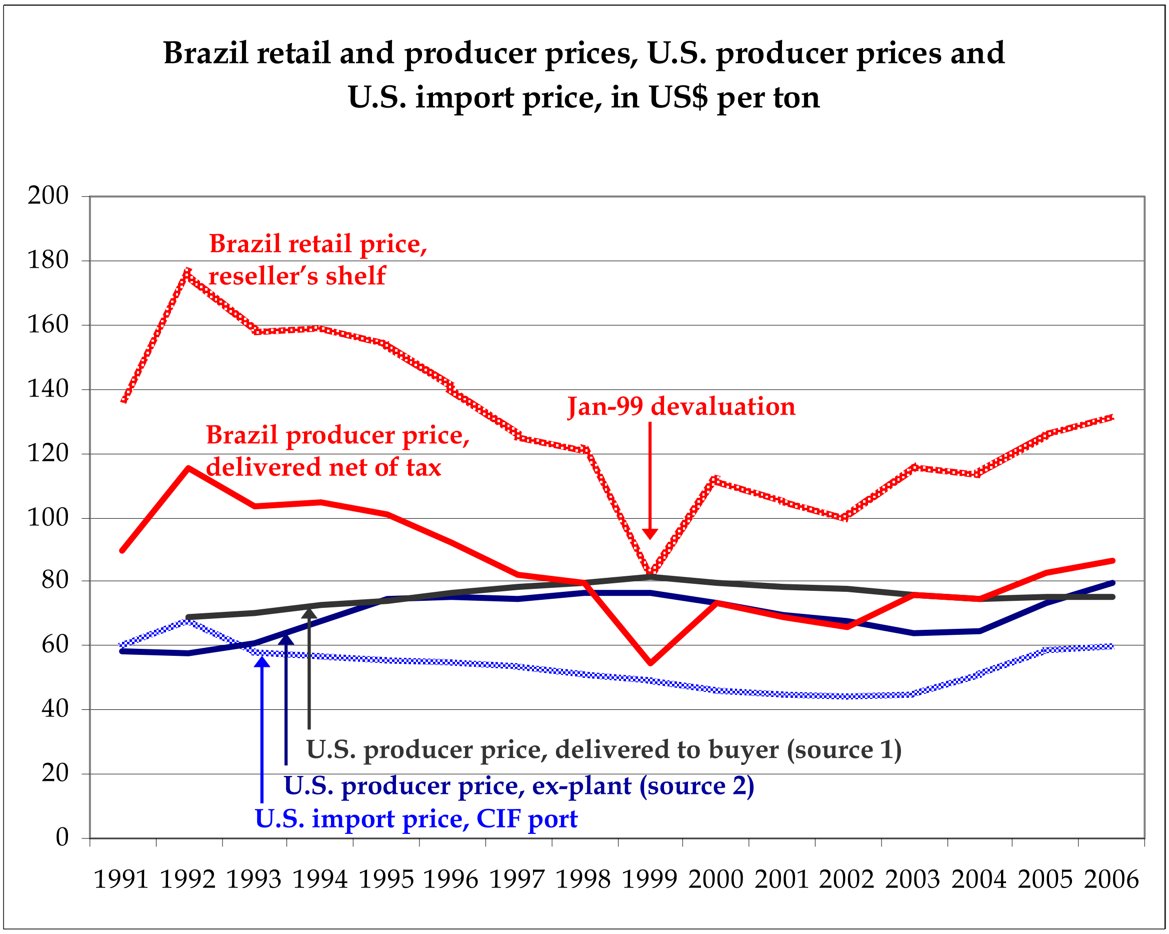


Figure 3: Evolution of average cement prices in the United States and in Brazil: (In descending order of price) (i) Retail price (reseller's shelf) in coastal states of Brazil (17 states, source: IBGE); (ii) Producer price (delivered to buyer net of tax) in coastal states of Brazil (source: calculated by author from IBGE retail prices); (iii) Producer price (delivered to buyer) in U.S. cities in East and Gulf coast states (9 cities, source: ENR); (iv) Producer price (mill, or factory gate) in U.S. districts along the East and Gulf Coasts (10 districts, source: US GS); and (v) Import price (CIF port of entry) for actual imports through U.S. ports along the East and Gulf Coasts (on average 14 ports, source: US GS). In constant US$ per ton (U.S. CPI, December 1999).

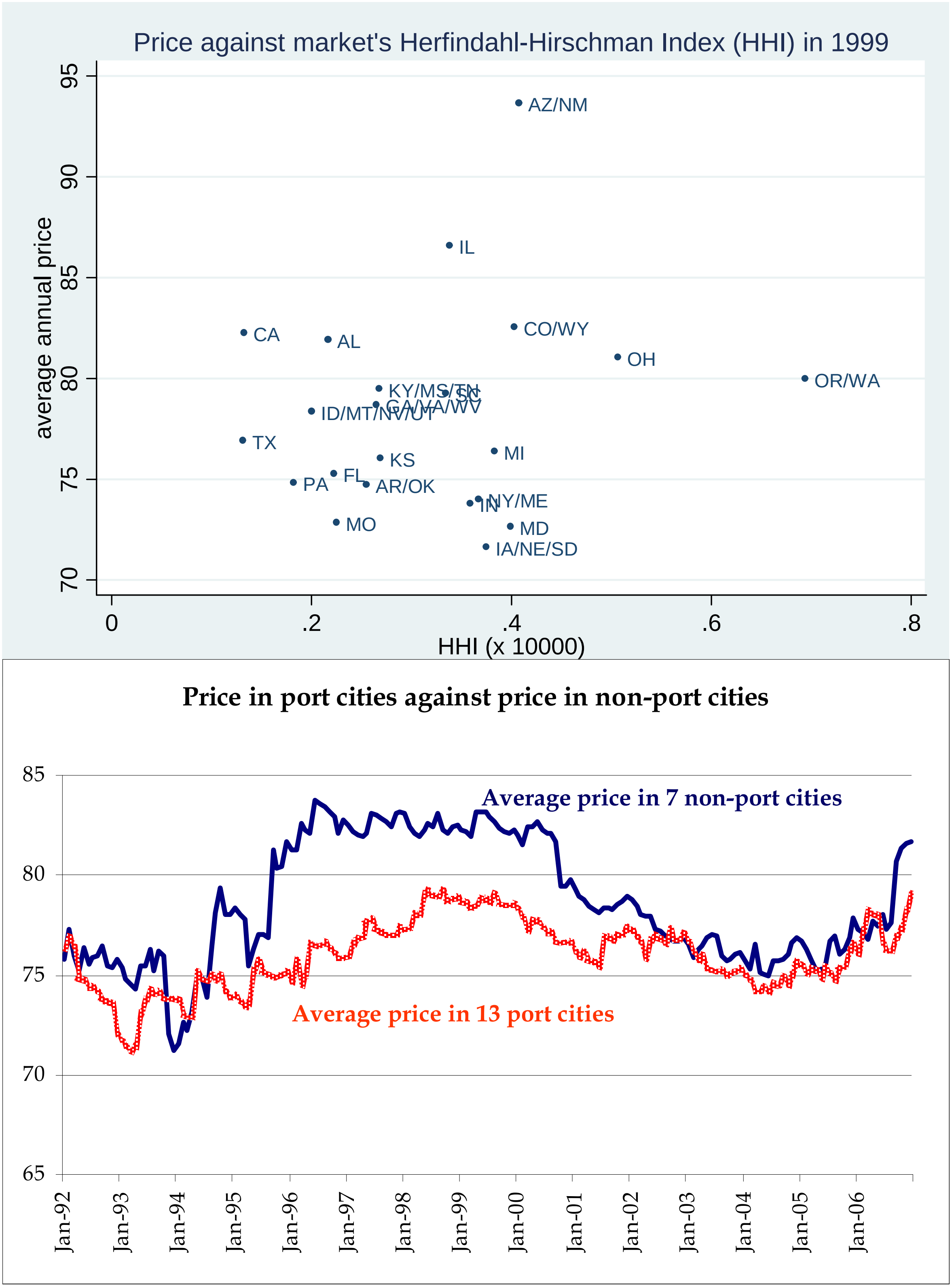


Figure 4: Variation in (producer) cement prices across U.S. local markets. Top panel: Price against ownership concentration of production assets located in district, as measured by the Herfindahl-Hirschman Index (HHI) of plant capacities, in 1999 (sources: US GS, US PCA). Bottom panel: Average price in 13 port cities against average price in 7 non-port cities, in the period Jan-1992 to Dec-2006 (source: ENR). In constant (December 1999) US$ per ton.

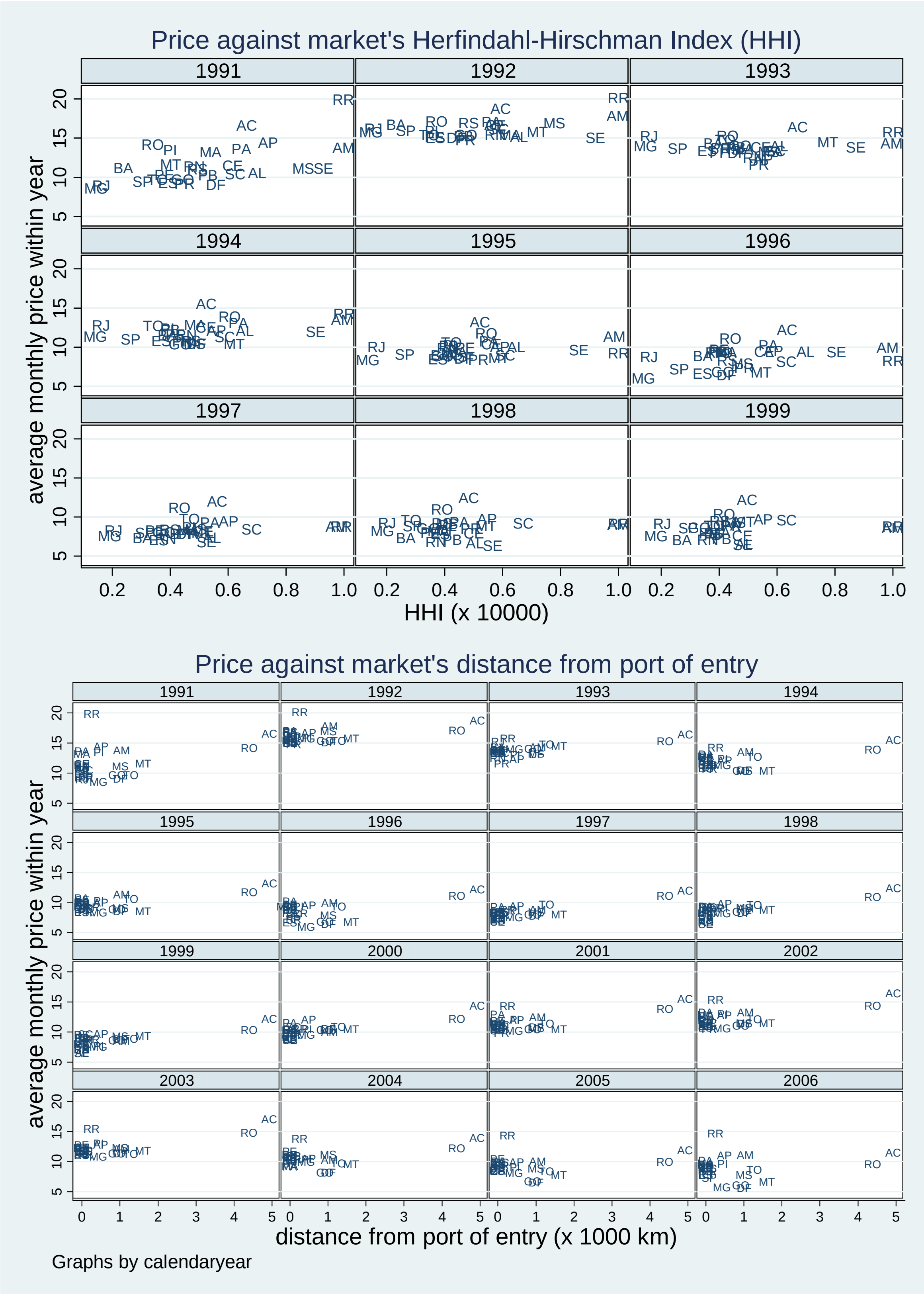


Figure 5: Variation in (retail) cement prices across Brazil's local markets, by year. Top panel: Price against (observed) local market's seller concentration, as measured by the Herfindahl-Hirschman Index (HHI), in the period 1991 to 1999 (sources: IBGE, SNIC). Bottom panel: Price against local market's distance from country's nearest port of entry (with handling capacity located on the border), in the period 1991 to 2006 (sources: IBGE, Ministry of Transport). In constant (December 1999) R$ per bag.

| Specification | I. Panel | II. Restricted panel | III. Market-specific | IV. Market-specific |
|---|---|---|---|---|
| Functional form | Linear | Linear | Linear | Loglinear |
| Number of units | 17 states, excl jungle | 27 states, incl jungle | NA | NA |
| Number of periods | 192 mo: 01/91-12/06 | 192 mo: 01/91-12/06 | 192 mo: 01/91-12/06 | 192 mo: 01/91-12/06 |
| Instruments | Imports cost shifters | Imports cost shifters | Imports cost shifters | Imports cost shifters |
| Restrictions on coefficients | | | | |
| Intercept | Market fixed effects | Zero | Market-specific | Market-specific |
| *Y* | Invariant across *l* | Invariant across *l* | Market-specific | Market-specific |
| *P* | Invariant across *l* | Zero | Market-specific | Market-specific |
| *YP* | Invariant across *l* | Invariant across *l* | Market-specific | Market-specific |

| State | Annual cement consumption (kt, 1991-2006) | Elasticity coef | s.e. | | Elasticity coef | s.e. | | Elasticity coef | s.e. | | Elasticity coef | s.e. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 *SP* | 10,138 | -0.152 | (0.035) | *** | -0.243 | (0.028) | *** | -0.123 | (0.047) | *** | -0.119 | (0.044) | *** |
| 17 *MG* | 4,068 | -0.166 | (0.037) | *** | -0.279 | (0.032) | *** | -0.317 | (0.043) | *** | -0.280 | (0.038) | *** |
| 19 *RJ* | 3,338 | -0.180 | (0.039) | *** | -0.310 | (0.036) | *** | -0.250 | (0.054) | *** | -0.217 | (0.051) | *** |
| 21 *PR* | 2,178 | -0.179 | (0.038) | *** | -0.322 | (0.037) | *** | -0.064 | (0.075) | | -0.059 | (0.074) | |
| 23 *RS* | 1,928 | -0.165 | (0.035) | *** | -0.310 | (0.036) | *** | -0.015 | (0.051) | | -0.055 | (0.045) | |
| 16 *BA* | 1,662 | -0.135 | (0.028) | *** | -0.272 | (0.032) | *** | -0.245 | (0.089) | *** | -0.191 | (0.073) | *** |
| 22 *SC* | 1,504 | -0.049 | (0.018) | *** | -0.150 | (0.017) | *** | 0.024 | (0.063) | | -0.001 | (0.068) | |
| 13 *PE* | 1,008 | -0.128 | (0.031) | *** | -0.310 | (0.036) | *** | -0.356 | (0.065) | *** | -0.382 | (0.064) | *** |
| 10 *CE* | 870 | -0.175 | (0.039) | *** | -0.398 | (0.046) | *** | -0.453 | (0.095) | *** | -0.460 | (0.108) | *** |
| 18 *ES* | 713 | -0.083 | (0.034) | ** | -0.271 | (0.031) | *** | -0.358 | (0.066) | *** | -0.319 | (0.060) | *** |
| 8 *MA* | 446 | 0.081 | (0.080) | | -0.135 | (0.016) | *** | -0.271 | (0.128) | ** | -0.245 | (0.121) | ** |
| 25 *MS* | 426 | -0.008 | (0.069) | | -0.276 | (0.032) | *** | -0.266 | (0.045) | *** | -0.308 | (0.044) | *** |
| 12 *PB* | 410 | 0.046 | (0.077) | | -0.197 | (0.023) | *** | -0.516 | (0.105) | *** | -0.505 | (0.083) | *** |
| 11 *RN* | 380 | 0.015 | (0.079) | | -0.268 | (0.031) | *** | -0.387 | (0.082) | *** | -0.389 | (0.071) | *** |
| 14 *AL* | 306 | 0.091 | (0.106) | | -0.214 | (0.025) | *** | -0.402 | (0.063) | *** | -0.404 | (0.062) | *** |
| 15 *SE* | 241 | 0.105 | (0.132) | | -0.281 | (0.033) | *** | -0.244 | (0.060) | *** | -0.193 | (0.063) | *** |
| 9 *PI* | 233 | 0.210 | (0.165) | | -0.186 | (0.022) | *** | 0.016 | (0.139) | | 0.014 | (0.141) | |
| Northwestern states ("jungle" essentially, mostly sparsely populated) | | | | | | | | | | | | | |
| 26 *GO* | 1,235 | | | | -0.140 | (0.016) | *** | -0.147 | (0.045) | *** | -0.138 | (0.040) | *** |
| 5 *PA* | 781 | | | | -0.387 | (0.045) | *** | -0.004 | (0.063) | | -0.076 | (0.073) | |
| 27 *DF* | 686 | | | | -0.173 | (0.020) | *** | -0.011 | (0.047) | | 0.006 | (0.055) | |
| 24 *MT* | 528 | | | | -0.191 | (0.022) | *** | 0.048 | (0.053) | | -0.033 | (0.045) | |
| 3 *AM* | 382 | | | | -0.425 | (0.049) | *** | 0.158 | (0.125) | | 0.118 | (0.095) | |
| 7 *TO* | 223 | | | | -0.066 | (0.008) | *** | -0.471 | (0.186) | ** | -0.188 | (0.163) | |
| 1 *RO* | 176 | | | | -0.714 | (0.083) | *** | -0.591 | (0.135) | *** | -0.703 | (0.124) | *** |
| 6 *AP* | 72 | | | | -0.111 | (0.013) | *** | 0.551 | (0.193) | *** | 0.537 | (0.175) | *** |
| 2 *AC* | 51 | | | | -0.535 | (0.062) | *** | -1.152 | (0.162) | *** | -1.434 | (0.203) | *** |
| 4 *RR* | 43 | | | | -0.259 | (0.030) | *** | 0.439 | (0.296) | | -0.090 | (0.377) | |
| 33 *Brazil* | 34,027 | -0.136 | (0.028) | *** | -0.278 | (0.032) | *** | | | | | | |
| Mean across states | | -0.051 | | | -0.275 | | | -0.200 | | | -0.226 | | |

Notes: Dependent variable is cement consumption (or its log, in the loglinear specification). 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. Elasticities (and standard errors) shown in the table are calculated at the mean value of covariates. Seasonality in: (i) market-specific estimations captured through dummy variables for quarters 1, 2 and 3, and (ii) in panel estimations embedded directly in *Y* (see the appendix).

Table 1: Price elasticities of demand at the local market level for Brazil, under different specifications, estimated by 2SLS

| Specification | I. Fixed effects panel | | | II. Fixed effects panel | | |
|---|---|---|---|---|---|---|
| Number of units | 27 states, incl jungle | | | 27 states, incl jungle | | |
| Number of periods | 192 mo: 01/91-12/06 | | | 192 mo: 01/91-12/06 | | |
| Behavioral model | Domestic competition with flat MC | | | Import competition (price ceiling binds) | | |
| | $p = W\beta + \varepsilon^s$ | | | $p = W^I \beta^I + \varepsilon^I$ | | |
| Factor prices $W$ or $W^I$ | coef | s.e. | | coef | s.e. | |
| Domestic $W$ | | | | | | |
| Oil-based kiln fuel | 1.094 | (0.109) | *** | | | |
| Coal-based kiln fuel | 0.643 | (0.049) | *** | | | |
| Electricity for grinding | 0.281 | (0.038) | *** | | | |
| Manufacturing wages | -5.517 | (0.283) | *** | | | |
| Diesel for road transp. | -0.179 | (0.046) | *** | | | |
| Imports $W^I$ | | | | | | |
| Exchange rate (Reais$/US$) | | | | 5.110 | (0.110) | *** |
| International oil (West Texas Intermediate) | | | | 0.222 | (0.019) | *** |
| Maritime bulk freight (Baltic Dry Index) | | | | 0.052 | (0.016) | *** |
| Diesel x Distance from port of entry | | | | -0.033 | (0.010) | *** |
| Import finance (real interest rate) | | | | 0.262 | (0.014) | *** |
| Immediate post devaluation dummy | | | | -2.506 | (0.125) | *** |
| Common $W$ or $W^I$ | | | | | | |
| Price controls: 01/91-10/91 | -4.154 | (0.246) | *** | -1.683 | (0.169) | *** |
| Market-specific fixed effects | Included | | | Included | | |
| $R^2$ | 0.462 | | | 0.712 | | |
| $R^2$ of specification without market-specific fixed effects | 0.314 | | | 0.602 | | |

| | III. Market-specific | IV. Market-specific | |
|---|---|---|---|
| | NA | NA | |
| | 192 mo: 01/91-12/06 | 192 mo: 01/91-12/06 | |
| | Domestic competition with flat MC | Import competition (price ceiling binds) | |
| | $p = W\beta + \varepsilon^s$ | $p = W^I \beta^I + \varepsilon^I$ | |
| State | $R^2$ | $R^2$ | Diff |
| 20 *SP* | 0.514 | 0.798 | 0.284 |
| 17 *MG* | 0.636 | 0.795 | 0.158 |
| 19 *RJ* | 0.603 | 0.798 | 0.195 |
| 21 *PR* | 0.545 | 0.802 | 0.257 |
| 23 *RS* | 0.484 | 0.784 | 0.299 |
| 16 *BA* | 0.738 | 0.752 | 0.015 |
| 22 *SC* | 0.524 | 0.801 | 0.277 |
| 13 *PE* | 0.591 | 0.735 | 0.144 |
| 10 *CE* | 0.656 | 0.708 | 0.051 |
| 18 *ES* | 0.581 | 0.824 | 0.243 |
| 8 *MA* | 0.666 | 0.701 | 0.034 |
| 25 *MS* | 0.228 | 0.768 | 0.540 |
| 12 *PB* | 0.764 | 0.700 | -0.064 |
| 11 *RN* | 0.650 | 0.682 | 0.032 |
| 14 *AL* | 0.717 | 0.639 | -0.078 |
| 15 *SE* | 0.758 | 0.684 | -0.075 |
| 9 *PI* | 0.618 | 0.677 | 0.059 |
| Northwestern ("jungle") states | | | |
| 26 *GO* | 0.223 | 0.795 | 0.572 |
| 5 *PA* | 0.432 | 0.668 | 0.236 |
| 27 *DF* | 0.207 | 0.827 | 0.620 |
| 24 *MT* | 0.210 | 0.842 | 0.632 |
| 3 *AM* | 0.509 | 0.644 | 0.135 |
| 7 *TO* | 0.337 | 0.730 | 0.393 |
| 1 *RO* | 0.208 | 0.799 | 0.591 |
| 6 *AP* | 0.349 | 0.629 | 0.280 |
| 2 *AC* | 0.164 | 0.776 | 0.611 |
| 4 *RR* | 0.496 | 0.653 | 0.156 |
| Mean | 0.497 | 0.741 | 0.244 |

Notes: Dependent variable is the cement price (at retail, in constant December 1999 Reais per bag). All domestic and imports factor prices in constant December 1999 Reais per unit of input, except: (i) import finance: real monthly interest rate on Brazilian Treasury bills, and (ii) immediate post devaluation, price controls and market fixed effects are dummies. (III) and (I) adopt the same specification for W. (IV) and (II) adopt the same specification for $W^I$. Coefficient estimates not shown for (III) and (IV). 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.

Table 2: Brazil's domestic cement prices projected (via OLS) onto (i) domestic cost-shifters, under the hypothesis of domestic competition, and (ii) imports cost-shifters, under the hypothesis of import competition.

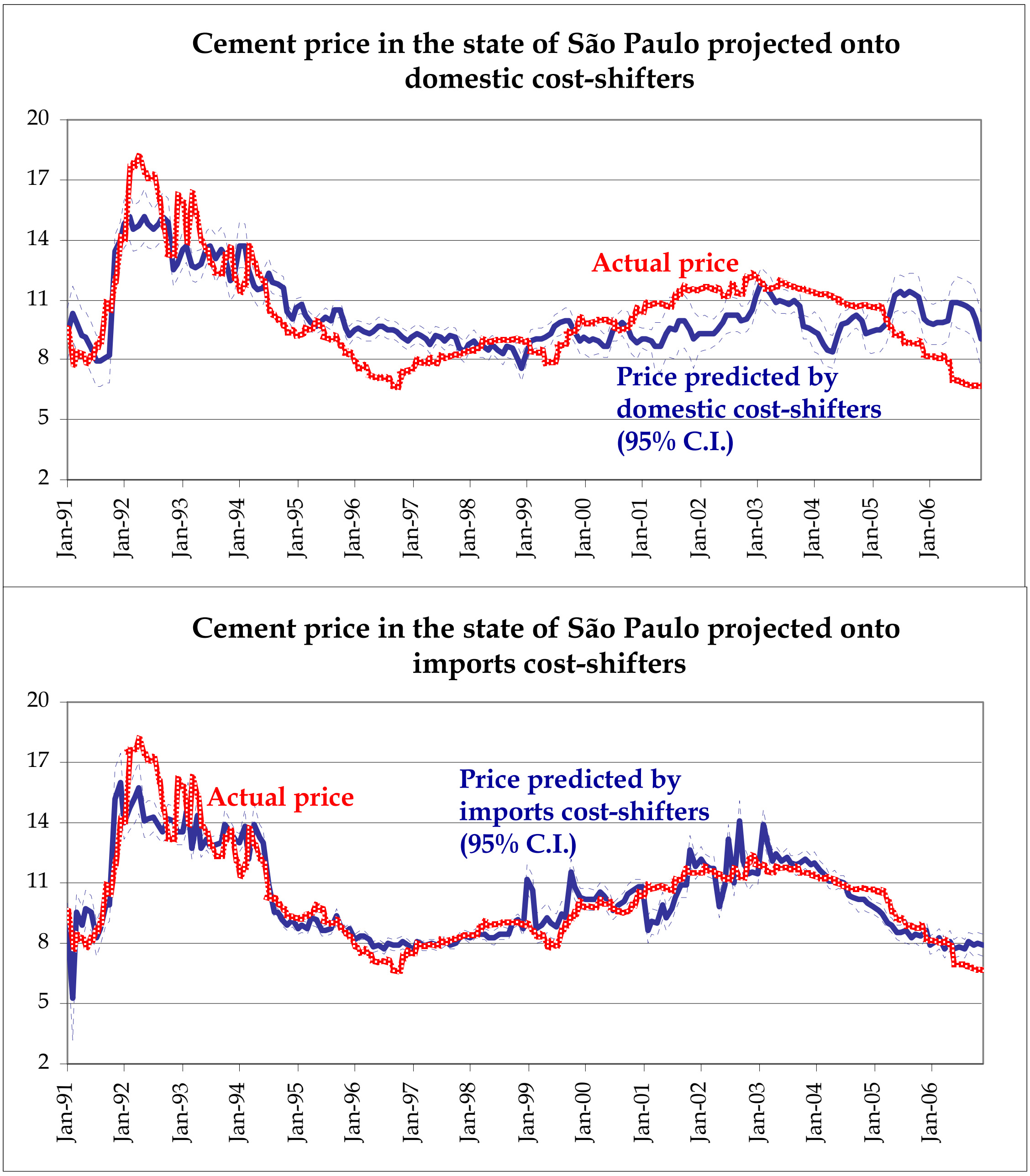


Figure 6: The explanatory power of imports cost-shifters relative to domestic cost-shifters, in the state of São Paulo. Top panel: Cement price, in red, and its projection onto domestic cost-shifters, in blue (as per specification (III) of Table 2). Bottom panel: Cement price, in red, and its projection onto imports cost-shifters, in blue (as per specification (IV) of Table 2). In constant (December 1999) Reais per bag.

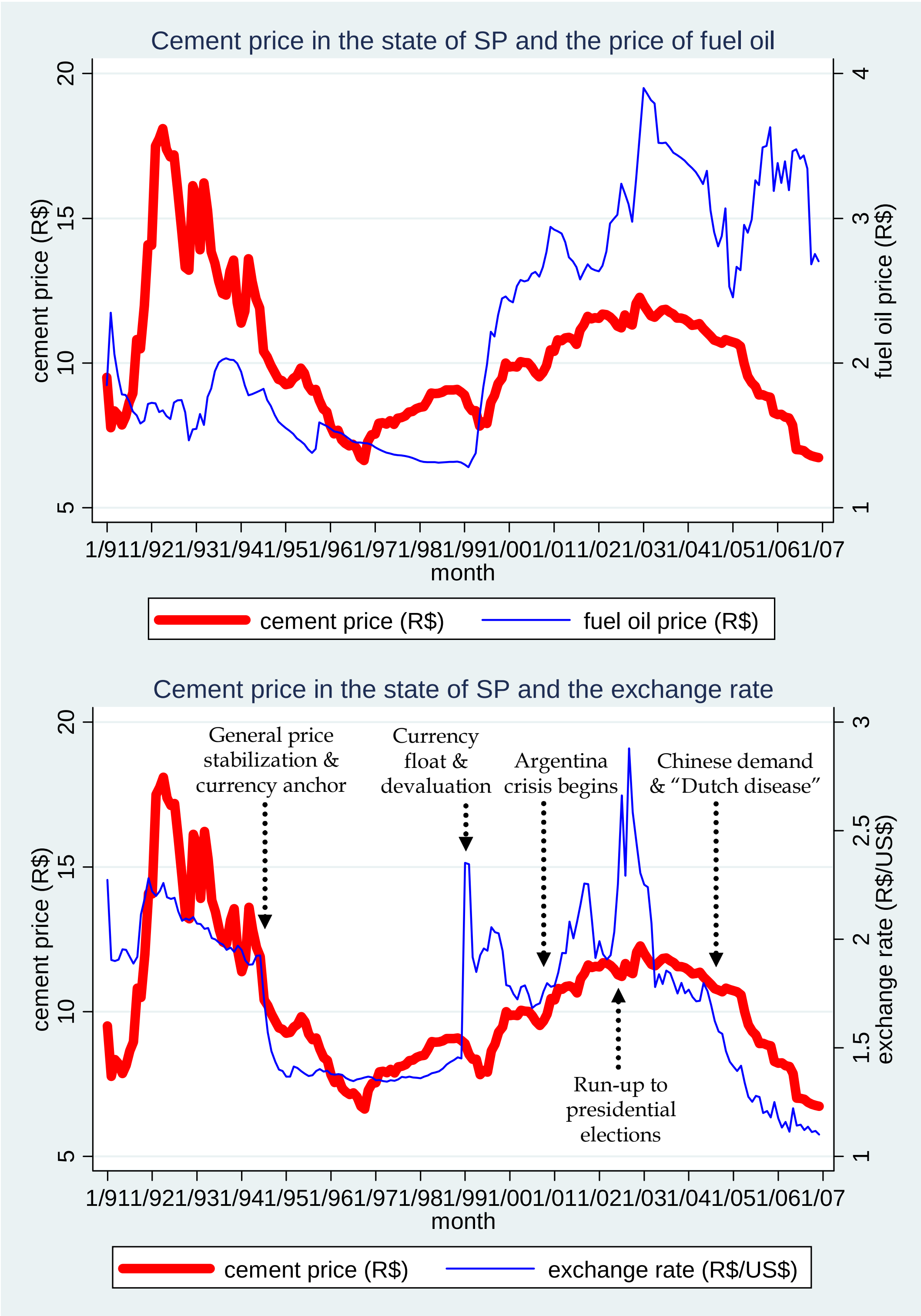


Figure 7: The evolution of cement prices in the state of São Paulo (in red) against (i) (Top panel, in blue) the evolution of the price of fuel oil (a key domestic cost-shifter), and (ii) (Bottom panel, in blue) the evolution of the exchange rate (a key imports cost-shifter). Prices in constant (December 1999) Reais (per bag, per kg, per US$, respectively). Bottom panel indicates key shocks in the foreign exchange market.

Specification B (Functional form, observations, identification)
(i) Demand is linear, coefficients are invariant across markets l and further restricted to zero for the Intercept and the P term
(ii) Domestic marginal cost is flat in output and linear in domestic factor prices and other supply-shifters
(iii) Import marginal cost is linear in import factor prices and other supply-shifters
(iv) N=4212, with set of observations given by 27 states (including jungle) over 156 months (01/91-12/03)
(v) Demand instruments given by domestic prices for fuel oil, coal, labor and transportation, the price control dummy and the exchange rate

Second stage estimates (Supply, conditional of Demand in first stage)

| Behavioral model: | Model 1 | | | Model 2 | | | Model 3 | | | Model 4 | | | Model 5 | | | Model 6 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description: | Mixture model of constrained monopoly | | | Mixture model of constrained Cournot | | | Unconstrained monopoly (a case of Model 1) | | | Unconstrained Cournot (a case of Model 2) | | | Competitive domestic industry (a case of Models 1,2) | | | Fully constrained domestic industry | | |
| Technique: | ML | | | ML | | | OLS (or ML) | | | OLS (or ML) | | | OLS (or ML) | | | OLS (or ML) | | |
| | coef | s.e. | | coef | s.e. | | coef | s.e. | | coef | s.e. | | coef | s.e. | | coef | s.e. | |
| Domestic $W$ | | | | | | | | | | | | | | | | | | |
| Fuel oil interacted with use | 8.524 | large | | -0.191 | (0.000) | ## | 2.266 | (0.413) | *** | 1.009 | (0.231) | *** | 1.714 | (0.079) | *** | | | |
| Coal interacted with use | 0.845 | large | | 0.939 | (0.000) | ## | -1.599 | (0.483) | *** | -0.515 | (0.270) | * | 0.759 | (0.126) | *** | | | |
| Electricity for grinding | -0.340 | (1.137) | | -0.447 | (0.715) | | -0.047 | (0.200) | | 0.229 | (0.112) | ** | 0.268 | (0.046) | *** | | | |
| Manufacturing wages | 7.712 | large | | -12.439 | large | | -36.031 | (1.584) | *** | -19.930 | (0.886) | *** | -11.732 | (0.488) | *** | | | |
| Diesel interact. with dist. | -2.130 | large | | -3.280 | (0.000) | ## | -1.748 | (0.245) | *** | -0.460 | (0.137) | *** | 0.161 | (0.052) | *** | | | |
| Size of sourcing plants | -1.991 | large | | -1.370 | large | | -0.858 | (0.110) | *** | 0.004 | (0.062) | | -0.047 | (0.020) | ** | | | |
| Age of sourcing plants | -5.783 | large | | -1.676 | (0.000) | ## | -1.953 | (0.664) | *** | -2.402 | (0.372) | *** | -0.807 | (0.149) | *** | | | |
| Price controls: 01/91-10/91 | -10.301 | large | | -10.883 | large | | -12.236 | (0.834) | *** | -6.566 | (0.467) | *** | -5.556 | (0.264) | *** | | | |
| Market-specific fixed effects | Included | | | Included | | | Included | | | Included | | | Included | | | | | |
| Imports $W^I$ | | | | | | | | | | | | | | | | | | |
| Exchange rate | 5.380 | (0.044) | *** | 5.530 | (0.069) | *** | | | | | | | | | | 5.344 | (0.221) | *** |
| International oil | 0.107 | (0.143) | | 0.101 | (0.073) | | | | | | | | | | | 0.104 | (0.048) | ** |
| Maritime bulk freight | 0.210 | (0.181) | | 0.219 | (0.385) | | | | | | | | | | | 0.206 | (0.026) | *** |
| Diesel interact. with dist. | 0.060 | (0.080) | | 0.082 | (0.259) | | | | | | | | | | | 0.064 | (0.016) | *** |
| Import finance | 0.248 | (0.144) | * | 0.241 | (0.315) | | | | | | | | | | | 0.248 | (0.017) | *** |
| Immediate post devaluation | -2.555 | (0.097) | *** | -2.638 | (0.131) | *** | | | | | | | | | | -2.545 | (0.129) | *** |
| Price controls: 01/91-10/91 | -1.729 | (0.112) | *** | -1.745 | (0.144) | *** | | | | | | | | | | -1.768 | (0.179) | *** |
| Market-specific fixed effects | Included | | | Included | | | | | | | | | | | | Included | | |
| Sigma-s | 1.452 | (0.189) | *** | 0.999 | (0.148) | *** | | | | | | | | | | | | |
| Sigma-I | 1.551 | (0.006) | *** | 1.563 | (0.007) | *** | | | | | | | | | | | | |
| Log likelihood | -7759.7 | | | -7765.6 | | | | | | | | | | | | | | |
| Mean Prob(ceiling binds) | 0.988 | | | 0.977 | | | | | | | | | | | | | | |
| OLS $R^2$ | | | | | | | 0.790 | | | 0.723 | | | 0.663 | | | 0.717 | | |

Notes: See text. Standard errors for models 1, 2, 3 and 4 are estimated through bootstrapping to account for demand estimation in the first stage: 200 repetitions with clustering by month (i.e. every bootstrap sample consists of 156 month draws with replacement, and for every month in the bootstrap sample there are 27 markets). Standard errors for models 5 and 6 are heteroskedasticity and autocorrelation-robust (Newey-West 1 lag).
*** Significant(ly different from zero) at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 3: Estimates for alternative supply models of the Brazilian cement industry, under Specification B (linear restricted demand, flat marginal cost, 27 states including jungle, 156 months including pre-stabilization period). Estimated under ML, 2SLS or OLS.

Specification B (Functional form, observations, identification)
(i) Demand is linear, coefficients are invariant across markets l and further restricted to zero for the Intercept and the P term
(ii) Domestic marginal cost is flat in output and linear in domestic factor prices and other supply-shifters
(iii) Import marginal cost is linear in import factor prices and other supply-shifters
(iv) N=4212, with set of observations given by 27 states (including jungle) over 156 months (01/91-12/03)
(v) Demand instruments are domestic prices for fuel oil, coal, labor and transport., the price control dummy and the exchange rate

Pairwise Vuong (1989) test
$H_0$: Structural models F and G fit the data equally well
Significantly positive test statistic: Reject the null in favor of $H_{AF}$: Structural model F fits the data better
Significantly negative test statistic: Reject the null in favor of $H_{AG}$: Structural model G fits the data better

Likelihood Ratio with no correction for different degrees of freedom

Test statistic

| | | Model G | | | | |
|---|---|---|---|---|---|---|
| | against | 2 | 3 | 4 | 5 | 6 |
| Model F | 1 | 0.381 | 36.147 | 31.703 | 8.092 | 5.404 |
| | 2 | | 36.465 | 31.726 | 7.921 | 2.936 |
| | 3 | | | -3.232 | -33.559 | -35.704 |
| | 4 | | | | -29.064 | -31.370 |
| | 5 | | | | | -7.246 |

P-values

| | | Model G | | | | |
|---|---|---|---|---|---|---|
| | against | 2 | 3 | 4 | 5 | 6 |
| Model F | 1 | 0.648 | **1.000** | **1.000** | **1.000** | **1.000** |
| | 2 | | **1.000** | **1.000** | **1.000** | **0.998** |
| | 3 | | | **0.001** | **0.000** | **0.000** |
| | 4 | | | | **0.000** | **0.000** |
| | 5 | | | | | **0.000** |

Correction according to Akaike (1973)

Test statistic

| | | Model G | | | | |
|---|---|---|---|---|---|---|
| | against | 2 | 3 | 4 | 5 | 6 |
| Model F | 1 | 0.381 | 35.897 | 31.462 | 7.399 | 0.978 |
| | 2 | | 36.213 | 31.485 | 7.233 | 0.164 |
| | 3 | | | -3.232 | -33.559 | -35.711 |
| | 4 | | | | -29.064 | -31.377 |
| | 5 | | | | | -7.266 |

P-values

| | | Model G | | | | |
|---|---|---|---|---|---|---|
| | against | 2 | 3 | 4 | 5 | 6 |
| Model F | 1 | 0.648 | **1.000** | **1.000** | **1.000** | 0.836 |
| | 2 | | **1.000** | **1.000** | **1.000** | 0.565 |
| | 3 | | | **0.001** | **0.000** | **0.000** |
| | 4 | | | | **0.000** | **0.000** |
| | 5 | | | | | **0.000** |

Correction according to Schwarz (1978)

Test statistic

| | | Model G | | | | |
|---|---|---|---|---|---|---|
| | against | 2 | 3 | 4 | 5 | 6 |
| Model F | 1 | 0.381 | 35.104 | 30.699 | 5.200 | -13.065 |
| | 2 | | 35.412 | 30.720 | 5.049 | -8.632 |
| | 3 | | | -3.232 | -33.559 | -35.734 |
| | 4 | | | | -29.064 | -31.399 |
| | 5 | | | | | -7.329 |

P-values

| | | Model G | | | | |
|---|---|---|---|---|---|---|
| | against | 2 | 3 | 4 | 5 | 6 |
| Model F | 1 | 0.648 | **1.000** | **1.000** | **1.000** | **0.000** |
| | 2 | | **1.000** | **1.000** | **1.000** | **0.000** |
| | 3 | | | **0.001** | **0.000** | **0.000** |
| | 4 | | | | **0.000** | **0.000** |
| | 5 | | | | | **0.000** |

Table 4: Selecting among alternative supply models of the Brazilian cement industry, under Specification B (linear restricted demand, flat marginal cost, 27 states including jungle, 156 months including pre-stabilization period). Unadjusted and adjusted Vuong (1989) test statistics and p-values.

Specification D (Functional form, observations, identification)
(i) Demand is linear, coefficients vary across markets l
(ii) Domestic marginal cost is linear in output and linear in domestic factor prices and other supply-shifters
(iii) Import marginal cost is linear in import factor prices and other supply-shifters
(iv) N=2652, with set of observations given by 17 states (excluding jungle) over 156 months (01/91-12/03)
(v) Demand instruments are domestic prices for fuel oil, coal, labor and transport., the price control dummy and the exchange rate

Second stage estimates (Supply, conditional of Demand in first stage)

| Behavioral model: | Model 1 | | | Model 2 | | | Model 3 | | | Model 4 | | | Model 5 | | | Model 6 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description: | Mixture model of constrained monopoly | | | Mixture model of constrained Cournot | | | Unconstrained monopoly (a case of Model 1) | | | Unconstrained Cournot (a case of Model 2) | | | Competitive domestic industry (a case of Models 1,2) | | | Fully constrained domestic industry | | |
| Estimation: | ML | | | ML | | | 2SLS (or ML) | | | 2SLS (or ML) | | | 2SLS (or ML) | | | OLS (or ML) | | |
| | coef | s.e. | | coef | s.e. | | coef | s.e. | | coef | s.e. | | coef | s.e. | | coef | s.e. | |
| Domestic $W$ | | | | | | | | | | | | | | | | | | |
| Fuel oil interacted with use | 51.570 | large | | 9.002 | large | | 14.317 | (13.93) | | 3.470 | (3.447) | | 1.604 | (0.105) | *** | | | |
| Coal interacted with use | -221.98 | large | | -36.229 | large | | 26.920 | (9.451) | *** | 7.657 | (2.305) | *** | 0.976 | (0.132) | *** | | | |
| Electricity for grinding | 7.556 | large | | 7.407 | large | | -3.787 | (6.327) | | -2.015 | (1.300) | | 0.359 | (0.056) | *** | | | |
| Manufacturing wages | 2542.4 | large | | 427.65 | large | | 224.913 | (62.90) | *** | 44.376 | (15.06) | *** | -9.534 | (0.527) | *** | | | |
| Diesel interact. with dist. | 95.561 | large | | 12.897 | large | | -11.699 | (11.82) | | -2.010 | (2.669) | | 0.844 | (0.146) | *** | | | |
| Size of sourcing plants | 70.994 | large | | 5.282 | large | | -10.269 | (2.976) | *** | -2.155 | (0.721) | *** | -0.027 | (0.022) | | | | |
| Age of sourcing plants | 1035.0 | large | | 278.90 | large | | 89.232 | (38.41) | ** | 23.344 | (9.539) | ** | -0.165 | (0.148) | | | | |
| Price controls: 01/91-10/91 | 191.00 | large | | 60.539 | large | | -41.501 | (20.82) | ** | -15.507 | (5.332) | *** | -5.299 | (0.276) | *** | | | |
| Market-specific fixed effects | Included | | | Included | | | Included | | | Included | | | Included | | | | | |
| Output | | | ## | | | ## | -0.162 | (0.103) | | -0.070 | (0.024) | *** | -0.002 | (0.001) | ** | | | |
| Imports $W^I$ | | | | | | | | | | | | | | | | | | |
| Exchange rate | 5.380 | (0.029) | *** | 5.434 | (0.104) | *** | | | | | | | | | | 5.380 | (0.256) | *** |
| International oil | 0.734 | large | | -0.149 | large | | | | | | | | | | | 0.060 | (0.059) | |
| Maritime bulk freight | 0.244 | (0.099) | ** | 0.242 | (0.815) | | | | | | | | | | | 0.245 | (0.029) | *** |
| Diesel interact. with dist. | 0.245 | (0.079) | *** | 0.246 | (0.511) | | | | | | | | | | | 0.217 | (0.095) | ** |
| Import finance | 0.060 | (0.093) | | 0.049 | (0.782) | | | | | | | | | | | 0.244 | (0.019) | *** |
| Immediate post devaluation | 0.217 | (0.097) | ** | 0.227 | (0.817) | | | | | | | | | | | -2.608 | (0.158) | *** |
| Price controls: 01/91-10/91 | -2.608 | (0.101) | *** | -2.621 | (0.821) | *** | | | | | | | | | | -2.319 | (0.177) | *** |
| Market-specific fixed effects | Included | | | Included | | | | | | | | | | | | Included | | |
| Sigma-s | 0.782 | (0.012) | *** | 0.831 | (0.074) | *** | | | | | | | | | | | | |
| Sigma-I | 752.794 | large | | 0.000 | (0.000) | *** | | | | | | | | | | | | |
| Log likelihood | -4676.8 | | | -4669.9 | | | | | | | | | | | | | | |
| Mean Prob(ceiling binds) | 1.000 | | | 1.000 | | | | | | | | | | | | | | |
| OLS $R^2$ | | | | | | | | | | | | | | | | 0.713 | | |

Notes: See text. Standard errors for models 1, 2, 3 and 4 are estimated through bootstrapping to account for demand estimation in the first stage: 200 repetitions with clustering by month (i.e. every bootstrap sample consists of 156 month draws with replacement, and for every month in the bootstrap sample there are 17 markets). Standard errors for models 5 and 6 are heteroskedasticity and autocorrelation-robust (Newey-West 1 lag).
*** Significant(ly different from zero) at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 5: Estimates for alternative supply models of the Brazilian cement industry, under Specification D (linear market-specific demand, linear marginal cost, 17 states excluding jungle, 156 months including pre-stabilization period). Estimated under ML, 2SLS or OLS.

Specification D (Functional form, observations, identification)
(i) Demand is linear, coefficients vary across markets l
(ii) Domestic marginal cost is linear in output and linear in domestic factor prices and other supply-shifters
(iii) Import marginal cost is linear in import factor prices and other supply-shifters
(iv) N=2652, with set of observations given by 17 states (excluding jungle) over 156 months (01/91-12/03)
(v) Demand instruments are domestic prices for fuel oil, coal, labor and transport., the price control dummy and the exchange rate

Pairwise Vuong (1989) test
$H_0$: Structural models F and G fit the data equally well
Significantly positive test statistic: Reject the null in favor of $H_{AF}$: Structural model F fits the data better
Significantly negative test statistic: Reject the null in favor of $H_{AG}$: Structural model G fits the data better

Test statistic / P-values

Likelihood Ratio with no correction for different degrees of freedom

| | against | Model G 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Model F | 1 | -0.949 | 39.134 | 29.346 | 2.874 | 0.006 |
| | 2 | | 38.563 | 28.949 | 2.986 | 0.949 |
| | 3 | | | -81.170 | -38.517 | -39.134 |
| | 4 | | | | -28.824 | -29.346 |
| | 5 | | | | | -2.874 |

| | against | Model G 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Model F | 1 | 0.171 | **1.000** | **1.000** | **0.998** | 0.502 |
| | 2 | | **1.000** | **1.000** | **0.999** | 0.829 |
| | 3 | | | **0.000** | **0.000** | **0.000** |
| | 4 | | | | **0.000** | **0.000** |
| | 5 | | | | | **0.002** |

Correction according to Akaike (1973)

| | against | Model G 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Model F | 1 | -0.949 | 39.052 | 29.269 | 2.300 | -1723.1 |
| | 2 | | 38.483 | 28.874 | 2.421 | -2.731 |
| | 3 | | | -81.170 | -38.517 | -39.141 |
| | 4 | | | | -28.824 | -29.352 |
| | 5 | | | | | -2.920 |

| | against | Model G 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Model F | 1 | 0.171 | **1.000** | **1.000** | **0.989** | **0.000** |
| | 2 | | **1.000** | **1.000** | **0.992** | **0.003** |
| | 3 | | | **0.000** | **0.000** | **0.000** |
| | 4 | | | | **0.000** | **0.000** |
| | 5 | | | | | **0.002** |

Correction according to Schwarz (1978)

| | against | Model G 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Model F | 1 | -0.949 | 38.813 | 29.045 | 0.611 | -6791.7 |
| | 2 | | 38.247 | 28.653 | 0.759 | -13.554 |
| | 3 | | | -81.170 | -38.517 | -39.160 |
| | 4 | | | | -28.824 | -29.370 |
| | 5 | | | | | -3.055 |

| | against | Model G 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Model F | 1 | 0.171 | **1.000** | **1.000** | 0.729 | **0.000** |
| | 2 | | **1.000** | **1.000** | 0.776 | **0.000** |
| | 3 | | | **0.000** | **0.000** | **0.000** |
| | 4 | | | | **0.000** | **0.000** |
| | 5 | | | | | **0.001** |

Table 6: Selecting among alternative supply models of the Brazilian cement industry, under Specification D (linear market-specific demand, linear marginal cost, 17 states excluding jungle, 156 months including pre-stabilization period). Unadjusted and adjusted Vuong (1989) test statistics and p-values.