

Trade Flows in a Spatial Oligopoly: Gravity Fits Well, But What Does it Explain?

SUPPLEMENTARY SECTION: INDUSTRY, DATA AND ROBUSTNESS

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November 2006

S.1 The cement industry

Cement is a homogeneous good produced largely from limestone and clay in weight proportion of roughly 5 to 1. Described simply, limestone and clay are ground and the mixture is burned at a very high temperature in a rotary kiln producing cement clinker. The clinker pellets – once cooled – are then ground and mixed with a retarding agent (gypsum) and varying types of additives to form different formulations of cement¹. Despite the relative simplicity of the product, the production of cement is capital intensive and is characterized by substantial economies of scale. Labor basically performs a supervisory role (Norman 1979). The process is also energy intensive, not only due to the operation of the kiln but also due to the grinding of raw material and clinker².

The process exhibits a fixed factor production function since factor inputs are not

¹The different formulations of cement are substitutes in most types of user applications. While clinker comprises around 96% of ordinary cement, this proportion can be considerably reduced in other formulations, such as (blast furnace) slag cement or pozzolanic cement. Usually the supply of these different formulations will depend on the availability of additives (i.e. slag or pozzolane) in the proximity of the cement plant, such as a steelworks in the case of slag cement. Each type of cement usually needs to conform to legislation that specifies its (physical and chemical) properties. Thus differentiation based on formulation is limited.

²In many regions, such as in the Americas and Europe, the supply of limestone is fairly ubiquitous; the raw material is thus usually extracted from a quarry located within the plant complex. The setup of a modern fully-integrated plant – comprised of limestone quarry, clinker-producing kiln, and grinding mill – with (say) capacity of 1.5 million tonnes per annum (mtpa), can require a capital outlay of up to US\$300 million (US\$200 per tonne of capacity), with kiln operations accounting for most of this capital investment. Barriers to entry may be further compounded by environmental restrictions, or due to the prospecting rights over limestone reserves lying in the hands of incumbents (despite their relative abundance).

substitutable. Yet marginal costs do vary across kilns and plants, according to the technology, capacity, age and fuel employed (Jans and Rosenbaum 1996). The last major innovation to the production process took place in the 1970s in response to the energy price shocks. The “wet” process kiln system was replaced by the “dry” process, which consumes less than half the respective energy (since no heat is needed to evaporate water). With the energy crisis in the foreground, firms invested in bigger, more energy-efficient kilns. Maximum kiln capacity in the four decades leading up to 2000 has increased six-fold to four million tonnes per annum (mtpa) (World Cement 2000)³. Although equipment suppliers and cement producers work closely together, most innovations seem to originate from the equipment suppliers, and technology can be purchased off-the-shelf⁴.

As cement is a low-value commodity relative to weight, transportation costs may assume a significant proportion of cost, leading to geographically segmented markets. Scherer et al (1975, p. 429) list cement as having the second highest freight cost index for shipments out of 101 US industries. In order to meet dispersed demand, firms may trade in (production) scale economies for lower transport costs by scattering their plants across markets⁵.

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

World demand, estimated at 1620 mt in 2000, has been growing at around 3% p.a. (International Cement Review 2001). Growth is concentrated in emerging markets while demand in North America and Western Europe has been growing slowly or is stagnant⁶. Over the past 15 years, a significant process of consolidation has been running its course in the global cement industry. While family-run and state-owned firms have been put on sale, a few multinational firms have been on a buying spree, aggressively moving into

³See Rosenbaum (1989) and Johnson and Parkman (1983) on process and capacity changes in the US industry.

⁴“Turn-key” plants may be ordered from suppliers. Research and development (R&D) spending by the cement producers themselves is limited: operating at the forefront of cement-production technology, the Japanese producer Taiheiyo spends less than 1% of sales revenue on R&D.

⁵See Scherer et al (1975) and Newmark (1998). Pre-empting entry may further reduce initial plant scale (Johnson and Parkman 1983).

⁶Around 30% of consumption occurs in China, notoriously a producer of low-quality cement in energy-inefficient, environmentally-unfriendly “backyard” mini cement plants.

new markets or expanding in markets where they previously operated. The combined production share (excluding China) of the world's six largest firms (C_6) in 2000 was estimated at 35%, up from 23% in 1995 and 14% in 1985.

S.2 Data

This section comments on the sources of data and how I treat the data (also used in Salvo 2005a, e.g. time-series aggregation at the monthly level rather than annual level is employed in Salvo 2005a). I also perform robustness checks on my direct computations of marginal cost.

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

S.2.1 Sources and treatment of data

Cement consumption by state (i.e. demand by local market) Monthly series by state, in 1000 tonnes of cement, are obtained from the annual reports (and other reports) of the Brazilian cement industry's trade association, the National Syndicate of the Cement Industry (SNIC). This body has played a leading role in the history of the Brazilian cement industry and represents almost the entirety of the set of producers⁷.

⁷Up until 2003 only two recent entrants were not members of the trade association: (i) Cimento Mizú, set up in 1998 by a large independent ready-mix concrete firm, Polimix, and (ii) Cimento Davi, set up in 2001. Both concerns consist of relatively small-scale grinding operations (respectively 0.7 mtpa and 0.4 mtpa to date), importing clinker from as far as Asia and producing slag cement (both are located in close proximity to steel producers, from whom they purchase blast furnace slag, based respectively in the states of Espírito Santo, *ES*, and Minas Gerais, *MG*.) See footnote 23.

To compile consumption figures for a given state, SNIC aggregates reported shipments by its members to that state. Thus I observe shipments by cement producers to buyers broken out by destination state. Four possible sources of distortion, each deemed to be small, are: (i) Consumption figures do not include shipments by non-members to the association (namely Mizú and Davi: see footnote 7). The distortion is small given the limited capacity, limited geographic scope and recent entry dates attached to these non-members; (ii) Consumption figures do not include imports. Again the distortion is small in view of the limited penetration of imports (see Salvo 2005a); (iii) Consumption figures do not account for any cross-state shipping *at the reseller level* (i.e. shipments by resellers in state l shipping across to buyers further downstream located in state $n \neq l$). In compiling consumption by state, a shipment by a cement producer to a buyer located in a given state counts towards consumption in that state. This distortion is considered small in that the high cost of transporting cement and the fact that the industry takes into account the possibility of trade arbitrage when setting commercial terms make the scope for cross-state shipping by resellers limited. Further, the bulkiness, fast turn and short shelf life of cement leads producers to reach far “down the trade”, via direct-from-plant deliveries and own distribution terminals: in spatial terms, reselling is largely a local business. In any case, shipments by resellers into a state ought to approximately cancel shipments by resellers out of that state; and (iv) Variation in inventories downstream are not accounted for. Again the distortion is small given that the characteristics of cement (e.g. short shelf life) mean inventory levels and their time-series variation are limited.

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

Cement prices by state Current retail cement prices in units of local currency for the standard 50 kg bag are provided by the Brazilian office of national statistics, the Brazilian Institute for Geography and Statistics (IBGE). This office is one of Brazil's two main providers of economic statistics, charged with carrying out population censuses, compiling the national accounts and publishing price indices. In effect, the cement price

series I use is collected to compute the latter. Monthly series by state are available on the median price for a sample of retail stores (commonly referred to as resellers) located in each state. (Producer prices are not observed; these are backed out from retail prices as explained below.) Owing to the high levels of inflation prevailing in the first *one-third* of the time period I consider⁸, particular attention has been paid to the conversion of current cement prices to constant prices (in December 1999 terms). While this is done using a General Price Index (GPI), I also convert cement prices using other (economy-wide) price indices, such as a Consumer Price Index (CPI) or a Wholesale Price Index (WPI), to check the robustness of the estimation results (these are, respectively, the “IGP-DI”, the “IPC-br” and the “IPA-DI”, all published by the Fundação Getúlio Vargas). Further, where possible, I compare the constant price series I calculate for each state with reports on cement prices to be found in trade publications or the press. For example, the constant cement price series I calculate indicate a sharp increase in real terms in 1992; this is confirmed by aggregate real cement price indices and accounts published in trade reports at the time. One must also point out that despite the high level of inflation in the first half of the 1990s, the economic environment was far from chaotic; economic agents had learned how to cope with a chronic and fast-changing price level, and to anticipate it reasonably well in the short term. It is thus possible for the researcher to filter (upward and downward) variation in real prices from the much larger (upward) variation in nominal prices in the pre-stabilization phase of the time period I cover.

Exogenous demand variables Several alternative series of economic activity, either in the construction and building sector or aggregated across sectors of the economy, are available as proxies for the exogenous demand for cement⁹. The favored series, issued by the Brazilian office of statistics (IBGE), reports the real index of activity in the construction sector for each of the 27 states, on an annual basis. Importantly, this series follows from a *volume* decomposition of Value Added in the construction sector (from the National Accounts) and should thus be a good proxy for exogenous demand. I blow up the index series for each state using the relative size of the construction sector between states, also obtained from the National Accounts; these can then be compared cross-sectionally (i.e. across states). Alternative quarterly series are available, which I use in checking the robustness of my estimation results.

⁸That is, the period that preceded the *Real* economic stabilization plan, enacted in July 1994.

⁹This follows from the fact that cement is an input to construction and yet accounts for a small share of construction budgets (see above). Taking such construction activity to exogenously move the demand curve for cement is a typical assumption: see, for example, Syverson (2004) who uses construction sector employment as an exogenous measure of demand in ready-mix concrete (an industry located downstream to cement).

Taking states to represent local markets In terms of geography, the lowest level of aggregation at which demand-side data are observed is the state level. Data availability thus require that I take each state to represent a market (i.e. I do not observe data at the “SMSA” or city/municipality level)¹⁰. However, I believe that this is sound, as follows. As the econometrician, I observe the flow of cement from each producer plant located anywhere in the country directly to buyers (i.e. to resellers and to consumers) aggregated within any given state. As explained above, the scope for cross-state shipping by resellers is limited. Thus price and consumption observations – obtained from different sources, as explained above – can reasonably be paired. A potential distortion arises from the possibility that the larger states may contain more than one local market with heterogeneous demand conditions, and that therefore identifying states with markets may hide variation at a more local level where agents interact. To my defence, however, I discard the largest northern states, albeit for another reason as I explain in the paper. Further, in the data I observe that cement *can* travel over significantly large distances from plants located in a state to buyers located in another state (though this does not occur frequently, for the behavioral reason I explore in the paper). Several field interviews and price data obtained directly from a sample of producers indicate that the spatial variation of prices within a state is minimal: prices are mostly uniform within a state. Of note, several studies in the literature have taken US states (of sizes similar to and as diverse as their Brazilian counterparts) to represent markets, such as Sutton (1998), FTC (1966) and Newmark (1998).

Factor prices Factor prices are either observed in the form of current prices, in which case they are converted to constant prices as explained above, or already reported in the form of constant prices. Though alternative series proxying for each factor price are available – which I use as alternative instruments in the demand estimation (Salvo 2005a) or to check the robustness of the supply-side estimation – the main series are:

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

¹⁰Notice that this is done only for the purpose of estimating demand. The availability of plant-to-state shipment data allows me to circumvent the tricky task of defining (geographic) markets in my treatment of supply: for any given plant, the geographic area which is relevant to its supply decision (i.e. that plant’s “market”) is endogenous – depending on demand, cost and conduct – and these plant-specific areas overlap across plants.

National Agency for Oil.

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

Plant characteristics Plant characteristics such as location, ownership, capacity (i.e. kiln pyroprocessing capacity and grinding capacity), number of kilns, age, technology (i.e. the type of equipment and process, whether dry or wet, whether a preheater is employed) and the fuel mix employed by kilns (largely either fuel oil, coal, or more recently pet coke or natural gas) is available from the Brazilian trade association¹¹ and from different editions of the World Cement Directory, published by the European Cement Association (Cembureau) every three years, compiling information on cement producers across the world. Data is complemented by or validated against information from (i) industry publications, (ii) investment banking reports, (iii) the press, (iv) companies' websites, (v) academic publications, and/or (vi) field interviews (see below). Of note, capacity and technology data may contain significant measurement error. The shortest distance by road from each plant to the main metropolitan areas in each state is available from the Ministry of Transport.

Computing plant marginal cost: an upper bound Using the fixed-coefficient nature of cement production technology, I can directly calculate marginal cost from observed factor prices, the observed plant characteristics and engineering estimates of the fixed coefficients. I employ the term “calculate” (“compute” or “construct”) rather than

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

“estimate” since obtaining marginal cost does not involve statistical inference; however, calculated marginal costs are indeed estimates – in fact they are estimated upper bounds to the true marginal costs – in the sense that there inevitably are unobserved plant characteristics, as I explain below. In view of the fixed-coefficient technology and my understanding of the industry, I model plant marginal cost as flat in quantity up to capacity. To the extent that marginal cost varies across kilns within the same plant complex, this will be an approximation to the true plant marginal cost which would then be a step function in quantity. (For example, if a plant consists of two kilns, labelled 1 and 2 in order of most efficient first, with kiln marginal costs denoted c_1 and $c_2 > c_1$, denoting other marginal cost by c , and denoting kiln capacities by K_1 and K_2 , then marginal cost would be $MC(q) = c + c_1$ if $q \leq K_1$ or $c + c_2$ if $K_1 \leq q \leq K_2$.) Clearly, this will be of relevance only if plant capacity utilization varies sufficiently over time that the *marginal kiln* in operation differs (e.g. a less efficient kiln is fired up and shut down for months at a time according to demand). I thus mitigate any distortion stemming from my approximation of plant marginal cost as being flat in quantity by taking capacity utilization (see below) and the characteristics of the marginal kiln into account when computing marginal cost. (It should also be noted that in recent decades the trend for cement plants has been to favor large single-kiln production lines as against multiple small lines, in view of the economies of scale.) It is also worth clarifying the way a kiln works. A kiln, when in operation, must run at close to full capacity; it cannot be operated at any given moment at, say, 50% capacity. Further, firing up a kiln is costly so when in operation a kiln typically runs for at least several days or weeks. As for plant marginal costs, it is clear that these will vary across plants according to the technology, capacity and age of the equipment and the fuel employed by the kiln; these are accounted for to the best of my knowledge as I explain below¹². Plant marginal costs fall into four main categories – kiln fuel, electricity, mineral extraction royalties, and labor/packaging/other costs – as follows:

1. Kiln fuel: This is the main component of plant marginal cost. Based on engineering estimates, the heat content required to produce 1 kg of clinker using the dry process (see S.1) will typically fall in the 650 - 850 kcal range (e.g. see World Cement, January 2000 issue). (The wet process consumes over double this.) A kiln’s (thermal) energy efficiency will depend on the capacity, technology (including the specifications of preheating, cooling and waste heat recovery systems used) and age of the kiln. (The kiln’s brick lining has to be changed periodically, and the time since the last relining will also impact the energy efficiency of the kiln.) Interview-based evidence, however, indicates that the energy efficiency of kilns in operation in the Brazilian cement industry is (i) high relative to its global peers

¹²To this end I have met with engineers working in cement plants or working for the technical arm of the cement producers’ trade association (the Brazilian Association for Portland Cement, ABCP), as well as meeting executives of equipment suppliers to the cement industry.

(including the US industry), with producers having shifted to the dry process chiefly over the 1980s, (ii) has continued to improve over the 1990s, and (iii) presents low variation across producers (with perhaps two exceptions, both with lower productivity). Based on observed plant characteristics and interviews, I classify the energy efficiency of each plant as “above average”, “average” and “below average”, assuming energy contents of 690, 730 and 800 kcal/kg of clinker respectively. (For example, with respect to kiln capacity, a kiln with capacity in excess of 1 mtpa will require a heat content approximately 6% below that of a kiln with capacity of 0.25 mtpa, controlling for other characteristics.)¹³ To arrive at the marginal cost relating to kiln fuel, I consider two types of fuel – fuel oil and coal – for which I observe prices, as explained above. I then use the observed fuel mix for each plant and the properties of each fuel to obtain fuel cost. (For example, an average-efficiency kiln burning a certain grade of fuel oil – with “inferior calorific power” of 9750 kcal/kg of fuel oil – will require $730/9750 \times 1000 = 75$ kg of fuel oil per tonne of clinker.)

2. Electricity: While thermal energy is required to produce clinker in the kiln, electricity is used mostly for grinding raw material, solid kiln fuel (such as coal) and clinker – a process known as comminution – and to a lesser extent to operate conveyor belts and packaging lines. Considerations here are similar to those made for kiln fuel. For example, in terms of technology, the more modern vertical roller mills tend to consume less power than the ball mill system. Again based on engineering estimates, the total plant electricity content required to produce 1 tonne of cement typically falls in the region of 90 - 105 kWh.
3. Mineral extraction royalties: The marginal cost component arising from the extraction of raw material (limestone and clay), from a quarry usually located within the plant complex, follows from legislation. The “Financial Compensation for the Extraction of Mineral Resources” (CFEM) requires that the cement producer collect 2% of its revenues from the sale of cement, net of sales taxes and freight, in the way of compensation to the government (see below for producer prices and sales taxes). Exceptions to this requirement, where negotiated between producers and the government, are not observed (see comment below on unobservables).
4. Labor/packaging/other costs: As mentioned in S.1, labor essentially performs a supervisory role. One may argue that a certain proportion of a plant’s labor cost is fixed. The variable proportion of labor would correspond to quarrying

¹³In addition to the above, I use other sources of information such as a report compiled by the industry’s trade association in 1993 on plant productivity with respect to energy inputs (stating the amount of hydrocarbon equivalent burned by tonne of clinker produced by plant). Note further that I neglect time-series variation in plant-specific energy efficiency given that this has been low over the time period of the study.

personnel and possibly workers involved with the packaging and distribution center operations. I refrain from discussion, given the relatively low cost of these plant operations and the fact any bias in the direction of overstating marginal cost reinforces the results of this study. Packaging costs will vary according to the proportion of a plant's production that is shipped in bags (largely in the form of the standard 50 kg bag) as opposed to bulk shipments; recall that I observe this proportion. As such, based on information at hand, I take this component of marginal cost to amount to around 5% of net producer price.

A final comment relates to unobservables. Despite a researcher calculating marginal cost to the best of his ability from observables, there will always be an unobserved (to the researcher) component to productivity across plants. In view of this, in computing marginal cost I choose to “err on the side of conservatism”, in this case by overstating marginal cost. I claim the calculated marginal cost is thus an upper bound to the true marginal cost, thus leading to an understated price-cost margin. The reason behind this choice is that, when I turn to the testing of firm behavior, such a bias reinforces the results of this study. There are several potential sources of bias (in the direction of overstating marginal cost). One source of unobserved plant heterogeneity may be the quantity discount enjoyed by Votorantim, the largest producer on a nationwide basis, in acquiring fuel oil, electricity or trucking services vis-à-vis the smaller producers. To the extent that producers manage to acquire factors on different terms (controlling for location), the marginal cost I compute may be overstated for the firms with greater bargaining power over suppliers. Another possibility is that producers substitute away from traditional kiln fuels such as fuel oil and coal in favor of cheaper alternatives¹⁴. Yet another bias stems from the formulation I use to compute the marginal cost of cement (see footnote 1). For simplicity I take 1 kg of cement to correspond to 1 kg of clinker. Now clinker is the most expensive input to the grinding process and even “pure” cement (referred to commonly as type I cement, or simply ordinary cement) is comprised of 96% clinker and 4% gypsum by weight. To the extent that different formulations of cement are produced, with a lower proportion of clinker (and a higher content of lower-cost additives, such as slag, pozzolane and/or filler), the bias in the direction of overstating marginal cost will be higher. For example, composite (type II) cement, with a clinker content in the region of 70 - 80%, accounted for 78% of the Brazilian industry's total production between 1999 and 2001. Finally, note that *fixed cost* heterogeneities across plants, stemming for example from decreasing unit capital costs as a function of capacity

¹⁴Indeed, since 2000 the use of pet coke (imported by some producers themselves from the Mexican Gulf) and natural gas (to the extent that a plant is located in proximity to a pipeline) is on the rise. A clinker kiln will in principle burn any material with a sufficiently high energy content, such as used rubber tyres, solvents and hazardous waste materials. The equipment supplier FLSmidth speculates that in the long term the cost of kiln fuel could fall to zero, or even turn negative, with cement producers being paid to dispose of waste materials.

(i.e. economies of scale), are not relevant for the computation of marginal cost and the resulting price-cost margins.

Computing plant-to-market freight cost This is the first component to explain marginal cost that I consider (the other two are the reseller mark-up and producers' sales taxes). In the cement industry, as seen in S.1, freight is a large component of cost. The vast majority of shipments from producers to buyers take place by road and are provided for by the producers. I do not observe the exact freight rates paid by cement producers. But fortunately I do observe a good proxy for the freight of cement. The transportation of agricultural goods such as soybean and maize is reportedly a close substitute to the supply of cement freight, in view of product and market characteristics (Soares and Caixeta Filho 1996)¹⁵. I use a database containing approximately 30,000 observations on freight prices for some agricultural goods collected over the period 1997 to 2003 for thousands of different routes across Brazil¹⁶. Figure 1 summarizes the results of some auxiliary reduced-form regressions. These should be seen as hedonic regressions with the purpose of predicting the price of freight. Given that I do not observe quantities demanded and supplied in the market for freight, I cannot estimate a structural model of the market for freight. (Nor do I think this is necessary in view of my objective, which is to predict the freight cost of cement from plant i to local market l based on observed data.) Freight prices (once converted to constant prices as explained earlier¹⁷) are regressed on exogenous variables such as the distance of the route, the squared distance, a shipment-to-port dummy (to capture exports), transportation-mode dummies (by water or by rail, as opposed to by road), seasonal dummies or monthly dummies (to capture the harvesting cycle), the price of diesel oil (the main cost component for freight), a packaging dummy (shipment of bagged produce as opposed to bulk) and product-type dummies (e.g. powdered soybean), in addition to interaction variables. It is clear from the R^2 (around 90%) of the OLS regressions that the fit is very high; the heteroskedasticity-robust standard errors are low. Freight prices (in R\$ per tonne) are increasing in distance (and concave, though slightly so over the relevant range). Consider the results for specification (II). At the sample means of the variables (735 km for distance and R\$ 0.422 per liter for

¹⁵For example, an interview with a cement industry executive revealed that during the soybean harvesting season (March through May) the producer he works for encourages large resellers to themselves pick orders up at the plant, for fear of relying too heavily on the scarce supply of outside truckers observed during these months. This further suggests that freight of cement and freight of soybean are close substitutes, and therefore that their prices should be similar. Most cement producers outsource trucking services, mostly to independent truckers who are registered in their databases and simply turn up at the door and are hired on the spot (or are hired through cooperatives or middlemen). According to this executive, the cement industry is the top industrial contractor of trucking services in the country.

¹⁶I am indebted to Professor José Vicente Caixeta Filho of ESALQ, at the University of São Paulo, for providing an extract of the SIFRECA freight database. Data pertaining to soybean, maize and (the mineral) limestone was kindly made available.

¹⁷Freight prices, in units of local currency per tonne of produce shipped, are thus in December 1999 terms.

the price of diesel oil), the predicted price of freight for a tonne of soybean shipped in bulk by road to a destination other than a port and in the month of April amounts to $3.358 + 0.0405 \times 735 - 5.44 \times 10^{-7} \times 735^2 + 6.519 \times 0.422 = 3.358 + 29.768 - 0.294 + 2.751 = \text{R\$ } 35.56$ (with a standard error of R\$ 0.21). Shipping to a port (possibly as a result of longer waiting times to unload) adds $1.813 + 0.00041 \times 735 = \text{R\$ } 2.12$ (s.e. R\$ 0.15), and when this shipping to a port takes place during the harvest season freight prices are predicted to increase by a further R\$ 2.30 (s.e. R\$ 0.32). Shipping by waterway costs $14.269 + 0.00498 \times 735 = \text{R\$ } 17.93$ (s.e. R\$ 0.25) less than by road, while shipping by railway costs $2.349 + 0.01538 \times 735 = \text{R\$ } 13.66$ (s.e. R\$ 0.28) less than by road. Shipping in bags as opposed to in bulk raises the price of freight by R\$ 0.25 though this estimate is not significantly different from zero. Compared to April, the peak month of the harvesting season, shipments in any other month of the year are cheaper (all coefficients on monthly dummies and their interactions with distance are negative). Shipments in January, the month in which prices are lowest, are R\$ 4.87 (s.e. R\$ 0.25) lower compared to April. Note that the variation in diesel oil prices over the period is R\$ 0.38, accounting thus for a R\$ 2.49 (s.e. 0.17) variation in freight prices (this is admittedly low, owing possibly to correlation between diesel oil prices and other variables). I choose to predict the plant-to-market freight cost for cement based on specification (II), on account of observables such as distance from the plant to the market, means of transport and the price of diesel oil.

Backing out net producer prices from retail prices The other components to ex-plant marginal cost, apart from plant-to-consumer freight, are the reseller (retailer) mark-up and producers' sales taxes. Recall that the lion's share of the Brazilian cement business consists of producers shipping bagged cement to resellers, who then sell directly to the end user (a small-scale consumer); I only observe the prices set by these resellers, not the prices set by producers. However, I back out producer prices as follows. Based on several field interviews¹⁸, I model the reseller as competitive. I thus avoid the issue of double marginalization. A reseller's cost consists largely of (i) two forms of sales tax ("PIS" and "COFINS", not to be confused with the sales taxes collected by the producer), which are proportional to the retail price (varying from 2.65 to 3.65% over the time period), and (ii) labor costs (for unloading the truck, storage handling and stocking shelves). While sales tax will be perfectly correlated with cement prices, this is not the case for labor costs. In any case, based again on the field interviews, I assume that resellers apply a fixed proportional mark-up over the producer price (namely in the region of 13%) and can then back out producer prices from observed retail prices. To the

¹⁸These interviews include cement producers' field representatives and sales executives, buyers of cement and representatives of the construction sector's trade associations across a sample of local markets. Information provided in these interviews was also consistent with a report on the supply chain prepared by a consulting firm for the cement industry trade association (Booz Allen & Hamilton 1990).

extent that (i) labor costs vary across markets, or (ii) some resellers evade taxes, or (iii) some resellers occasionally choose to price cement as a “loss leader” to lure consumers into their stores, the reseller mark-up may vary across resellers. This variation, however, should be small (and the bias, again, is in the direction of overstating marginal cost). Further, price discrimination by producers on the basis of customer size (i.e. quantity discounts) is very limited across resellers¹⁹. A 5-10% discount may be offered to large buyers who buy in bulk (ready-mix concrete firms and large construction firms) yet again this corresponds to a small share of the business compared to that flowing through resellers. Among the robustness checks I perform, I compare *observed* producer prices that I was fortunate to obtain from a subset of producers to the backed-out producer prices, and confirm that they are similar. Finally, to calculate producers’ sales taxes and thus arrive at net producer prices, I consider federal and state-level tax legislation. Despite the awkwardness of Brazil’s sales tax system (one needs to compute five different sales taxes, namely “ICMS-normal”, “ICMS-ST”, “IPI”, in addition to the producer’s own collection of “PIS” and “COFINS”; note further that tax rates vary according to the origin and destination of the shipment) the total sales tax collected by a producer upon selling to a buyer is conveniently proportional to the (net or gross) price set. Despite sales taxes on cement (and on other products in general) being high (e.g. towards the end of the time period of study, sales taxes owed by a producer located in the state of São Paulo selling to a buyer located in the same state amounted to 28% of the gross producer price), sales tax evasion on the part of producers is considered to be minimal. However, to the extent that producers manage to negotiate reductions in their tax liabilities with state governments eager to attract investments – negotiations which I do not observe – the marginal cost I calculate will again be overstated (see the earlier paragraph on unobservables).

A glance at some data series Figure 2 depicts (constant) cement prices, cement consumption and exogenous demand (activity in the construction sector) from January 1991 through December 2003 for the largest market, the state of São Paulo (*SP*)²⁰. The month in which the *Real* economic stabilization plan was enacted, July 1994, corresponds to observation (month) 43 in the graphs (marked by dotted lines). Following the lifting of price controls in November 1991, prices approximately doubled, remaining in the high R\$ 14 to R\$ 16 range until 1994. In the post-stabilization period they gradually declined back to R\$ 7 by late 1996, gradually rising thereafter. The sharp increase in consumption

¹⁹As mentioned earlier, in view of the bulkiness, fast turn and short shelf life of cement, producers reach far “down the trade”, via direct-from-plant deliveries and own distribution terminals. They resort to distributors for a minor share of their business. Even a relatively small retailer (reseller) will be able to place an order directly with the producer: a 15 ton “half-truck” (25 ton “full-truck”) load corresponds to only 300 (500) bags.

²⁰In addition to accounting for around one-third of the nation’s cement consumption, the case for the state of São Paulo is broadly representative for Brazil as a whole.

following stabilization, from a level of 600 mt per month to 1000 mt per month within two years, pulled by a 20% jump in the level of construction activity, is evident from the graphs. Some factor prices are also portrayed. Of note, there is high correlation in the post-stabilization phase between the price of cement and the prices of fuel oil and diesel oil²¹. This is expected in view of (i) evidence in Salvo (2005a) that imports set a price ceiling for cement and thus the price of cement (in local currency) is highly correlated with the exchange rate, and (ii) oil is a global commodity and policy in the oil sector from the second half of the 1990s has prescribed domestic oil prices varying in line with the world price (and hence with the exchange rate).

A glance at price-cost margins With respect to firm profitability, Figure 3 shows the evolution of average consumer prices, marginal cost and price-cost margins on the leading firm Votorantim's actual sales across Brazil, in constant local currency units per bag. Prices and marginal cost have been increasing since late 1996, the latter owing chiefly to increases in the price of fuel oil and diesel (freight) and the fact that sales taxes are proportional to prices – recall that cost relates to the entire supply chain, including freight, sales taxes and the reseller's cost. The picture is similar across firms. Across producers, across states and over time, the price-cost margin as a proportion of the consumer price lies in the region of 25-45% (equivalent to 40-65% as a proportion of the producer price net of sales tax). (Figure 4 is the by-state counterpart to Figure 3, displaying the evolution of consumer prices, marginal cost and price-cost margins, since July 1994, on Votorantim's actual sales to each of the 25 states where the firm is present.)

Capacity utilization As mentioned above, among other plant characteristics I observe capacity. As is usually the case with capacity figures, these are admittedly prone to considerable measurement error. Nevertheless, I proceed to analyzing the evolution of plant capacity utilization, including the three years post stabilization of steep consumption growth (1995 to 1997). Throughout the time period, capacity outstrips production (*including* the growth years, although the slack is lower²²), with capacity utilization hovering around an average 65%. This (low) capacity utilization appears to be fairly

²¹Fuel oil and diesel oil, used respectively in production and in transportation, are the two major components of cost. From July 1994, correlation coefficients (all highly significant) are as follows: 0.72 between the price of cement and the (US dollar) exchange rate; 0.86 between the price of cement and the price of fuel oil; 0.77 between the price of fuel oil and the exchange rate.

²²Note therefore that the post-stabilization boom in demand did not catch the cement industry unprepared in terms of capacity. Other industries with tighter capacity facing the same boom in demand in this period saw either entry (such as imports) or an increase in prices, neither of which was the experience of the cement industry. During this period, cement imports remained subdued and domestic cement prices actually fell (thanks to the appreciation of the local currency and, thus, a reduction in the domestic price ceiling posed by imports – see Salvo 2005a).

symmetric across plants and firms, despite the asymmetric capacities across these plants and firms. Thus, for instance, plant 1 with a capacity of 2 mtpa may be running at a 65% capacity utilization while plant 2, owned by a rival firm, with a capacity of 1 mtpa may be operating at the same 65% capacity utilization. The fairly high observed stability of market shares (with some exceptions) ensures that the time series of firms' capacity utilization rates are correlated across firms. This finding further supports my modelling of marginal cost as being flat in quantity (up to capacity). To the extent that as capacity utilization rises, older, smaller and energy-inefficient kilns may be put back into use, marginal costs may rise as capacity becomes tight. In view of the paper's finding that firm behavior tends to be more collusive than the Cournot benchmark, the correlation of firms' capacity utilization rates is consistent with a situation where *all* domestic producers adhere to the collusive arrangement, with no producer "free riding". (This is reinforced by the fact that all producers are long-time members of the cement producers' trade association (SNIC), an active lobbying outfit for the industry.) The corollary to this observation is that there appears to be no relevant fringe to the (tacit) cartel²³. Further, evenly-distributed idle capacity across firms would serve the important purpose of disciplining the cartel: the threat of punishment would not be credible were capacity to be tight^{24 25}.

S.2.2 Robustness checks on direct measures of marginal cost

In addition to checking my calculation of the reseller's mark-up on a subset of the data where I *do* observe producer prices – thus enabling these to be compared to the producer prices I back out from observed consumer prices, as explained above – I perform two other robustness checks of the constructed marginal costs. The first check is centered on the Portugal-based multinational Cimpor, which in 1997 bought its way into Brazil

²³As mentioned in footnote 7, the entrant Mizú has recently managed to establish a foothold in local markets in and around the state of Espírito Santo (*ES*), where it is based. Set up in 1998 by a large independent ready-mix concrete firm, Mizú signed a long-term contract with a steel producer (Companhia Siderúrgica de Tubarão) to supply it with steel slag, which it grinds and mixes with ground clinker, imported from as far as Japan, producing slag cement. Mizú's *grinding-only* plant is located conveniently next door to the steelworks and to the port of Vitória. In contrast to established cement producers, by 2003 Mizú was selling *up to capacity* (0.7 mtpa). It would appear that the established producers have accommodated Mizú's entry, given its limited capacity, its reliance on outside (imported) clinker, and the irreversibility of its investment. (As noted in S.2.1, consumption and shipment figures compiled by the cement producers' trade association, and used in this paper, do not consider Mizú. The distortion nevertheless is small in view of Mizú's (to date) limited capacity, limited geographic scope and recent entry.)

²⁴A further strategic role may be that of helping deter entry, as studied in the literature (e.g. Dixit 1980).

²⁵A final comment regarding the possibility that producers collude in capacity investments, in addition to colluding in product market outcomes. Rather than restricting capacity and hence output, producers overinvest in capacity, as just discussed. Other characteristics of the cement industry, such as the lumpiness, infrequency, long life and irreversibility of investment, would further suggest that the scope for collusion in capacities is limited. See Ivaldi et al (2003) for a discussion.

and in 1999 became the third largest firm in the country upon acquiring Brenmand. This firm is of particular interest in that it is listed on the Lisbon stock exchange and chooses to report its financial results broken out by country of operation (and line of business). I can thus use their reported results for Brazil as a robustness check for my calculated price-cost margins. The evolution of the calculated price-cost margin, as a percentage of net producer sales (i.e. net of sales taxes), is graphed in Figure 5. This evolution is compared to Cimpor's reported EBITDA (earnings before income tax and depreciation allowance, also known as operating cash flow) as a percentage of net sales, over the period 1998 to 2003. (I can further check my estimates of resellers' mark-ups and sales taxes by comparing my calculated net producer sales, backed out from observed consumer prices, to their reported net sales.) The time series fit between constructed and reported figures is good. For example, I estimate Cimpor's average price-cost margins as a percentage of net producer sales rising from around 47% in 2000 to 56% in 2002. Cimpor reports a similar rise in this period, from 44% to 55%.²⁶ If anything, my calculated price-cost margins are slightly higher than the EBITDA figures Cimpor reports. This is to be expected, for while my cost estimates include only (constant) marginal cost, Cimpor's EBITDA figures are net of other costs such as plant overhead and sales and administrative expenses. Indeed, my price-cost margins appear to be conservative (on the low side), as expected from the discussion above regarding the directional bias in the construction of marginal cost owing to unobservables (in the way of overstating marginal cost).

The second additional robustness check is based on accounting data of the cement industry surveyed annually by the Brazilian Institute for Geography and Statistics (IBGE) as part of their Annual Industry Survey (PIA) series. Figure 6 depicts the average accounting gross margin (defined as producers' Net Sales minus Cost of Goods Sold) as a percentage of net sales for a sample of establishments over the 1990s; the number of establishments varies between 33 and 55 and only aggregate data is published. The accounting gross margin is high, hovering around 50%. Note that the accounting definition of Cost of Goods Sold does not include freight expenses but does include accounting depreciation, so the accounting gross margin cannot be immediately compared to my constructed price-cost margin (which does consider freight but not depreciation). Further, I do not know the identity of the surveyed establishments. However, the magnitude of both series appears to be consistent. Of perhaps greater importance, the variation in the surveyed accounting gross margin is consistent with the observed fall in prices beginning in 1992 and the rise in prices commencing in 1997. (Notice the capital-intensive nature of the industry: on average payroll – corresponding not only to plant but also

²⁶Comparing operating cash flow (EBITDA) margins across the 9 countries (in Iberia, Africa and South America) where the firm is active, *Cimpor's Brazilian cement operations are the most profitable*: a 55.5% EBITDA margin in Brazil compared to an average 39.2% across all countries.

to sales and administrative employees – accounts for less than 10% of a producer's net sales.)

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

Note: Heteroskedasticity-robust standard errors

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

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

Figure 1: Auxiliary OLS regressions for plant-to-market freight cost

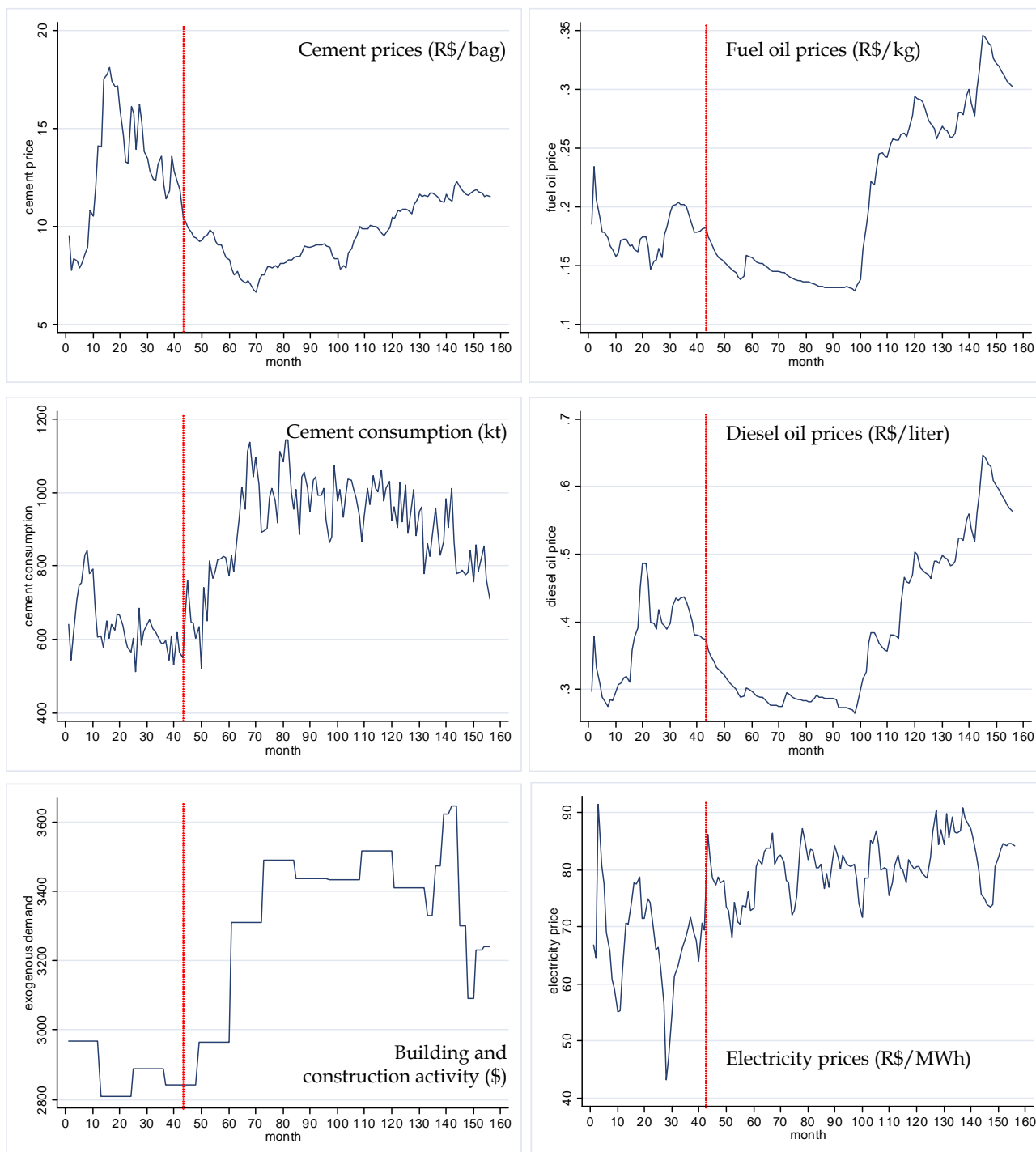


Figure 2: Cement prices, consumption, exogenous demand and factor prices for the state of São Paulo. All prices are in constant December 1999 values. Monthly observations, observation 1 corresponding to January 1991. July 1994, the month in which the stabilization plan was enacted, is marked by the dotted lines.

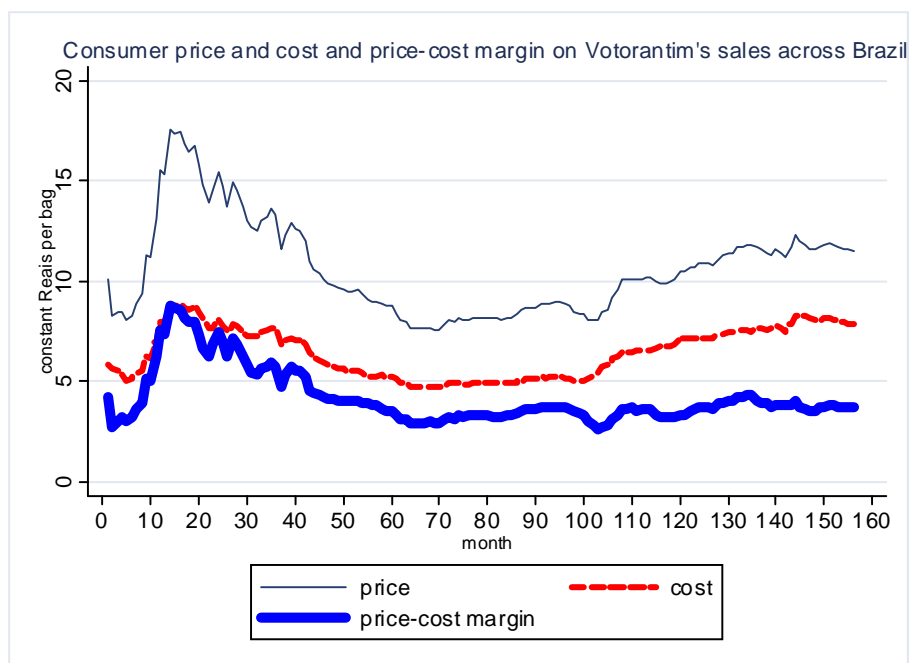


Figure 3: Evolution of consumer prices, marginal costs and price-cost margins on Votorantim's sales. Averaged across all states. In constant Reais per bag (at December 1999 values).

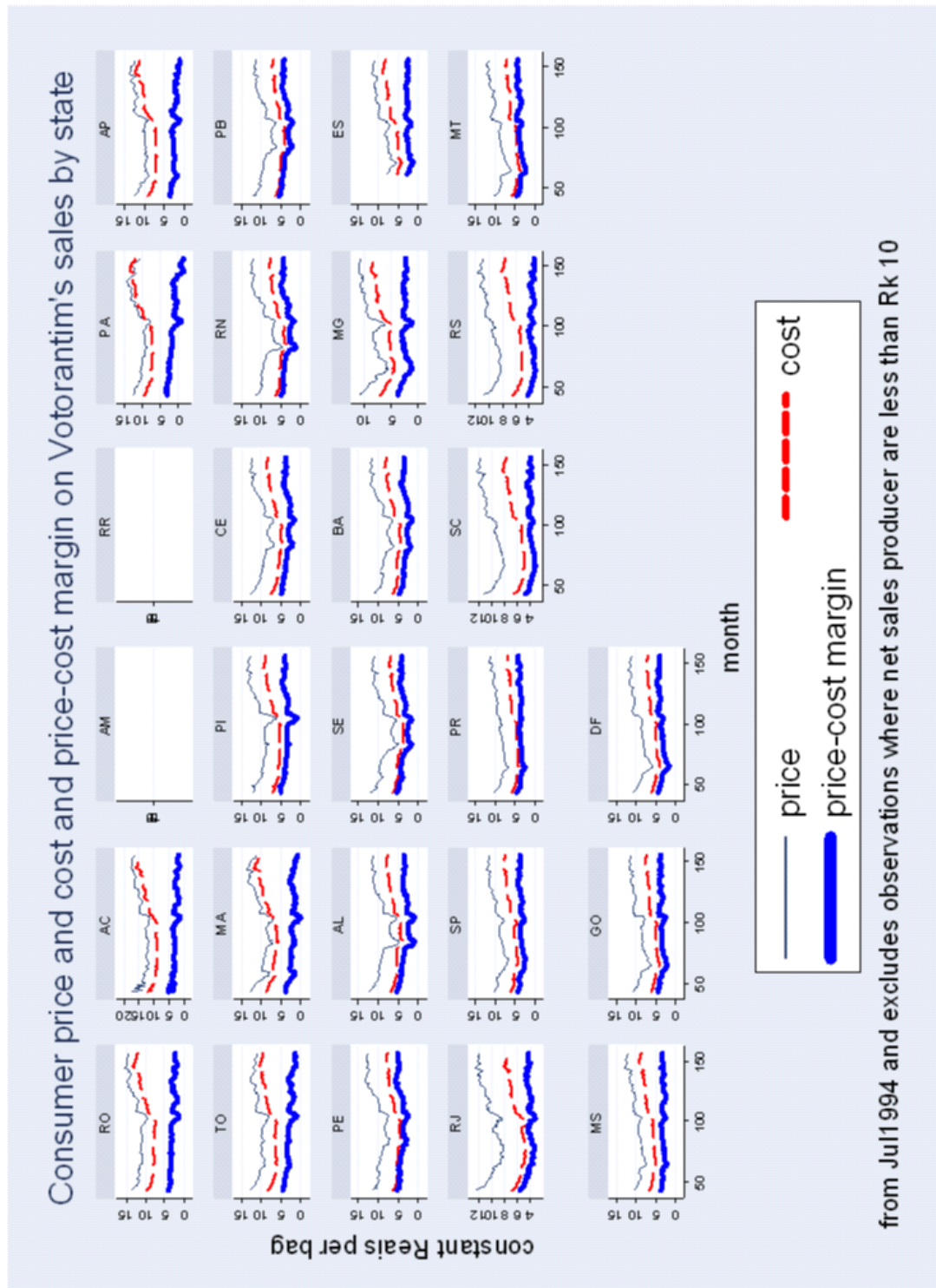


Figure 4: By-market evolution of consumer prices, marginal costs and price-cost margins since July 1994 (post-stabilization phase) on Votorantim's sales. In constant Reais per bag (at December 1999 values).

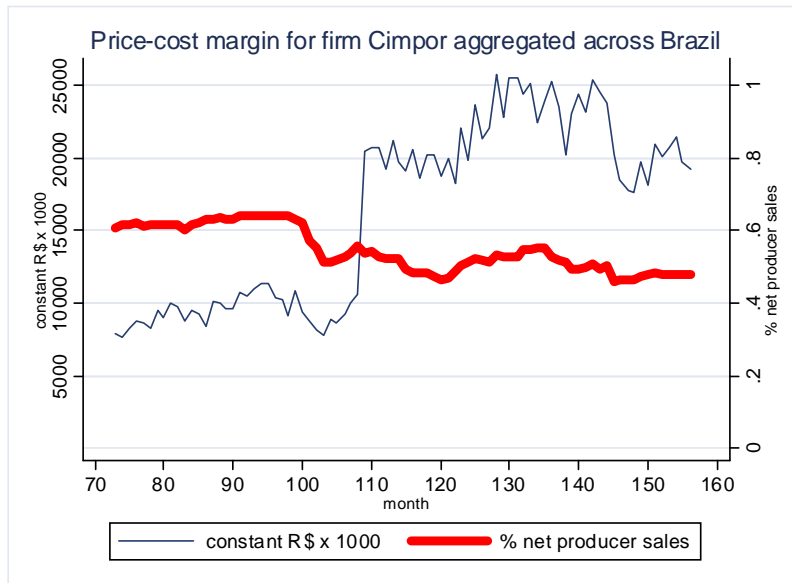


Figure 5: Evolution of the average price-cost margin for firm Cimpor. In constant Reais x 1000 per month (at December 1999 values) and as a percentage of net producer sales. Aggregated across all states.

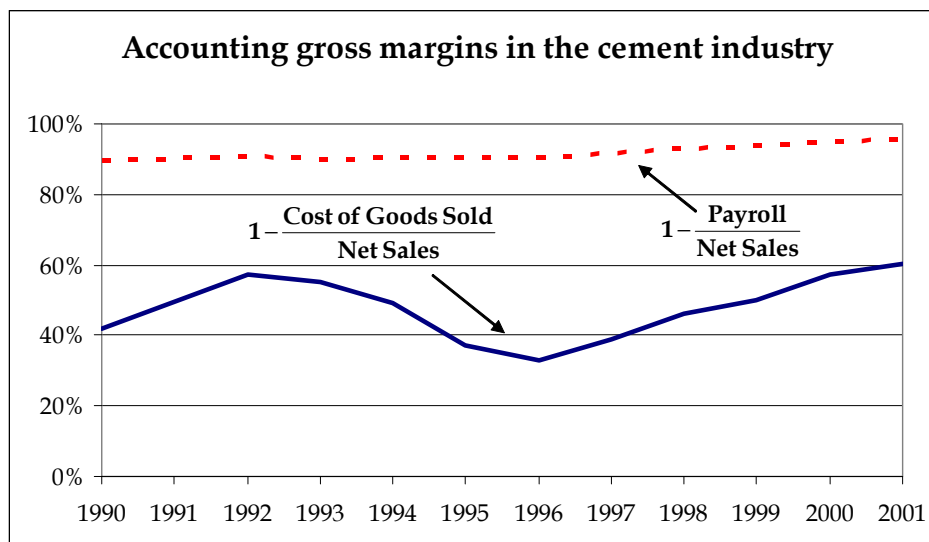


Figure 6: Accounting gross margins in the cement industry, from surveys conducted by the Brazilian Institute for Geography and Statistics (IBGE)