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

ONLINE APPENDIX: MONTE CARLOS, INDUSTRY AND DATA

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S.1 Further Monte Carlo experiments

In addition to considering a modification of the Monte Carlo experiment (1) provided in the paper, in which I sharply raise the proportion of constrained markets, I report results for three other simulated industries: (2) a loglinear demand and linear marginal cost monopoly; (3) a linear demand and linear marginal cost monopoly, with non-diagonal covariance matrix of exogenous variables; and (4) an exponential demand and linear marginal cost monopoly. Unless noted otherwise, specifications follow those of Experiment 1, e.g. $S = 2000$ simulations, $N = 1000$ markets per simulation. I also derive, for the algebraically simple case of Experiment 1, an analytical expression for the asymptotic 2SLS estimator plim $\widehat{\theta}$ in the misspecified autarkic pricing model.

S.1.1 Modified experiment 1: Linear demand and flat marginal cost monopoly, with $\Pr(\chi_t = 1) \to 0$

Consider the setup for Experiment 1 detailed in the paper, but let $\beta_4 = 2$ and $T \sim N(.1, .01^2)$. (Note that $c^I > c$ still holds for all market realizations.) The domestic industry is now highly constrained, with the proportion of constrained markets in the simulated datasets ranging from 96% to 99%. Demand estimates (omitted) are again consistent. In the imports cost specification, $c^I(W^I;\beta^I)$, relabel $\beta_1(1+\beta_4) \equiv \beta_5 = 3$; the domestic supply parameters are now $(\theta, \beta_1, \beta_2, \sigma_s)$ and the imports supply parameters are $(\beta_3, \beta_5, \sigma_I)$. First consider the situation where the researcher imposes autarky (estimates are again omitted). As in Experiment 1 in the paper, supply estimates (with observed p, q) are inconsistent. For example, the mean $\widehat{\theta}$ across simulations is 0.01 (standard deviation 0.01, minimum -0.05, maximum 0.06), against an actual $\theta = 1$. The downward bias in the estimated degree of market power is severe: the estimated markup $-\eta\left(p - \widehat{c}\right)/p$ averages (i) 10% across unconstrained observations (against an actual realized markup of 93%), and (ii) 1% across constrained observations (against a realized markup of 49%). Now consider the situation where the import threat is modeled. Due to the low number of unconstrained markets, there is much variation in the estimated domestic supply parameters. Even discounting some simulated datasets for which the optimizer returns huge estimates, I am unable to consistently recover domestic supply parameters (see the medians in the table below). On the other hand, estimated imports cost parameters are consistent. Optimization returns $\phi\left(S\left(.;\widehat{\theta}_s,\widehat{\beta}_{1,s},\widehat{\beta}_{2,s}\right)/\widehat{\sigma}_{s,s}\right) \approx 0$ and $\Phi\left(-S\left(.;\widehat{\theta}_s,\widehat{\beta}_{1,s},\widehat{\beta}_{2,s}\right)/\widehat{\sigma}_{s,s}\right) \approx 1$ for the vast majority of the $SN = 2 \times 10^6$ simulated markets. Intuitively, variation in the domestic supply parameters around a large subregion of parameter space hardly impacts the log likelihood function, as observed prices are largely driven by the imports pricing equation (and the demand curve).

SUPPLY:		ML estimation with full sample $\chi_t \in \{0,1\}$ of:	
CONSTRAINT		**Observed variables** p, q (noting that $\Pr(\chi_t = 1) \to 0$)	
MODELED		(**Threat of entry**, with censoring condition accounted for)	
Mean (Std.Dev.) {Median} over simulations s:			[Actual]
$\widehat{\theta}_s$	domestic	7.0×10^{10} (1.5×10^{12}) {1.64}	[$\theta = 1$]
$\widehat{\beta}_{1,s}$	domestic	-9.2×10^{10} (1.9×10^{12}) {0.46}	[$\beta_1 = 1$]
$\widehat{\beta}_{2,s}$	domestic	-8.2×10^{10} (2.0×10^{12}) {0.31}	[$\beta_2 = 1$]
$\widehat{\beta}_{3,s}$	imports	1.01 (0.07) {1.01}	[$\beta_3 = 1$]
$\widehat{\beta}_{5,s}$	imports	2.99 (0.07) {2.99}	[$\beta_5 = 3$]
$\widehat{\sigma}_{s,s}$	domestic	9.7×10^{10} (2.8×10^{12}) {0.54}	[$\sigma_s = 1$]
$\widehat{\sigma}_{I,s}$	imports	0.99 (0.02) {0.99}	[$\sigma_I = 1$]

Notes: I include median estimates in braces to discount those simulations where domestic supply estimates are large in absolute value. In separate optimizations bounding θ between 0 and 1, domestic supply estimates still varied considerably and were biased; means (standard deviations) across simulations were: $\widehat{\theta}_s$ 0.85 (0.19), $\widehat{\beta}_{1,s}$ 1.18 (0.70), $\widehat{\beta}_{2,s}$ 1.22 (0.88), $\widehat{\sigma}_{s,s}$ 0.74 (0.43) against actual parameters $\theta = \beta_1 = \beta_2 = \sigma_s = 1$.

S.1.2 Experiment 2: Loglinear demand and linear marginal cost monopoly

I now specify loglinear demand and domestic marginal cost that increases linearly in output. Demand is

$$\begin{aligned}
\ln(q) &= \alpha_1 + \alpha_2 \ln(p) + \alpha_3 Y_1 + \alpha_4 Y_2 \ln(p) + \varepsilon^d \\
Y_1 &\sim N(10, 1^2), Y_2 \sim N(3, .6^2) \\
\alpha_1 &= 1, \alpha_2 = -1, \alpha_3 = .3, \alpha_4 = -.1, \sigma_d = .4
\end{aligned}$$

such that $-q\partial p(q,.)/\partial q$ becomes $-p\left(\alpha_2 + \alpha_4 Y_2\right)^{-1}$. Supply is specified as

$$\begin{aligned}
c &= \beta_1 W_1 e + \beta_2 W_2 q \\
c^I &= \beta_1 (1+\beta_4) W_1 e + \beta_3 W_3 e \\
W_1 &\sim N(3, .3^2), W_2 \sim N(.2, .02^2), e \sim N(1, .1^2), W_3 = 5\frac{W_2}{e} + T, T \sim N(9, .9^2) \\
\theta &= 1, \beta_1 = 1, \beta_2 = 1, \beta_3 = 1, \beta_4 = 1, \sigma_s = 1, \sigma_I = 1
\end{aligned}$$

(Other specifications are as in Experiment 1.) The reduced-form solution to the constraint-free system is obtained implicitly:

$$p^*\left(1 + \theta\frac{1}{\alpha_2 + \alpha_4 Y_2}\right) - (p^*)^{\alpha_2 + \alpha_4 Y_2} \beta_2 W_2 e^{\alpha_1 + \alpha_3 Y_1 + \varepsilon^d} = \beta_1 W_1 e + \varepsilon^s$$

Given these specifications, the proportion of constrained observations t now ranges from 35% to 45% over simulations s. Demand estimates using observed variables p, q are consistent.

DEMAND	**2SLS estimation** with full sample $\chi_t \in \{0,1\}$ of: **Observed variables** p, q	 **Latent variables** p^*, q^*	
Mean (Std.Dev.) over simulations s:			[Actual]
$\widehat{\alpha}_{1,s}$	0.99 (0.44)	0.99 (0.38)	$[\alpha_1 = 1]$
$\widehat{\alpha}_{2,s}$	-0.99 (0.15)	-0.99 (0.11)	$[\alpha_2 = -1]$
$\widehat{\alpha}_{3,s}$	0.30 (0.01)	0.30 (0.01)	$[\alpha_3 = .3]$
$\widehat{\alpha}_{4,s}$	-0.10 (0.01)	-0.10 (0.02)	$[\alpha_4 = -.1]$

Notes: See notes to the table of demand estimates for Experiment 1.

Supply: Imposing autarky Similar comments to those for Experiment 1 apply. Estimation of the misspecified model, with observed variables p, q, again understates the true degree of market power: the 95% C.I. for the estimated elasticity-adjusted price-cost markup $-\eta\left(p - \widehat{c}\right)/p$ lies below the actual realized (and sometimes constrained) markup $-\eta\left(p - c\right)/p$ in all but 1 (i.e. $\simeq 0.0\%$) of the $SN = 2 \times 10^6$ simulated markets. The magnitude of the downward bias is considerable.

SUPPLY:	**2SLS estimation** with full sample $\chi_t \in \{0,1\}$ of:		
CONSTRAINT	**Observed variables** p, q	**Latent variables** p^*, q^*	
UNMODELED	(**Threat of entry**)	(**Bresnahan/Porter**)	
Mean (Std.Dev.) over simulations s:			[Actual]
$\widehat{\theta}_s$	0.79 (0.03)	1.00 (0.01)	$[\theta = 1]$
$\widehat{\beta}_{1,s}$	1.59 (0.10)	1.00 (0.06)	$[\beta_1 = 1]$
$\widehat{\beta}_{2,s}$	1.21 (0.23)	0.99 (0.20)	$[\beta_2 = 1]$

Estimation with **observed variables** p, q: Proportion of the SN markets such that the 95% C.I. for the estimated markup $-\eta\frac{p-\widehat{c}}{p}$ lies below the actual markup $-\eta\frac{p-c}{p}$: $\simeq$100%.
Mean over s of means over $t \in s$ (Std.Dev. over s of means over $t \in s$), where t is...

...unconstrained	Estimate $-\eta\frac{p-\widehat{c}}{p}$:	[Actual $-\eta\frac{p-c}{p}$:	Estimate $\widehat{c}$:	[Actual c:
$(\chi_t = 1)$	0.71 (0.04)	0.92 (0.01)]	5.31 (0.35)	3.45 (0.02)]
...constrained	Estimate $-\eta\frac{p-\widehat{c}}{p}$:	[Actual $-\eta\frac{p-c}{p}$:	Estimate $\widehat{c}$:	[Actual c:
$(\chi_t = 0)$	0.84 (0.03)	0.99 (0.00)]	5.30 (0.35)	3.43 (0.02)]

Notes: Similar comments to those of the corresponding table in Experiment 1 apply. Endogenous variables are now $-q\partial p(q,.)/\partial q = -p\left(\alpha_2 + \alpha_4 Y_2\right)^{-1}$ and $W_2 q$, and excluded instruments are Y_1, Y_2 and W_2Y_1, W_2Y_2. Using fitted demand $(\widehat{\eta})$ from a first stage yields similar supply estimates but larger standard errors.

Supply: Modeling the import threat Since $0 \ll \Pr(\chi = 1) \ll 1$, MLE of the true mixture model recovers the structural (domestic and imports) supply parameters.

SUPPLY:	**ML estimation** with full sample $\chi_t \in \{0,1\}$ of:	
CONSTRAINT	**Observed variables** p, q	
MODELED	(**Threat of entry**, with censoring condition accounted for)	
Mean (Std.Dev.) over simulations s:		[Actual]
$\widehat{\theta}_s$	1.00 (0.02)	$[\theta = 1]$
$\widehat{\beta}_{1,s}$	1.00 (0.08)	$[\beta_1 = 1]$
$\widehat{\beta}_{2,s}$	1.02 (0.16)	$[\beta_2 = 1]$
$\widehat{\beta}_{3,s}$	1.00 (0.05)	$[\beta_3 = 1]$
$\widehat{\beta}_{4,s}$	1.02 (0.25)	$[\beta_4 = 1]$
$\widehat{\sigma}_{s,s}$	1.00 (0.07)	$[\sigma_s = 1]$
$\widehat{\sigma}_{I,s}$	1.00 (0.05)	$[\sigma_I = 1]$

Notes: Similar comments to those of the corresponding table in Experiment 1 apply. Using fitted demand $(\widehat{\eta})$ from a first stage yields similar supply estimates but larger standard errors.

S.1.3 Experiment 3: Linear demand and linear marginal cost monopoly, non-diagonal covariance matrix

Demand is linear (as in Experiment 1) and domestic marginal cost increases linearly in output (as in Experiment 2). Observed exogenous covariates are drawn from the following distributions:

$$\begin{aligned} Y_1 &\sim N(20, 1^2), Y_2 = \frac{Y_1}{20}\widetilde{Y}_2, \widetilde{Y}_2 \sim N(1, .1^2), W_1 \sim N(3, .3^2), W_2 = \frac{Y_1}{20}\widetilde{W}_2, \\ \widetilde{W}_2 &\sim N(.3, .03^2), e \sim N(1, .1^2), W_3 = 10\frac{W_2}{e} + T, T \sim N(4, .4^2) \end{aligned}$$

Notice that $Corr(Y_1, Y_2) > 0$ and $Corr(Y_1, W_2) > 0$. The structural parameters are:

$$\begin{aligned} \alpha_1 &= 10, \alpha_2 = -1, \alpha_3 = 1, \alpha_4 = -.2, \sigma_d = 1 \\ \theta &= 1, \beta_1 = 1, \beta_2 = 1, \beta_3 = 1, \beta_4 = 2.5, \sigma_s = 1, \sigma_I = 1 \end{aligned}$$

The reduced-form solution to the constraint-free system is given by

$$p^* \left(1 + \theta - \beta_2 W_2 \left(\alpha_2 + \alpha_4 Y_2\right)\right) = -\theta \left(\frac{\alpha_1 + \alpha_3 Y_1 + \varepsilon^d}{\alpha_2 + \alpha_4 Y_2}\right) + \beta_1 W_1 e + \beta_2 W_2 \left(\alpha_1 + \alpha_3 Y_1 + \varepsilon^d\right) + \varepsilon^s$$

The proportion of constrained observations t ranges from 15% to 23% over simulations s. Demand estimates are consistent.

DEMAND	**2SLS estimation** with full sample $\chi_t \in \{0,1\}$ of: **Observed variables** p, q	**Latent variables** p^*, q^*	
Mean (Std.Dev.) over simulations s:			[Actual]
$\widehat{\alpha}_{1,s}$	9.96 (0.87)	9.85 (1.00)	[$\alpha_1 = 10$]
$\widehat{\alpha}_{2,s}$	-0.99 (0.08)	-0.97 (0.13)	[$\alpha_2 = -1$]
$\widehat{\alpha}_{3,s}$	1.00 (0.05)	0.98 (0.09)	[$\alpha_3 = 1$]
$\widehat{\alpha}_{4,s}$	-0.20 (0.02)	-0.20 (0.03)	[$\alpha_4 = -.2$]

Notes: See notes to the table of demand estimates for Experiment 1.

Supply: Imposing autarky Similar comments to those of the earlier experiments apply. Estimation of the misspecified model, with observed variables p, q, again understates the true degree of market power. The 95% C.I. for the estimated elasticity-adjusted price-cost markup lies below the actual realized markup in all but 10 (i.e. $\simeq 0.0\%$) of the $SN = 2 \times 10^6$ simulated markets. The magnitude of the downward bias is considerable.

SUPPLY:	**2SLS estimation** with full sample $\chi_t \in \{0,1\}$ of:		
CONSTRAINT	**Observed variables** p, q	**Latent variables** p^*, q^*	
UNMODELED	(**Threat of entry**)	(**Bresnahan/Porter**)	
Mean (Std.Dev.) over simulations s:			[Actual]
$\widehat{\theta}_s$	0.62 (0.04)	1.00 (0.04)	[$\theta = 1$]
$\widehat{\beta}_{1,s}$	2.11 (0.09)	1.00 (0.06)	[$\beta_1 = 1$]
$\widehat{\beta}_{2,s}$	0.94 (0.10)	1.00 (0.08)	[$\beta_2 = 1$]

Estimation with **observed variables** p, q: Proportion of the SN markets such that the 95% C.I. for the estimated markup $-\eta\frac{p-\widehat{c}}{p}$ lies below the actual markup $-\eta\frac{p-c}{p}$: $\simeq$100%. Mean over s of means over $t \in s$ (Std.Dev. over s of means over $t \in s$), where t is...

...unconstrained	Estimate $-\eta\frac{p-\widehat{c}}{p}$:	[Actual $-\eta\frac{p-c}{p}$:	Estimate $\widehat{c}$:	[Actual c:
($\chi_t = 1$)	0.64 (0.04)	1.00 (0.00)]	9.70 (0.41)	6.44 (0.02)]
...constrained	Estimate $-\eta\frac{p-\widehat{c}}{p}$:	[Actual $-\eta\frac{p-c}{p}$:	Estimate $\widehat{c}$:	[Actual c:
($\chi_t = 0$)	0.55 (0.04)	0.80 (0.01)]	9.01 (0.42)	6.40 (0.04)]

Notes: Similar comments to those of the corresponding table in Experiment 1 apply (endogenous variables are $-q\partial p(q,.)/\partial q = -q\left(\alpha_2 + \alpha_4 Y_2\right)^{-1}$ and $W_2 q$, and excluded instruments are Y_1, Y_2 and $W_2 Y_1$, $W_2 Y_2$).

Supply: Modeling the import threat MLE of the true mixture model again recovers the structural supply parameters. Notice the lower precision of $\widehat{\sigma}_{I,s}$ relative to $\widehat{\sigma}_{s,s}$, which one may tentatively attribute to the lower proportion of constrained markets.

SUPPLY:	**ML estimation** with full sample $\chi_t \in \{0,1\}$ of:	
CONSTRAINT	**Observed variables** p, q	
MODELED	(**Threat of entry**, with censoring condition accounted for)	
Mean (Std.Dev.) over simulations s:		[Actual]
$\widehat{\theta}_s$	1.00 (0.05)	[$\theta = 1$]
$\widehat{\beta}_{1,s}$	1.00 (0.09)	[$\beta_1 = 1$]
$\widehat{\beta}_{2,s}$	1.00 (0.10)	[$\beta_2 = 1$]
$\widehat{\beta}_{3,s}$	1.00 (0.08)	[$\beta_3 = 1$]
$\widehat{\beta}_{4,s}$	2.54 (0.38)	[$\beta_4 = 2.5$]
$\widehat{\sigma}_{s,s}$	1.00 (0.03)	[$\sigma_s = 1$]
$\widehat{\sigma}_{I,s}$	1.00 (0.06)	[$\sigma_I = 1$]

Notes: Similar comments to those of the corresponding table in Experiment 1 apply.

S.1.4 Experiment 4: Exponential demand and linear marginal cost monopoly

I now specify exponential demand:

$$\begin{aligned}
\ln(q) &= \alpha_1 + \alpha_2 p + \alpha_3 Y_1 + \alpha_4 p Y_2 + \varepsilon^d \\
Y_1 &\sim N(10, 1^2), Y_2 \sim N(3, .6^2) \\
\alpha_1 &= -.2, \alpha_2 = -.07, \alpha_3 = .3, \alpha_4 = -.012, \sigma_d = .4
\end{aligned}$$

such that $-q\partial p(q,.)/\partial q$ becomes $-\left(\alpha_2 + \alpha_4 Y_2\right)^{-1}$. Supply is defined by

$$\begin{aligned}
c &= \beta_1 W_1 e + \beta_2 W_2 q \\
c^I &= \beta_1(1+\beta_4) W_1 e + \beta_3 W_3 e \\
W_1 &\sim N(3, .3^2), W_2 \sim N(.2, .02^2), e \sim N(1, .1^2), W_3 = 10\frac{W_2}{e} + T, T \sim N(7, .7^2) \\
\theta &= 1, \beta_1 = 1, \beta_2 = 1, \beta_3 = 1, \beta_4 = 1, \sigma_s = 1, \sigma_I = 1
\end{aligned}$$

The reduced-form solution to the constraint-free system is obtained implicitly:

$$\ln(q^*) - \left(\alpha_2 + \alpha_4 Y_2\right)\beta_2 W_2 q^* = \alpha_1 + \alpha_3 Y_1 + \varepsilon^d - \theta + \left(\alpha_2 + \alpha_4 Y_2\right)\left(\beta_1 W_1 e + \varepsilon^s\right)$$

The proportion of constrained observations t now ranges from 16% to 26% over simulations s. Demand estimates are consistent.

DEMAND	**2SLS estimation** with full sample $\chi_t \in \{0,1\}$ of: **Observed variables** p, q	 **Latent variables** p^*, q^*	
Mean (Std.Dev.) over simulations s:			[Actual]
$\widehat{\alpha}_{1,s}$	-0.22 (0.42)	-0.24 (0.48)	$[\alpha_1 = -.2]$
$\widehat{\alpha}_{2,s}$	-0.07 (0.03)	-0.07 (0.03)	$[\alpha_2 = -.07]$
$\widehat{\alpha}_{3,s}$	0.30 (0.01)	0.30 (0.02)	$[\alpha_3 = .3]$
$\widehat{\alpha}_{4,s}$	-0.012 (0.003)	-0.012 (0.004)	$[\alpha_4 = -.012]$

Notes: See notes to the table of demand estimates for Experiment 1.

Supply: Imposing autarky Similar comments to those of the earlier experiments apply. Estimation of the misspecified model, with observed variables p, q, again understates the true degree of market power: the 95% C.I. for the estimated elasticity-adjusted price-cost markup lies below the actual realized markup in all but 224 (i.e. $\simeq 0.0\%$) of the $SN = 2 \times 10^6$ simulated markets. The magnitude of the downward bias is considerable.

SUPPLY: **CONSTRAINT** **UNMODELED**	**2SLS estimation** with full sample $\chi_t \in \{0,1\}$ of: **Observed variables** p, q (**Threat of entry**)		**Latent variables** p^*, q^* (**Bresnahan/Porter**)	
Mean (Std.Dev.) over simulations s:				[Actual]
$\widehat{\theta}_s$	0.80 (0.03)		1.00 (0.03)	[$\theta = 1$]
$\widehat{\beta}_{1,s}$	1.54 (0.08)		1.00 (0.07)	[$\beta_1 = 1$]
$\widehat{\beta}_{2,s}$	0.95 (0.14)		1.00 (0.14)	[$\beta_2 = 1$]
Estimation with **observed variables** p, q: Proportion of the SN markets such that the 95% C.I. for the estimated markup $-\eta\frac{p-\widehat{c}}{p}$ lies below the actual markup $-\eta\frac{p-c}{p}$: $\simeq$100%.				
Mean over s of means over $t \in s$ (Std.Dev. over s of means over $t \in s$), where t is...				
...unconstrained	Estimate $-\eta\frac{p-\widehat{c}}{p}$:	[Actual $-\eta\frac{p-c}{p}$:	Estimate $\widehat{c}$:	[Actual c:
($\chi_t = 1$)	0.81 (0.03)	0.98 (0.00)]	5.57 (0.28)	3.94 (0.02)]
...constrained	Estimate $-\eta\frac{p-\widehat{c}}{p}$:	[Actual $-\eta\frac{p-c}{p}$:	Estimate $\widehat{c}$:	[Actual c:
($\chi_t = 0$)	0.79 (0.03)	0.93 (0.01)]	5.30 (0.28)	3.87 (0.05)]

Notes: Similar comments to those of the corresponding table in Experiment 1 apply (noting that since $-q\partial p(q,.)/\partial q = -\left(\alpha_2 + \alpha_4 Y_2\right)^{-1}$, only $W_2 q$ is endogenous and is instrumented with $W_2 Y_1$).

Supply: Modeling the import threat MLE of the mixture model again recovers the structural supply parameters.

SUPPLY: **CONSTRAINT** **MODELED**	**ML estimation** with full sample $\chi_t \in \{0,1\}$ of: **Observed variables** p, q (**Threat of entry**, with censoring condition accounted for)	
Mean (Std.Dev.) over simulations s:		[Actual]
$\widehat{\theta}_s$	1.00 (0.03)	[$\theta = 1$]
$\widehat{\beta}_{1,s}$	1.00 (0.10)	[$\beta_1 = 1$]
$\widehat{\beta}_{2,s}$	1.01 (0.10)	[$\beta_2 = 1$]
$\widehat{\beta}_{3,s}$	1.01 (0.09)	[$\beta_3 = 1$]
$\widehat{\beta}_{4,s}$	1.02 (0.37)	[$\beta_4 = 1$]
$\widehat{\sigma}_{s,s}$	1.00 (0.03)	[$\sigma_s = 1$]
$\widehat{\sigma}_{I,s}$	0.99 (0.07)	[$\sigma_I = 1$]

Notes: Similar comments to those of the corresponding table in Experiment 1 apply.

S.1.5 An analytical expression for plim $\widehat{\theta}$ in the misspecified autarkic model

I consider the asymptotics of the 2SLS estimator $\widehat{\theta}$—which does not account for the price ceiling—for an algebraically simple case. Further simplify the setup of Experiment

1 (a linear demand, flat marginal cost industry) by considering the special case where (i) demand is $q = D(p, Y, \varepsilon^d; \alpha) = \alpha_1 + \alpha_2 p + \alpha_3 Y + \varepsilon^d$, (ii) domestic marginal cost is $c(W; \beta) = \beta W$, and (iii) the marginal cost of imports is $c^I(W^I; \beta^I) = \beta(W + T)$. The estimated model is

$$p = X\delta + \xi^s \tag{1}$$

where $X = (X_1 \;\; W)$, recalling that $X_1 = -q\partial p(q,.)/\partial q = -q\,(\alpha_2)^{-1} > 0$ and $\delta = (\theta \;\; \beta)'$. Consider the matrix of instruments $Z = (Y \;\; W)$ where $rank(Z) = rank(X) = 2$, i.e. there is just identification. The 2SLS estimator (see the Appendix to the paper) collapses to

$$\widehat{\delta} = (Z'X)^{-1}Z'p$$

which rearranges to

$$\begin{aligned} Z'X\widehat{\delta} &= Z'p \\ (Y \;\; W)'(X_1 \;\; W)\begin{pmatrix} \widehat{\theta} \\ \widehat{\beta} \end{pmatrix} &= (Y \;\; W)'p \end{aligned}$$

or the system of equations

$$\left.\begin{aligned} Y'X_1\widehat{\theta} + Y'W\widehat{\beta} = Y'p \\ W'X_1\widehat{\theta} + W'W\widehat{\beta} = W'p \end{aligned}\right\}$$

Solving for $\widehat{\theta}$ (noting that $W'W$ and $(W'WY' - Y'WW')\,X_1$ are scalars), and substituting for p from (1):

$$\begin{aligned} \widehat{\theta} &= \frac{(W'WY' - Y'WW')\,p}{(W'WY' - Y'WW')\,X_1} \qquad (2) \\ &= \theta + \frac{(W'WY' - Y'WW')\,W\beta}{(W'WY' - Y'WW')\,X_1} + \frac{(W'WY' - Y'WW')\,\xi^s}{(W'WY' - Y'WW')\,X_1} \\ &= \theta + \frac{\left(\frac{1}{N}W'W\right)\left(\frac{1}{N}Y'\xi^s\right) - \left(\frac{1}{N}Y'W\right)\left(\frac{1}{N}W'\xi^s\right)}{\left(\frac{1}{N}W'W\right)\left(\frac{1}{N}Y'X_1\right) - \left(\frac{1}{N}Y'W\right)\left(\frac{1}{N}W'X_1\right)} \end{aligned}$$

since $(W'WY' - Y'WW')\,W = 0$. For convenience, rewrite the vectors of covariates such that the first N_1 elements (i.e. $1, 2, ..., N_1$) correspond to unconstrained observations (indicated by $\chi_t = 1$) and the last $N - N_1$ elements (i.e. $N_1 + 1, N_1 + 2, ..., N$) correspond to constrained observations ($\chi_t = 0$). In view of the chosen functional forms and the DGP, the condition that partitions the data is given by

$$\chi_t = \mathbf{1}\left[p_t^* \leq p_t^I\right] = \mathbf{1}\left[\frac{\theta}{-\alpha_2}\left(\alpha_1 + \alpha_3 Y_t + \varepsilon_t^d\right) \leq \beta\theta W_t + (1+\theta)\left(\beta T_t + \varepsilon_t^I\right) - \varepsilon_t^s\right] \tag{3}$$

and X_1 and ξ^s are each drawn from two distributions, as follows:

$$\begin{aligned} X_{1t} &= \frac{q_t^*}{-\alpha_2}\chi_t + \frac{q_t}{-\alpha_2}(1-\chi_t) \qquad (4) \\ &= \frac{\alpha_1 + \alpha_3 Y_t + \varepsilon_t^d + \alpha_2(\beta W_t + \varepsilon_t^s)}{-\alpha_2(1+\theta)}\chi_t + \frac{\alpha_1 + \alpha_3 Y_t + \varepsilon_t^d + \alpha_2\left(\beta(W_t + T_t) + \varepsilon_t^I\right)}{-\alpha_2}(1-\chi_t) \end{aligned}$$

$$\begin{aligned} \xi_t^s &= \varepsilon_t^s \chi_t + \xi_t^s(1-\chi_t) \qquad (5) \\ &= \varepsilon_t^s \chi_t + \left(\frac{\theta}{\alpha_2}\left(\alpha_1 + \alpha_3 Y_t + \varepsilon_t^d\right) + \beta\theta W_t + (1+\theta)\left(\beta T_t + \varepsilon_t^I\right)\right)(1-\chi_t) \end{aligned}$$

Applying a standard law of large numbers to each term of (2) along with Slutsky's theorem yields

$$\begin{aligned} \text{plim}\,\widehat{\theta} &= \theta + \text{plim}\left(\frac{\left(\frac{1}{N}W'W\right)\left(\frac{1}{N}Y'\xi^s\right) - \left(\frac{1}{N}Y'W\right)\left(\frac{1}{N}W'\xi^s\right)}{\left(\frac{1}{N}W'W\right)\left(\frac{1}{N}Y'X_1\right) - \left(\frac{1}{N}Y'W\right)\left(\frac{1}{N}W'X_1\right)}\right) \qquad (6) \\ &= \theta + \frac{E(W^2)E(Y\xi^s) - E(YW)E(W\xi^s)}{E(W^2)E(YX_1) - E(YW)E(WX_1)} \\ &= \theta + \frac{Var(W)E(Y)E(\xi^s) + E(W^2)Cov(Y,\xi^s) - E(Y)E(W)Cov(W,\xi^s)}{Var(W)E(Y)E(X_1) + E(W^2)Cov(Y,X_1) - E(Y)E(W)Cov(W,X_1)} \end{aligned}$$

noting that the unconditional covariance $Cov(Y,W) = 0$ (and where letters now denote random variables rather than vectors of realizations $t = 1,...,N$). The value of plim $\widehat{\theta}$ relative to θ turns on the signs and magnitudes of the numerator and denominator of the second term of (6). Because some prices in the sample are capped, one intuitively expects the 2SLS estimate $\widehat{\theta}$ to (asymptotically) lie below the latent markup $\theta = -\eta^*(p^* - c^*)/p^*$, i.e. plim $\widehat{\theta} < \theta$. (This is confirmed in the Monte-carlo experiments.) Indeed (i) the first term of the numerator of the second term of (6) is negative (recall from the proof of Proposition 1 that $E(\xi^s) < 0$), and (ii) the first term of the denominator is clearly positive. The question, then, is whether (i) in the numerator, $E(W^2)Cov(Y,\xi^s) - E(Y)E(W)Cov(W,\xi^s)$ is sufficiently positive to reverse the negative sign of $Var(W)E(Y)E(\xi^s)$, and (ii) in the denominator, $E(W^2)Cov(Y,X_1) - E(Y)E(W)Cov(W,X_1)$ is sufficiently negative to reverse the positive sign of $Var(W)E(Y)E(X_1)$. For a wide range of simulations I have conducted, this does not happen. Analytically, inspection of (3), (4) and (5) indicate that (i) in the numerator, the conditional covariances $Cov_{\chi=1}(Y,\xi^s)$ and $Cov_{\chi=0}(Y,\xi^s)$ are both negative while the conditional covariances $Cov_{\chi=1}(W,\xi^s)$ and $Cov_{\chi=0}(W,\xi^s)$ are both positive, and (ii) in the denominator, the conditional covariances $Cov_{\chi=1}(Y,X_1)$ and $Cov_{\chi=0}(Y,X_1)$ are both positive while the conditional covariances $Cov_{\chi=1}(W,X_1)$ and $Cov_{\chi=0}(W,X_1)$ are both negative.

S.2 The cement industry

Cement is a homogeneous good produced largely from limestone and clay in weight proportion of roughly 5 to 1. Described simply, limestone and clay are ground and the mixture is burned at a very high temperature in a rotary kiln producing cement clinker. The clinker pellets—once cooled—are then ground and mixed with a retarding agent (gypsum) and varying types of additives to form different formulations of cement[1]. The different formulations of cement are near substitutes in most types of user applications. Despite the relative simplicity of the product, the production of cement is capital intensive and is characterized by substantial plant-level 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 clinker[2].

The process exhibits a fixed factor production function since factor inputs are not substitutable. Yet marginal costs do vary across kilns and plants, according to the technology, capacity, age and fuel employed (Jans and Rosenbaum 1996). The last major innovation to the production process took place in the 1970s in response to the energy price shocks. The "wet" process kiln system was replaced by the "dry" process, 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 tons per annum (mtpa) (World Cement 2000)[3]. Although equipment suppliers and cement producers work closely together, most innovations are done by equipment suppliers. "Turn-key" plants can be ordered from suppliers, and technology can be purchased off-the-shelf. Research and development (R&D) spending by the cement producers themselves is limited[4].

As cement is a low-value commodity relative to weight, transport costs may assume a significant proportion of cost, leading to geographically segmented markets. Scherer

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[1] While clinker comprises around 96% of ordinary cement, this proportion is 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.

[2] 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 annual capacity of (say) 1.5 million tons, can require a capital outlay of up to 300 US$ million (200 US$ per ton 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).

[3] Rosenbaum (1989) and Johnson and Parkman (1983) document process and capacity changes in the U.S. industry.

[4] For perspective, operating at the forefront of cement-production technology, the Japanese producer Taiheiyo spends less than 1% of sales revenue on R&D.

et al (1975, p. 429) list cement as having the second highest freight cost index for shipments out of 101 U.S. industries. In order to meet dispersed demand, firms may trade in (production) scale economies for lower transport costs by scattering their plants across markets[5].

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 (i.e. retailers) who sell on to individuals ("do-it-yourself buyers"). 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 stagnant[6]. Over the past 15 years, a significant process of consolidation has been running its course in the global cement industry. 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.3 Data

This section comments on data sources and data treatment. I also perform robustness checks on my direct computation of price-cost margins.

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

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[5] See also Newmark (1998). Pre-empting entry may further reduce initial plant scale (Johnson and Parkman 1983).

[6] Over one-third of consumption occurs in China, notoriously a producer of low-quality cement in energy-inefficient, environmentally-unfriendly "backyard" mini cement plants.

firms and concrete product manufacturers); 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.3.1 Sources and treatment of data

Cement consumption quantities by state (i.e. demand by local market) Monthly quantity series by state, in 1000 tons 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 entire set of producers[7]. To compile consumption figures for a given state, SNIC aggregates reported shipments by its members to that state. Thus, in practical terms, I observe all shipments by cement producers to the aggregation of buyers in each 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, the limited geographic scope and that these non-members entered only toward the end of the sample period; (ii) Consumption figures do not include imports. Again the distortion is small in view of the limited penetration of imports[8]; (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

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

[8] See Salvo (2008) for actual import quantities (of both cement and clinker) in the period 1990 to 2006, including a comparison to cement import penetration in the United States.

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[9].

Quantity flows 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 quantity series by state are extracted. Thus I observe, for each year T, an $I \times L$ shipment matrix with element q_{ilT} denoting cement 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 state l across supplying plants is invariant over the 12 months in each year. Thus I take plant i's shipments to state l in month $t \in T$ to be $q_{ilt} = \frac{q_{ilT}}{\sum_i q_{ilT}} q_{lt}$ where q_{lt} denotes cement consumption in state l in month t, as detailed above.

Cement prices by state Retail cement prices in units of local currency (the Real, R$) 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 that prevailed in the first *one-quarter* of months in my sample[10], particular attention has been paid to the conversion of current cement prices to constant prices (base Dec-1999). I chose to work with an economy-wide General Price Index (GPI) but, to check the robustness of the estimation results, I separately converted cement prices using other economy-wide price indices, such as a Consumer Price Index (CPI) or a Wholesale Price Index (WPI) (these indices 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 in 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

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[9] Stocks at producers amount to approximately one week of sales, with roughly another week of sales being stocked down the trade. Cement buyers typically have short payment terms (about 1 week). Given the low inventories and the shorter duration of Accounts Receivable relative to Accounts Payable (chiefly energy bills), coupled with cement's low variable cost relative to price, it is safe to say that working capital needs are limited (i.e. cement is a cash rich operation).

[10] The pre-stabilization phase encompasses the 42 months between Jan-1991 and Jun-1994, out of a total 156 months (Jan-1991 to Dec-2003) in my sample.

and accounts published in trade reports at the time. It should be noted that despite the high level of inflation in the first half of the 1990s, the economic environment was relatively "stable", as economic agents had learned to anticipate the change in the price level reasonably well, at least in the short term. Thus, over the pre-stabilization phase it is still possible to filter (upward and downward) variation in real prices from the much larger (upward) variation in nominal prices.

Exogenous demand variables Several alternative series of economic activity, either in the construction and building sector or aggregated across sectors of the economy, are available as proxies for the exogenous demand for cement. The 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, these time series follow from a *volume* decomposition of Value Added in the construction sector (obtained from the National Accounts) and should thus be a good proxy for exogenous demand. I normalize the time series for each state using that state's share of the country's construction sector (also from the National Accounts), thus forming a data panel which is comparable cross-sectionally (i.e. across states) as well as over time. Alternative quarterly series are available, which I use in checking the robustness of my estimation results.

Local factor prices Local 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 reported in the form of constant prices. Though alternative series proxying for each factor price are available—which I use to verify the robustness of reported estimates—the main series are:

- Fuel oil: monthly countrywide delivered prices from refineries in R$ per kg (excluding sales taxes) are obtained 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 has been minimal during the sample period.)
- Diesel oil: monthly countrywide delivered prices from refineries in R$ per liter are obtained from the oil industry regulator, the National Agency for Oil.
- Coal: annual FOB prices of coal in R$ per ton are obtained, 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: monthly state-level delivered prices to (high-voltage) industrial consumers in R$ per MWh are obtained from the electricity industry regulator, the National Agency for Electrical Energy.
- Labor: monthly real manufacturing wage indices in the 12 states with the largest industrial output, in addition to a countrywide index, are obtained from the Confederation of National Industry.

Plant-level characteristics Observed plant-level characteristics include location; ownership; capacity (i.e. kiln pyroprocessing capacity and grinding capacity); number of kilns and their age, technology (i.e. the type of equipment and process, whether dry or wet, whether a preheater is employed); and fuel mix (largely either fuel oil or coal, and more recently pet coke). This data is available from the Brazilian trade association[11] 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). The shortest distance by road from each plant to the main metropolitan areas in each state is available from the Ministry of Transport.

Constructing 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, observed plant characteristics and engineering estimates of the fixed coefficients. I employ the term "calculate" rather than "estimate" since obtaining marginal cost does not involve statistical inference; however, calculated marginal costs are indeed estimates—in fact they are estimated upper bounds to the true marginal costs—in the sense that there inevitably are unobserved plant characteristics, as I explain below. In view of the fixed-coefficient technology and my understanding of the industry, I model plant marginal cost as flat in quantity up to capacity. To the extent that marginal cost varies across kilns within the same plant complex, this will approximate the true plant marginal cost, which would then be a step function in quantity. (For example, say a plant consists of two kilns, labeled 1 and 2, with respective kiln marginal costs c_1 and $c_2 > c_1$. Denote non-kiln marginal cost by c and kiln capacities by K_1 and K_2.

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[11] Plenty of other plant-level information is available, such as stock levels and the form shipments take, both in terms of packaging (in bags or in bulk) and in terms of modal choice (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.

Plant marginal cost would then be $MC(q) = c + c_1$ if $q \leq K_1$ and $c + c_2$ 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. an older and smaller energy-inefficient 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 constructing marginal cost. (It should also be noted that in recent decades cement plant design has favored large single-kiln production lines over multiple small lines, thanks to scale economies.) 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. Marginal cost varies across plants according to the technology, capacity and age of the equipment and the fuel employed by the kiln; these characteristics are accounted for to the best of my knowledge as I explain below[12]. 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 typically falls in the 650-850 kcal range (e.g. see World Cement, Jan-2000 issue). (The wet process consumes over double this.) A kiln's (thermal) energy efficiency depends on the capacity, technology (including the specifications of preheating, cooling and waste heat recovery systems used) and age of the kiln. (The kiln's brick lining has to be changed periodically, and the time since the last relining will also impact the energy efficiency of the kiln.) Interview-based evidence, however, indicates that the energy efficiency of kilns in operation in the Brazilian cement industry is (i) high relative to its global peers (including the U.S. industry), with producers having shifted to the dry process chiefly over the 1980s, and (ii) 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 obtain

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

[13] In addition to the above, I use other sources of plant-level information such as a 1993 report compiled by the industry's trade association on energy productivity (stating the amount of hydrocarbon

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 ton 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 ton 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 above, labor essentially performs a supervisory role. One may argue over the proportion of a plant's labor cost that is fixed. The variable proportion of labor would correspond to quarrying personnel and possibly workers involved with the packaging and distribution center operations. In any case, these operations are relatively low cost, and any bias from assuming they contribute to marginal cost works in a conservative direction, understating actual price-cost margins. Packaging costs 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 constructing marginal cost to the best of my ability, there will always be a component that I do not observe. In

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equivalent burned for each ton of clinker produced at the plant). I neglect time-series variation in plant-specific energy efficiency, assuming that this has been low over the sample period.

view of this, I chose to err on the side of caution by (somewhat) overstating marginal cost. By constructing what I claim to be an upper bound to the true marginal cost, I am thus understating the price-cost margin. One potential source of marginal cost overstatement is that the factor prices I observe do not include any quantity discount that may be offered to large producers on acquiring fuel oil, electricity and trucking services. Another possible source of bias is that producers substitute away from traditional kiln fuels such as fuel oil and coal in favor of cheaper alternatives. For example, 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. Another bias stems from the formulation I use to compute the marginal cost of cement (see footnote 1). For simplicity I take the composition of 1 kg of cement to be 1 kg of clinker—the most expensive input to the grinding process—but even “pure” cement (referred to as ordinary “type 1” 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 increases. For example, composite “type 2” 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.

Constructing plant-to-market freight cost This is the first component to ex-plant marginal cost that I consider (the other two are the cost of the reseller and the producer’s sales tax). In this industry, freight is a considerable 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 them. The transport of agricultural goods such as soyabean and maize is a close substitute in the supply of cement freight, in view of product and market characteristics (Soares and Caixeta Filho 1996)[14]. I use a database containing about 30,000 observations on (predominantly road) freight prices for certain farm goods collected over the period 1997 to 2003 for thousands of different routes across Brazil[15]. Table 2 summarizes the results of some reduced-form OLS regressions. These

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[14] For example, an interview with the logistics director for a leading cement producer revealed that during the soyabean harvesting season (March through May) his firm exceptionally encourages the largest cement buyers to arrange for orders to be picked 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 cement freight and soyabean freight, being close substitutes, are similarly priced. Producers mostly outsource trucking services on the spot market to independent truckers who are registered in their databases and simply turn up at the factory gate (or are hired through cooperatives or middlemen). According to this executive, the cement industry is the top industrial purchaser of trucking services in the country.

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

should be seen as hedonic regressions with the purpose of predicting the price of (farm or cement) freight. Since I do not observe quantities demanded and supplied in the market for freight, I do not estimate a structural model of that market. (Nor is this necessary in view of my objective, which is to predict the freight cost of cement from plant i to state l based on observed data.) Using the farm freight data, I regress freight prices, in constant R$ per ton of produce shipped (Brazil GPI base Dec-1999, as explained earlier), on explanatory variables such as the distance of the route (road mostly), the squared distance, a shipment-to-port dummy (to capture exports), modal-choice dummies (by water or rail, as opposed to road), seasonal dummies or monthly dummies (to capture the harvesting cycle), the price of diesel oil (a key cost component for freight), a packaging dummy (shipment of bagged produce as opposed to bulk) and product-type dummies (e.g. powdered soyabean), in addition to interaction variables. The R^2 indicate that the fit is very high[16]; the heteroskedasticity-robust standard errors are low. Freight prices are increasing in distance (and concave, though slightly so over the relevant range). Consider the estimates for specification (II). At the sample means of the variables (a route distance of 735 km and a diesel oil price of 0.451 R$ per liter), the predicted price of freight for a ton of soyabean shipped in bulk by road to a destination other than a port and in the month of April amounts to $3.11+0.0409\times735-7.2\times10^{-7}\times735^2+5.84\times0.451$ $=3.11+30.06-0.39+2.63=35.39$ R$ (with a standard error of 0.19 R$). Shipping to a port (possibly as a result of longer waiting times to unload) adds $1.56+0.0006\times735=2.01$ (s.e. 0.14) R$, and when this shipping to a port takes place during the harvest season freight prices are predicted to increase by a further 2.37 (s.e. 0.29) R$. Shipping by waterway costs $13.40+0.0064\times735=18.12$ (s.e. 0.23) R$ less than by road, while shipping by railway costs $3.44+0.0134\times735=13.28$ (s.e. 0.27) R$ less than by road. Shipping in bags as opposed to in bulk raises the price of freight by 0.29 R$ (and this difference is not statistically significant; this is probably because such heavy goods fill up a truck's weight capacity long before its "cube" capacity binds, and the form of packaging matters most for cube). 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—not reported—are negative). Shipments in January are the least expensive: prices are 4.64 (s.e. 0.23) R$ lower compared to April. Note that the variation in diesel oil prices over the period is 0.464 R$, accounting thus for a $5.84\times0.464=2.71$ (s.e. 0.16) R$ variation in freight prices—this appears somewhat low. I then use specification (II) to predict the plant-to-market freight cost for cement based on observables such as distance from the plant to the market, modal choice and the price of diesel oil.

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

Backing out net producer prices from retail prices The other components to ex-plant marginal cost, apart from plant-to-consumer freight, are the cost of the reseller and the producer's sales tax. Recall that the lion's share of the Brazilian cement business involves producers shipping cement in bags to resellers, who then sell directly to the end user (a small-scale consumer). I only observe prices at which these resellers sell cement, not the prices set by producers[17]. However, I back out producer prices as follows. Based on several field interviews[18], 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", varying from 2.65 to 3.65% of the retail price over the sample period, not to be confused with the sales tax collected by the producer), and (ii) the cost of labor (for unloading the truck, storage handling and stocking shelves). Based again on the field interviews, I assume that resellers have a gross margin in the region of 13% of the producer price. By subtracting this margin from observed retail prices, I back out producer prices. To the extent that some resellers evade taxes, or occasionally choose to price cement as a "loss leader" to lure consumers into their stores, the reseller's cost may be lower; this bias, however, will be small and again works conservatively in the direction of overstating my constructed measure of marginal cost. To check the backed-out producer prices, I compare these to *reported* producer prices that I was able to obtain directly from a subset of producers. The outcome is reassuring. Finally, to obtain the net producer price I further deduct the producer's sales tax, which I calculate based on federal and state tax legislation. Brazil has an awkward 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", and some of these vary according to the origin and destination of the shipment. I consider sales tax evasion on the part of cement producers to be minimal, despite the high value of the tax. (For example, towards the end of the sample period, the sales tax 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.) 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 construct will again be overstated (see the earlier paragraph on unobservables).

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[17] Within a same region, resellers tend to buy cement at a similar price, as even a relatively small retail operation is able to place a fairly efficient order with the producer; a 15 ton "half-truck" (25 ton "full-truck") load corresponds to only 300 (500) 50 kg bags. Because cement producers reach far down the trade, they resort to distributors for a minor share of their business. A 5-10% discount may be offered to buyers of bulk cement (e.g. ready-mix concrete firms) but, again, this accounts for a small share of the business.

[18] These interviews include cement producers' field representatives and sales executives, cement buyers, 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).

A look at the data The summary statistics of Table 1 report on state-level variation in the industry, as well as its oligopolistic nature. On average, a state hosts 2 cement plants, and cement-producing states sell 60% of their output within state borders, and 92% including bordering states. The mean one-firm concentration ratio is 57%, rising to 83% for two firms. Figure 1 considers one firm—the nationwide leader Votorantim—and aggregates retail prices, delivered marginal costs and price-cost margins on its actual sales across Brazil, in constant R$ per bag (Brazil GPI base Dec-1999). Delivered marginal cost is the sum of plant marginal cost and ex-plant marginal cost, which is itself the sum of plant-to-market freight cost, the cost of the reseller and the producer's sales tax. The horizontal axis depicts the number of months from Jan-1991, the first time period in the sample. Month 156, the last time period, is Dec-2003. At this level of aggregation, consumer prices doubled to over 15 R$/bag after the lifting of price controls in Nov-1991, then fell back to around 8 R$/bag by 1996, steadily rising to 12 R$/bag by 2003. With the exception of the earlier months in the sample, price-cost margins on Votorantim's realized sales hover around 4 R$/bag. (Figure 2 provides the same data at the state rather than nationwide sales level, but only for the post-stabilization period, i.e. from Jul-1994.) The picture is similar across firms (not shown). Across producers, across states and over time, the price-cost margin as a proportion of the retail price lies in the region of 25-45%, which is equivalent to 40-65% as a proportion of the producer price net of sales tax. I present robustness tests of these price-cost margins below.

Capacity utilization Throughout the sample period, capacity outstrips production. This is the case not only at the country level but also at the local level, including the three years post stabilization—1995 to 1997—of steep growth in cement consumption, so much so that no increase in imported cement and clinker was observed in this period (as documented in the paper—and despite cement prices falling on the back of an exchange rate appreciation). Capacity utilization hovers around 65%. Interestingly, capacity utilization appears to be similar across plants and firms, with firms' capacity utilization rates being correlated over time, as firms' local market shares are fairly stable (though very asymmetric). 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[19].

Imports cost-shifters In addition to some data series presented above, imports cost-shifters include:

- R$/US$ exchange rate: the current price of 1 U.S. dollar in units of R$ is obtained

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[19] In contrast to incumbents, the entrant Mizú (recall footnote 7), with its imported clinker and local grinding operation, was selling up to capacity (0.7 mtpa) by 2003.

from the Central Bank of Brazil. I convert the price of the exchange rate in current R$ into constant R$ using the Brazil GPI (base Dec-1999), as explained earlier.

- World crude oil prices: monthly spot prices of West Texas Intermediate crude oil at Cushing, OK, in US$ per barrel are obtained from the Energy Information Administration, U.S. Department of Energy. The world oil price in current US$ is then converted into constant R$ using the exchange rate in constant R$ (Brazil GPI base Dec-1999). (Equivalently, I could first convert the world oil price in current US$ into current R$ using the exchange rate in current R$, and then convert the resulting world oil price in current R$ into constant R$ using the Brazil GPI.)
- Maritime bulk freight: the Baltic Dry Index of US$ per day charter prices is obtained from the London Baltic Exchange. The price of maritime bulk freight in current US$ is then converted into constant R$ using the exchange rate in constant R$ (Brazil GPI base Dec-1999).
- Import finance/bank letter of credit: the nominal yield on Brazilian Treasury bills is available from Gazeta Mercantil. To obtain the real yield, to be used as a proxy for the cost of import finance, I similarly deflate the series using the Brazil GPI.

S.3.2 Robustness checks on my direct measure of the price-cost margin

I check my constructed measure of cement producers' price-cost margins in two ways.

The Cimpor test The first check is centered on the multinational firm Cimpor, listed on the Lisbon stock exchange, which in 1997 bought its way into Brazil and in 1999 became the third largest firm in the country upon acquiring Brennand. This firm is of particular interest in that, most unusually, it details its annual financial statements by country of operation and by line of business. I thus use the results that Cimpor reports for its Brazilian cement operations to validate my price-cost margin measures. My calculated price-cost margin for Cimpor, as a percentage of net producer sales (i.e. net of sales taxes), is indicated in Figure 3. I compare this to Cimpor's reported "Earnings Before Income Tax and Depreciation Allowance" (EBITDA, also known as operating cash flow) as a percentage of "Net Sales", over the period 1998 to 2003. The time series fit between constructed and reported figures is good. For example, my calculated price-cost margin for Cimpor rises from around 47% in 2000 (Q4, months 118-120) to 55% in 2002 (Q1, months 133-135). Cimpor reports a similar rise in its EBITDA margin over this period, from 44% to 55%.[20] In fact, my calculated price-cost margins, if unbiased, should be higher relative to EBITDA, since EBITDA figures are net of costs such as plant overhead and sales and administrative expenses which are not included as part of marginal cost. The fact that my calculated price-cost margins are not substantially higher than reported EBITDA provides support for the arguments above that I conservatively overstated constructed marginal cost. (I further check my above calculations of the reseller's cost and the producer's sales tax by comparing the net producer sales, which I backed out from observed retail prices, to Cimpor's reported net sales.)

The Annual Industry Survey test The second 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 4 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 includes accounting depreciation, so the accounting gross margin cannot be immediately compared to my constructed price-cost margin (which does consider freight but not depreciation). Further, I do not know the identity nor the location of the surveyed establishments. However, the magnitude of both series appears to be consistent. The variation in the surveyed accounting gross margin is also consistent with the observed fall in prices beginning in 1992 and the rise in prices commencing in 1997. (Notice the capital-intensive nature of the industry: on average payroll—corresponding not only to plant but also to sales and administrative employees—accounts for less than 10% of a producer's net sales.)

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[20] Comparing across the 9 countries where Cimpor is active (in Iberia, Africa and South America), I note that its Brazilian cement operations were the most profitable: in 2002, for example, a 56% EBITDA margin in Brazil compared to an average 39% across all countries.

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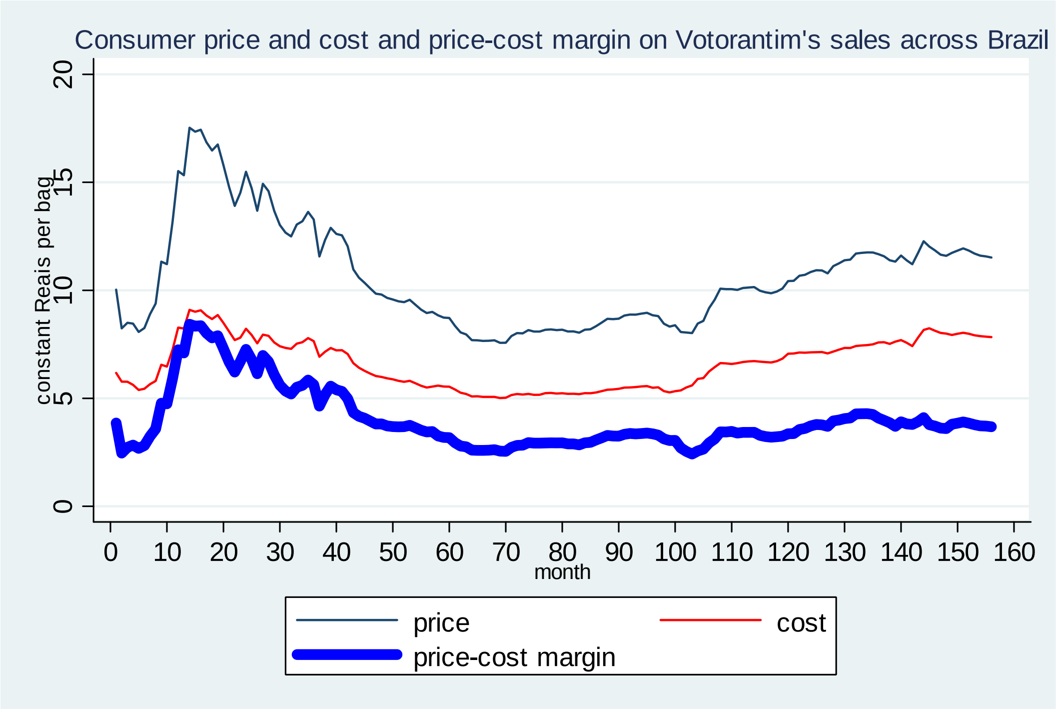

Figure 1: Evolution of retail prices, delivered marginal costs and price-cost margins on Votorantim's sales. Averaged across all states. In constant R$ per bag (Brazil GPI base Dec-1999). The horizontal axis depicts the number of months from Jan-1991.

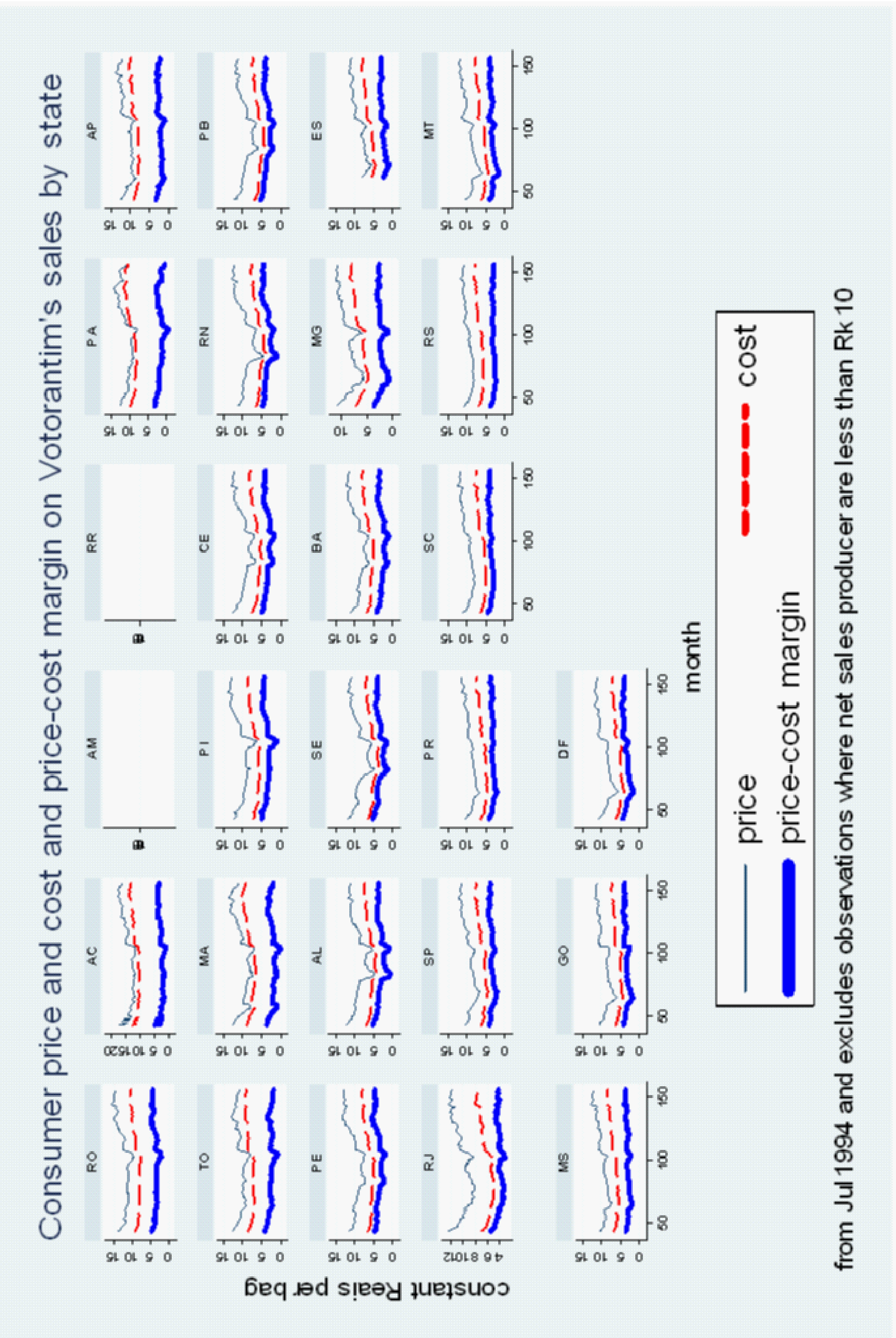

Figure 2: By-market evolution of consumer prices, delivered marginal costs and price-cost margins since July 1994 (i.e. over the post-stabilization phase) on Votorantim's sales. In constant R$ per bag (Brazil GPI base Dec-1999). The horizontal axis depicts the number of months from Jan-1991.

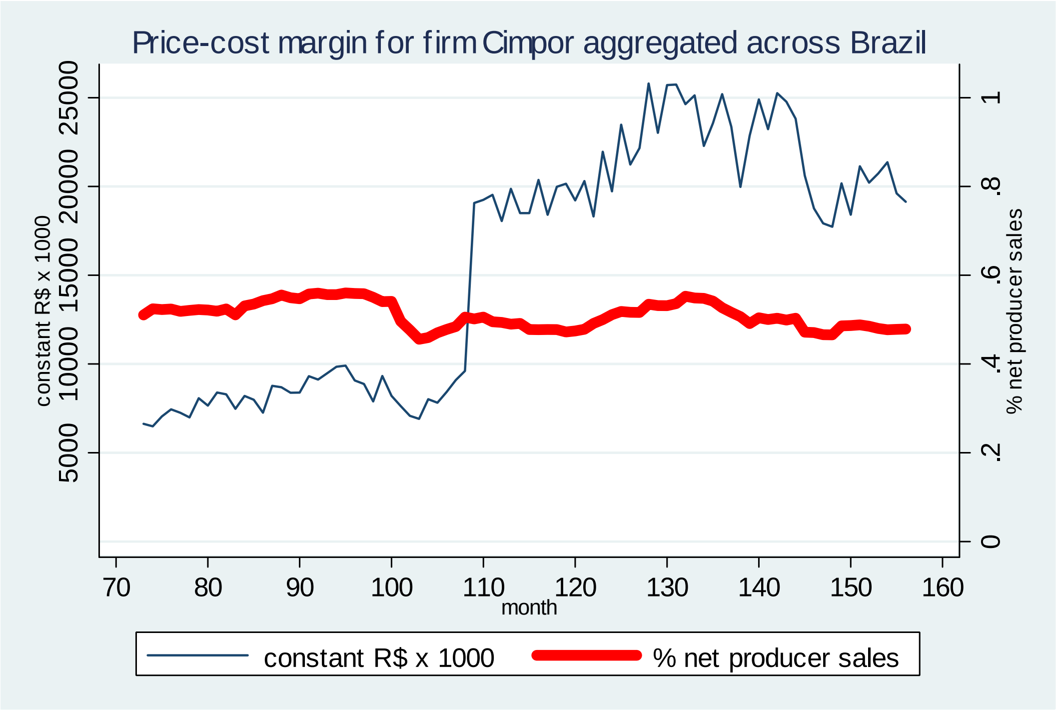

Figure 3: Evolution of (my directly constructed measure of) the price-cost margin for Cimpor. Aggregated across all states. In constant thousands of R$ per month (Brazil GPI base Dec-1999) and as a percentage of net producer sales. The horizontal axis depicts the number of months from Jan-1991.

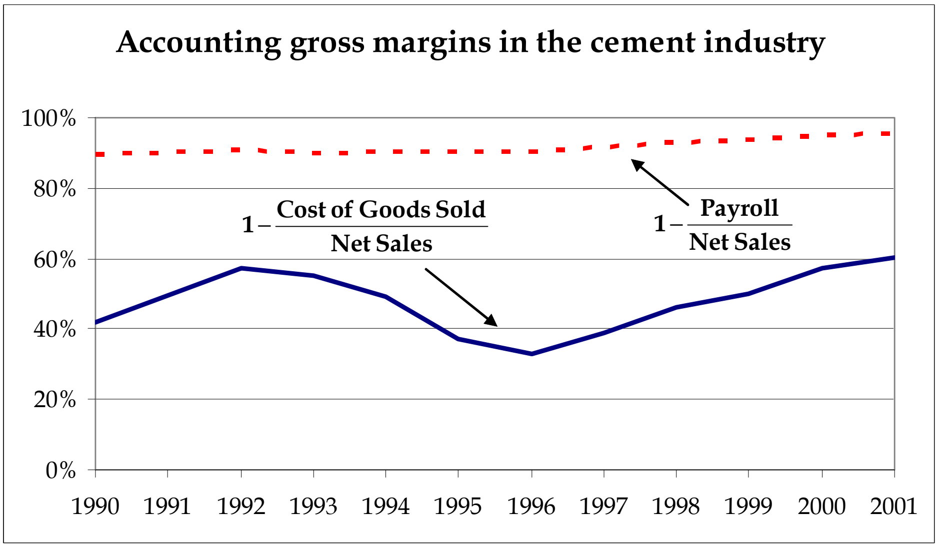

Figure 4: Accounting gross margins in the cement industry, from surveys conducted by the Brazilian Institute for Geography and Statistics (IBGE)

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

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

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

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

[3] In rescaled constant monetary units

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

Table 1: Variation across 27 states of the Brazilian federation, Summary statistics (time-varying figures refer to 1999)

Specification	(I)		(II)		(III)	
	coef	s.e.	coef	s.e.	coef	s.e.
No. obs.	30367		30367		30367	
R^2	0.89		0.90		0.90	
Intercept	1.45	(0.22) ***	3.11	(0.32) ***	5.41	(0.45) ***
Distance of route	0.0393	(0.0005) ***	0.0409	(0.0007) ***	0.0433	(0.0008) ***
Distance of route squared	-1.0E-06	(2.5E-07) ***	-7.2E-07	(2.6E-07) ***	-9.6E-07	(2.4E-07) ***
Port destination dummy	2.01	(0.16) ***	1.56	(0.26) ***	1.72	(0.24) ***
Water transport dummy	-17.59	(0.20) ***	-13.40	(1.05) ***	-11.52	(1.25) ***
Rail transport dummy	-12.29	(0.30) ***	-3.44	(0.58) ***	-3.15	(0.54) ***
Harvest season dummy	2.21	(0.11) ***				
Port during harvest dummy	2.85	(0.29) ***	2.37	(0.29) ***	2.25	(0.28) ***
Price of diesel oil	6.04	(0.35) ***	5.84	(0.35) ***		
Shipment in bags dummy			0.29	(0.20)	0.49	(0.20) **
Powdered soya dummy			1.94	(0.13) ***	1.75	(0.13) ***
Maize dummy			-0.71	(0.09) ***	-0.98	(0.10) ***
Limestone dummy			-2.18	(0.14) ***	-1.82	(0.14) ***
Monthly dummies			Included (except April)		Included (except April)	
Year dummies					Included (except 1997)	
Distance interacted with:						
Port dummy			0.0006	(0.0003) **	0.0006	(0.0003) **
Water transport dummy			-0.0064	(0.0016) ***	-0.0086	(0.0018) ***
Rail transport dummy			-0.0134	(0.0009) ***	-0.0132	(0.0008) ***
Monthly dummies			Included (except April)		Included (except April)	
Year dummies					Included (except 1997)	

Notes: Dependent variable is freight price (in constant Dec-1999 R$ per ton of produce shipped). Estimated through OLS. Heteroskedasticity-robust standard errors. *** Significant(ly different from zero) at the 1% level; ** 5% level; * 10% level.

Table 2: Auxiliary OLS regressions for plant-to-market freight cost