Post-Cartel Competition - An Application to the Brazilian Ready-Mix Concrete Industry

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Abstract

Post-cartel changes in firm behavior are essential to restore competition. Entry and exit help break tacit collusion after a cartel case conviction. To assess post-cartel competition, we use the model of Abbring and Campbell (2010) to estimate demand thresholds for entry and exit. These thresholds, along with the demand process, are estimated using data from the Brazilian ready-mix concrete industry. The simulations predict that post-cartel entry and exit rates decrease, while the number of plants increases on average by 0.2 per market, improving the overall competition environment in the industry.
(JEL L22, L13, L41, K21, L61)

1 Introduction

Residual collusion refers to the continuation of prices above competitive levels after a cartel has been shut down, by which firms do not communicate for price coordination. A typical cartel price path associated with a cartel discovered is a sharp decline. However, there are documented episodes for which prices remained at the level when the cartel was active. Post-cartel changes in firm behavior are fundamental to restoring competition, destabilizing this tacit equilibrium (HARRINGTON, 2023). New firm entry and exit of incumbent ones are an important tool to effect this change.

In this paper, we examine the effect of the breakdown of the Brazilian Ready-Mix concrete and cement cartel. The cement cartel existed for at least 20 years, from 1987 to 2007, with an estimated damage of BRL 28 billion during this period with an overcharge of 10% to 20%.

The issue that I address in this paper is the change in firm behavior after the dismantling of the Brazilian Ready-mix concrete cartel. I define a ready-mix concrete market following Bresnahan e Reiss (1991), Collard-Wexler (2014) as "isolated markets", that is, a town

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that is more than 40 kilometers from any other town. The number of ready-mix concrete firms comes from the Annual Listing of Social Information (*RAIS*), between 1993 and 2007. Using these data, we estimate the demand threshold at which new firms enter and incumbent firms exit. Using this threshold, we simulated the evolution of market demand.

Ready-mix concrete is an industry characterized by high competition between firms and very local markets due to the perishability of concrete and high transportation costs. A substantial sinking cost also characterizes Ready-mix concrete plants.

One of the biggest challenges facing antitrust authorities concerns the effects of changes in market structure. In a market without sunk cost or another entry barrier, these effects are not relevant because whenever a firm leaves, another enters the market. However, when a market has either sunk costs or adjustment costs, it takes time for the effects of changes in market structures to die out (COLLARD-WEXLER, 2014). Indeed, the changes in market structure are well understood since at least the earlier literature on barriers to entry (BAIN, 1956; DEMSETZ, 1982).

The exit threshold is much smaller than the entry threshold since an incumbent firm already incurred the sunk cost to be in the market, so the level of demand needed for a firm to continue in a market is smaller than the level of demand required for a new entry. The difference between the thresholds is greater as the sunk cost size increases. In a perfectly competitive market, there is no difference between these thresholds (BRESNAHAN; REISS, 1994).

The ready-mix concrete and cement industries are closely related through vertical and horizontal mergers (HORTAÇSU; SYVERSON, 2007; SYVERSON, 2008). In Brazil, this process started in 1992 when the cement cartel decided to enter the ready-mix concrete market to prevent the concrete firms - downstream sector - enters their market. Thus, they also formed a cartel in the ready-mix concrete market. The ready-mix concrete industry has cartel problems around the world. In Europe Bundeskartellamt (2001), United States Justice (2005) and Brazil CADE (2014) the largest domestic fines were applied in the sector, indicating the importance of competition for this industry. This paper looks at the effect of the fall of the ready-mix concrete cartel on market outcomes.

The empirical approach of this work is based on Collard-Wexler (2014). I also use Abbring e Campbell (2010) model of oligopoly industry dynamics which provides a game of entry and exit decisions with an unique equilibrium given by the demands thresholds of entry and continuation. Similarly to Bresnahan e Reiss (1994), we estimated these demand thresholds with a multivariate probit using the GHK algorithm. Then we simulated the counterfactual to look at the effect of post-cartel entry and exit.

After the cartel dismantling, it was estimated an increase of an average of 0.20 plants per market. It was estimated a decrease in entry of 3.79 percent points per year. It was also estimated a decrease in the exits of the market by 1.59 percentage points per year. Therefore, the cartel breakdown improved the overall conditions of the markets, with a larger number of firms.

The most related works in the literature on entry models use the Conditional Choice Probability (henceforth, CCP) approach as Benkard, Bodoh-Creed e Lazarev (2010), Collard-Wexler (2013) and Arcidiacono e Ellickson (2011). This approach involves first estimating the distribution of choices conditional on the state (and the transition law for the state) variable directly from the data and then finding parameter values that rationalize this conditional distribution as the optimal choice probability. Different from this literature we follow the model proposed by Collard-Wexler (2014).

The key difference between these two models is that the CCP models are structural, the unobservables are independently and identically distributed across periods whereas, Collard-Wexler (2014) is a reduced form and is serially correlated. This is critical for the counterfactual of looking at the effect of changes in market structure, since the demand shock process, both observed and unobserved, is essential to evaluating the speed of post-cartel fall entry.

The present project beyond this Introduction, in Section II, will discuss the Brazilian Ready-Mix Concrete Industry. Section III presents the model, Section IV discusses data construction, Section V presents the econometric model, which is estimated in Section VI., and Section VII the counterfactual analysis. Section VIII concludes.

2 Brazilian Ready-Mix Concrete Industry

Ready-mix concrete is a mixture of cement, sand, gravel, water, and chemical admixtures. After one hour, the mixture hardens into a material with very strength. Because concrete is very perishable the average time to delivery is about 40 minutes. Thus, the markets became local, in general with a 40-kilometer radius with an oligopoly structure.

The industry is characterized by high sunk costs. In the United States, the sunk cost is about USD 2 million. Almost all capital expenditures are sunk and is common to see concrete plants abandoned, indicating the importance of sunk costs in this industry (COLLARD-WEXLER, 2014).

Ready-mix concrete does not have many substitutes, so if there are no plants near a construction site, either a mobile plant will be used to produce concrete or concrete will be mixed by hand. Market demand for concrete will be relatively inelastic, even though concrete itself is close to a commodity, generating competition between plants within a market. Given these characteristics, the profit of firms is related to the number of firms within a market.

The concrete sector is highly related to the cement sector, mainly through vertical integration of concrete plants by the cement producers[1]. Ready-mixed plants owned by vertically integrated companies show higher productivity on average than unintegrated plants, related to delivery flexibility, capacity, and backup capability (LAFARGE, 2005).

In Brazil, both sectors were condemned for forming a cartel. The case had the cement companies as defendants, although it directly affected the concrete companies since the remedies imposed by the antitrust authority were applied to both markets. Initially, the cartel operated only in the cement market by market allocation, fixing prices and quantities, and changing the quality standards of the product to raise additional entry barriers. Thus, its impact on concrete companies was a cost increase, since cement is their main input in the production of concrete.

In response to the increasing costs of purchasing cement, some ready-mix concrete companies began to import clinker [2], adding additives and blending, and producing their own cement for concrete production to avoid purchasing from the cartel. Faced with the threat of competition from importers and large ready-mixed concrete companies, the

[1] See Hortaçsu e Syverson (2007) and Syverson (2008).

[2] Clinker is the backbone of cement production. It is essentially a mixture of limestone and minerals that have been heated in a kiln and transformed by the heat.

cartel members decided in 1992 to enter the ready-mixed concrete market to weaken these potential entrants in the cement market (CADE, 2014).

In search of stability, cartel members determined that they would have the same market shares as they had in the cement market. To achieve these goals, the cartel decided to pursue mergers and acquisitions of concrete companies because it would be cheaper and faster than engaging in price wars. Asset swaps were also heavily used to optimize cartel operations in the ready-mix concrete sector.

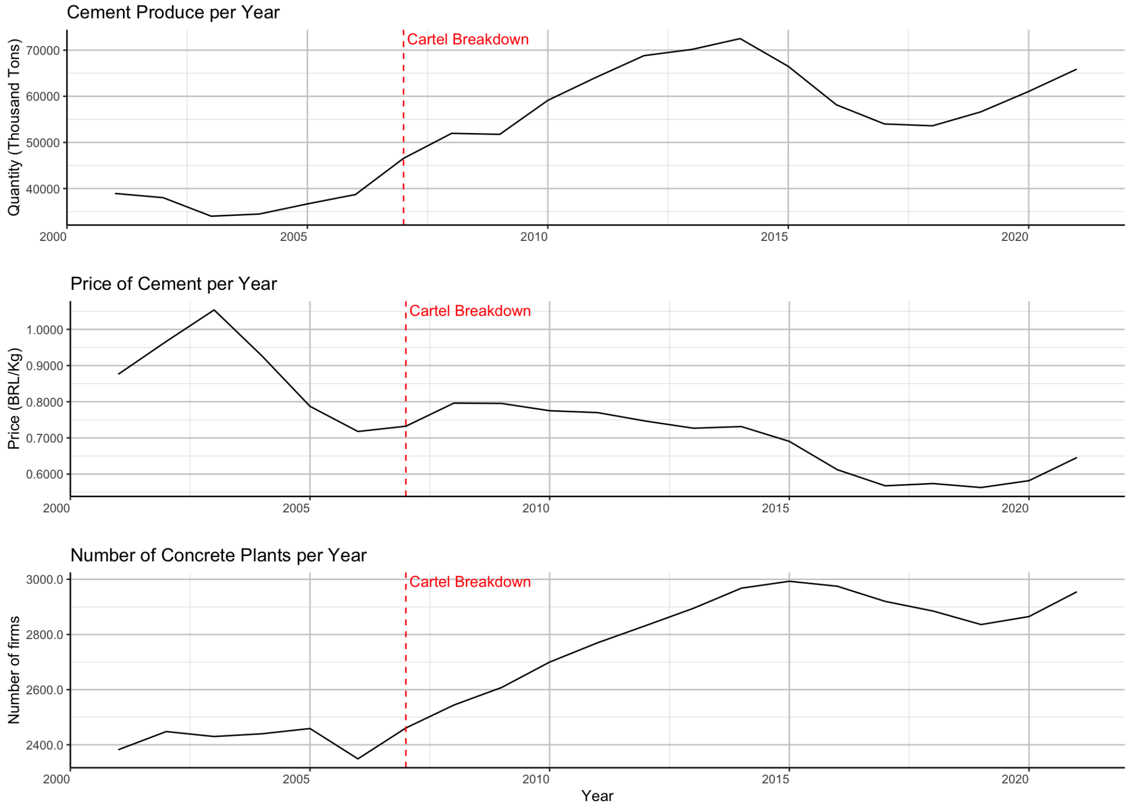
The cement cartel may have existed for at least 20 years, from 1987 to 2007, with an estimated damage of BRL 28 billions during this period with an estimated overcharge of 10% to 20%. The cement cartel comprised most of both markets. The CR8 of the cement industry in 2012 was 87%, of which 7 of the largest firms were cartel participants. The cartel decided to enter the ready-mix concrete market in 1992 lasting until 2007 (CADE, 2014).

The sentence of cement and ready-mix concrete cartels was the biggest in Brazilian Antitrust Authority (*CADE*) history, BRL 3.1 billions. The remedy proposed by CADE included the sale of some cement and concrete plants, such as every cartel participant should sell 20% of concrete plant units and every participation they have in other concrete firms. In this way, the authority sought to diminish the barrier to entry into this market and make the market more competitive. Any kind of transaction between the defendants in the concrete market was also prohibited for 5 years.

Although the cement and concrete markets are closely related in the same production chain, with synergies from vertical integration, they are very different in their competitive structure. The cement market is highly concentrated, with the top 8 companies in Brazil having a share of above 90% in 2022 (CIMENTO, 2023). The market is regional with a radius of 300 kilometers around the cement plant. In Brazil, there are 100 cement plants (SNIC, 2020). The concrete market is more granular once the markets are local, usually within a city with about 3,000 plants in Brazil. However, the competition within each market is an oligopoly.

Figure 1 shows the cement market and ready-mix conditions before and after the cartel breakdown. Cement prices increased at the beginning of 2000 followed by a decrease until 2005, and stabilized. The cement market also showed a strong increase in the quantity produced after the cartel dismantling. The number of concrete plants per year increased after the cartel breakdown.

Figure 1 – Cement and Ready-Mix Concrete Market Conditions



Source: Author Elaboration.

The civil construction sector has also experienced a demand increase since 2007, driven by industrial policies such as the Growth Acceleration Program (PAC), which spent more than BRL 500 billion [3] from 2007 to 2011. This policy is also reflected in the demand growth for cement and concrete and the entry of ready-mix concrete plants.

3 Model

The model we will use in this work, following Collard-Wexler (2014), is the Last-In-First-Out (LIFO) equilibrium model developed by Abbring e Campbell (2010). This model presents a unique equilibrium to an entry and exit game characterized by demand thresholds. These demand thresholds will be the basis of my estimation strategy.

3.1 Setup

In each time period t, the market is characterized by a demand level D_t and the set of firms in each market. Each firm $j = 1, ..., J$ can be a potential entrant ($\mathcal{E}_t$) or an incumbent ($\mathcal{C}_t$). The number of firms, J, is countably infinite, so there are always potential entrants, and the number of incumbents is N_t. Then, the state s_t is defined as $s_t \equiv \{\mathcal{E}_t, \mathcal{C}_t, D_t\}$.

The game in t can be written as beginning in s_{t-1}:

[3] About US$ 238 billion at 2007 values.

(i) The demand D_t follows a first-order Markov process $Q(.|D_{t-1})$;

(ii) Profits earned each period $\Pi(D_t, N_{t-1})$ which are determined by the number of firms in the market and the size of the market. The profit are multiplicatively separable in market size: $\Pi(D_t, N_{t-1}) = \frac{D_t}{N_{t-1}}\pi(N_{t-1}) - k$;

(iii) Each period t, firms make entry and exit decisions sequentially. Each firm incumbent j decides irreversibly to leave or to continue in the market, with an indicator variable $\chi_j \in \{0, 1\}$. Upon exiting, the firm does not receive any scrap value. Each potential entrant decides to enter through the indicator $\chi_j^{\mathcal{E}} \in \{0, 1\}$. If enter pay the ϕ cost. These entry and exit decisions generate a new set of incumbents $(\mathcal{C}_t)$ and potential entrants $(\mathcal{E}_t)$.

The incumbent firm j value function $V_j^{\mathcal{C}}$ follows a usual Bellman equation:

$$V_j^{\mathcal{C}}(s_t) = \int_{D_{t+1}} [\pi(D_{t+1}, N_t) + \beta \max_{\chi_j \in \{0,1\}} E(1-\chi_j)(V_j^{\mathcal{C}}(s_{t+1}))] \times Q(D_{t+1}|D_t)dD_{t+1} \quad (1)$$

where the expectation operator E incorporates the fact that in $t+1$ the j firm knows both demand D_{t+1} and entry and existing choices of lower ranked firms $1, ..., j-1$, but not the entry and exit choices of firms with higher rankings than j.

Likewise, potential entrants have value functions as:

$$V_j^{\mathcal{E}}(s_t) = \int_{D_{t+1}} [\max_{\chi_j^{\mathcal{E}} \in \{0,1\}} E(1-\chi_j^{\mathcal{E}})\beta(V_j^{\mathcal{E}}(s_{t+1}) + \chi_j^{\mathcal{E}}(-\phi + \beta V_j^{\mathcal{C}}(s_{t+1})] \times Q(D_{t+1}|D_t)dD_{t+1} \quad (2)$$

3.2 Demand Threshold

The AC model requires assumptions both on strategies and on the process for demand characterized by the equilibrium policies in the game:

A1 Firms use LIFO strategies which default to inactivity: the firms that enter earliest are the firms that exit last.

A2 Stochastic monotonicity: to ensure higher demand today implies a higher distribution of demand tomorrow, the expected demand $E[D_t|D_{t-1}]$ must be increasing in D_{t-1}.

A3 The inovation error in demand, $u_t = D_t - E[D_t|D_{t-1}]$, must be independent of D_{t-1}.

A4 The demand process $Q(.|D_t)$ must be continuous.

A5 The innovation u in the demand process must be drawn from a concave distribution.

Given the LIFO assumptions, Abbring e Campbell (2010) shows that the Markov equilibrium of the entry-exit game will be unique. In contrast to other games of entry-exit of the oligopoly literature [4], the model generates a unique prediction, considerably simplifying counterfactual experiments, and allowing for estimation techniques, such as maximum likelihood.

[4] See Besanko et al. (2010)

Considering the order of movements by continuers, incumbents that decided to continue on the market, and entrants do not change over time, combined with the LIFO assumptions ensures that the number of plants in the market N_t is a sufficient statistic to describe the set of entrants ($\mathcal{E}_t$) and continuing firms ($\mathcal{C}_t$), then, under the LIFO strategies, the state at the end of each period can be described as $s_t = \{D_t, N_t\}$.

The entry or exit decisions in a market are characterized by demand thresholds, meaning there is a demand level that only one firm enters the market, another higher demand level that the second firm enters, and so on. Likewise, for continuation, there will be a level of demand below which an nth firm will exit. Given the LIFO strategies employed by firms, one can label j such that $j = 1$ indicates the oldest incumbent, $j = 2$ is the second oldest incumbent, and so on.

As mentioned before, the decision of entry-exit in a market is characterized by a demand threshold. Exit decisions are in the threshold if $\chi_j(D_{t+1}, N_t) = 1(D_{t+1} \leq D_j^C)$, i.e., an Nth incumbent continues if an only if $D > D_N^C$. Likewise, entry decisions are in the threshold if $\chi_j^{\mathcal{E}}(D_{t+1}, N_t) = 1(D_{t+1} > D_j^E)$.

The stochastic process for market structure can be described as coming from the demand process, $D_{t+1} \sim Q(.|D_t)$, and conditions on the number of firms (N), depending on whether the number of firms in a market is growing, shrinking or remaining the same.

In a growing market with N firms, the level of demand must lie between the entry threshold for N and $N + 1$:

$$D_N^E < D_t < D_{N+1}^E \tag{3}$$

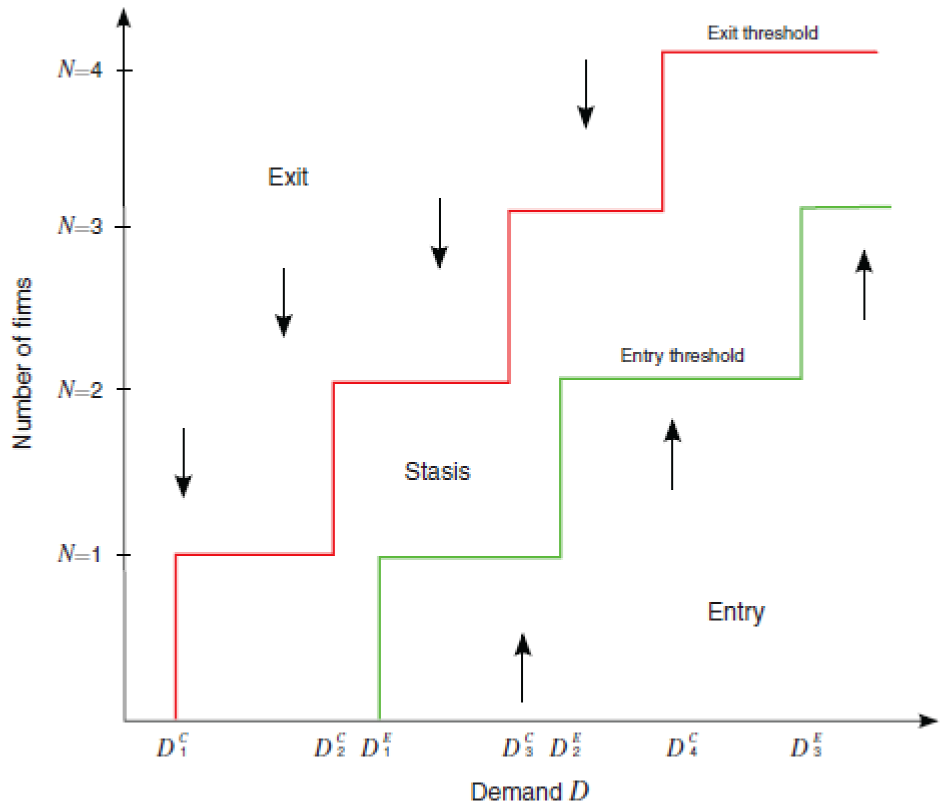
In a shrinking market with N firms, the level of demand must lie between the continuation threshold for N and $N + 1$:

$$D_N^C < D_t < D_{N+1}^C \tag{4}$$

In a market with no change in the number of firms, demand must lie between the continuation threshold for N firms and the entry threshold for $N + 1$ firms:

$$D_N^C < D_t < D_{N+1}^E \tag{5}$$

Figure 2 – Entry and Continuation Thresholds in a Market with sunk cost



Note: D_1^E *represents the level of demand required for one firm to enter, and* D_2^E *represents the level of demand required to keep two existing firms in the market.*
Source: Collard-Wexler (2014)

Figure 2 captures the predictions of the model by presenting the transition dynamics for the industry, along with the entry and exit thresholds. The difference between the entry and exit threshold indicates the level of demand where there will be no change in the number of firms, which is called the stasis zone.

In an industry without sunk costs, the entry and exit threshold are the same $D_N^C = D_N^E$. Thus, the gap between the entry and exit threshold indicates the level of demand required to induce a firm to exit a market and the level of demand required to have this firm enter in the first place. The higher the stasis zones, the longer the effects of changes in the market structure will last in the market (COLLARD-WEXLER, 2014).

4 Data

Our data allow us to observe entry and exit patterns in isolated markets for ready-mix concrete. Isolated cities give us a clear identification of competition once firms within a market are unlikely to compete in more than one geographic market. We use the *Relação Anual de Informações Sociais* (RAIS) database to obtain the entry and exit data in the ready-mix concrete sector, as well as employment data for the construction sector, which will be our measure of demand. Our sample covers a 15-year window, from 1993 to 2007, which matches the existence of the ready-mix concrete cartel.

4.1 Isolated Cities

After the Bresnahan e Reiss (1991) and Collard-Wexler (2014), we selected a sample of isolated cities. These cities are far enough away from other cities that concrete cannot be shipped in from outside, which means there is no competition from competitors located in neighboring cities.

The ready-mix concrete markets are well suited to be characterized by isolated cities, once concrete does not travel to neighboring cities due to high transportation costs and perishability. Concrete hardens in about one and a half hours which limits the distance of delivery to about 30 minutes on average.

The isolated cities were constructed according to a central point in urban areas of each Brazilian city with a radius of 40 kilometers. Therefore, if we are considered isolated in any city the radius does not overlap any other city. In addition, there were selected cities that had over 5000 population. Out of 5,570 cities, we obtained 260 isolated cities in Brazil [5].

4.2 Concrete and Construction Data

The data on concrete plants and construction employees were gathered from the *Relação Anual de Informações Sociais* (RAIS) database, managed by the Brazilian Ministry of Labor [6]. RAIS is a firm- and worker-level data, the most important source of formal labor information in Brazil. Except for the informal sector and a subset of self-employed businesses, its coverage is almost universal. I can observe the number of firms in any given economic sector and their number of employees. Therefore, we observed the number of plants in a market, the number of employees in each plant, and the number of construction employees. Using confidential data, I can also observe the firm identifier code and their zip code.

We collect the data on establishments in the construction sector (CNAE 41, 42 and 43 [7]) and the concrete sector (CNAE 23303) for the period 1993 to 2007. Following Collard-Wexler (2014) construction employees will be the measure of demand since almost all concrete demand comes from the construction sector.

Table 1 – Summary Statistics

Variable	Mean	SD	Min	Max
Population	42,288	130,947	5,053	2,455,903
Log of Population	10.12	0.85	8.53	14.71
Construction Employment	216.70	1,987	0	43,792
Log Construction Employment	1.41	0.88	0	4.64
Concrete establishments	1.94	3.70	0	20
Number of employee per plant	7.66	33.58	0	452

Note: The data is a fully balanced panel of 260 markets over 15 years.

5 To obtain a balanced panel, cities that were founded during our sample period were excluded.

6 The RAIS database is considered a high-quality census of formal labor market (MENEZES-FILHO; MUENDLER; RAMEY, 2008; DIX-CARNEIRO, 2014; HELPMAN et al., 2016; COLONNELLI; PREM, 2022; COLONNELLI et al., 2022)

7 CNAE - National Code of Economic Activity. It is the equivalent of North American Industry Classification System (NAICS).

Table 1 presents the summary statistics for the 260 isolated cities over 15 years. The population ranges from 5,053 to 2,455,903, which shows a highly skewed. This high variation show can be explained by Federal District and Palmas (state capital), which are isolated cities under the criteria presented before. The population also shows an average of 42,288.

Construction employment, used here as a proxy for demand, shows on average 216 employees per market with a variation from 0 to 43,792 displaying markets with no demand and markets with huge demand for construction. The are between 0 and 20 concrete plants in a market, with an average of 1.94 concrete plants. The standard deviation of plants across markets is 3.70 which indicates a large difference in market size. The number of employees per plant is on average 7.66 with also a large standard deviation.

Table 2 – Summary Statistics by Market Structure

Number of plants	Count	Mean Population	Mean construction employment	Share of plants with at least 8 employees
0	1863	23,156	22.22	N.A
1	818	28,842	72.91	5.38%
2	410	34,790	62.84	13.17%
3	202	40,284	99.18	25.25%
4	130	49,155	159.57	27.68%
5 and more	477	145,492	1,420	77.99%
All	3900	42,288	216.70	27.35%

Table 2 shows summary statistics of the data by the number of plants in a given a market. Notice that 48% of the markets have no plants, 21% are monopolies, 10.5% are duopolies, and the balance of markets (20,5%) have more than 1 plant. Construction employment increases as the number of ready-mix concrete plants per market. The share of employees in plants greater than 8 increases with market size.

Table 3 – Transition of the Number of Plants on a One- and Ten-Year Horizon

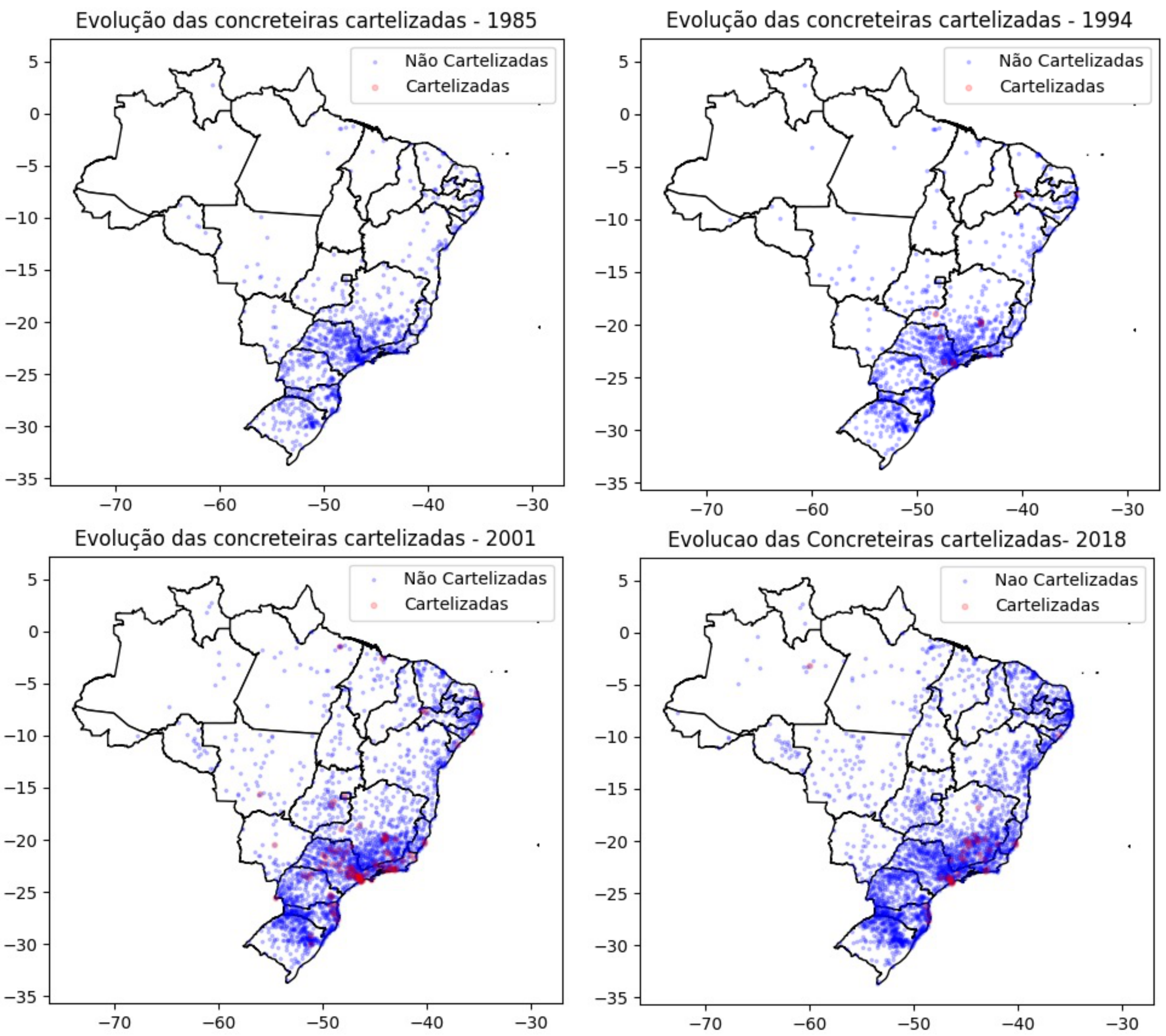
	Plants this year						
Plants last year	0	1	2	3	4	5+	Total
Panel A. One-year transition probabilities							
0	86.70	10.74	1.73	0.35	0.05	0.15	1,965
1	17.39	63.04	14.83	2.69	1.41	0.63	782
2	3.29	22.84	49.49	16.50	5.08	2.79	394
3	1.01	8.08	24.25	31.31	20.20	14.65	198
4	1.65	4.13	11.57	24.79	25.62	32.23	121
5 and more	0.22	0.68	0.45	3.86	6.14	88.64	440
	Plants this year						
Plants ten years ago	0	1	2	3	4	5+	Total
Panel B. Ten-year transition probabilities							
0	49.12	28.50	9.82	3.89	2.53	5.15	1028
1	16.18	24.07	20.33	12.03	4.98	22.40	214
2	8.47	20.33	16.10	10.17	11.02	33.90	118
3	0.00	17.24	6.89	10.34	8.62	56.89	58
4	0.00	9.52	14.28	0.00	3.57	75.00	28
5 and more	53.52	17.76	9.60	4.73	3.00	11.37	2,427

Table 3 illustrates changes in market structure with the transition probabilities of the number of plants in a given market on a one and ten-year horizon. Markets with at least one plant have about a 30% chance of changing the market structure from one year to another. The 10-year transition probabilities show, that a market with no firm has over 50% chance to have an entry. While markets have over 5+ plants that have about 54% to have zero plants 10 years later.

The data has also confirmed the Last-In-First-Out hypotheses for the market [8]. The oldest firms are the ones that continue while the exit rate of younger firms is very high. The exit rate for firms with one year is almost 12%, this rate drops by half for five-year-old firms. For firms with 10 years, the rate of exit is 2.13% and for firms with more than 15 years, the rate of exit is less than 1%.

Looking at the dispersion of the plants across the country is possible to see the growth dynamics of the industry. There is evidence that the cement cartel started to operate in the ready-mix concrete market in 1992 and the first cartel plants we have on our dataset are from 1994. The ready-mix concrete cartel operated until 2007, and after that period we saw a decrease in the number of cartel-affiliated plants, which strengthens the hypothesis that the cement cartel only entered the ready-mix concrete market to prevent concrete firms from entering the cement market.

[8] Assumption A1


Evolução das concreteiras cartelizadas - 1985
Não Cartelizadas
Cartelizadas
Evolução das concreteiras cartelizadas - 1994
Não Cartelizadas
Cartelizadas
Evolução das concreteiras cartelizadas - 2001
Não Cartelizadas
Cartelizadas
Evolucao das Concreteiras cartelizadas- 2018
Nao Cartelizadas
Cartelizadas

5 Econometric Strategy

5.1 Demand Threshold estimation

The estimation procedure follows Collard-Wexler (2014), using maximum likelihood to estimate entry and exit thresholds and the demand process for demand $Q(.|D_t)$. The demand will be measured with error since there are differences in concrete demand in different markets that are difficult to capture with observable demand shifters only.

True demand D_t^*, which is the demand discussed in section II, can be written as $D_t^* = D_t + \epsilon_t$, where ϵ_t is the unobserved demand component and D_t are the observed demand components. However, for every market to have the same underlying demand thresholds D_N^C and D_N^E, the process for demand $Q(.|D_t)$ must be the same in every market.

The number of firms in a market m at time t denoted $N_{m,t}$, must lie between the entry and continuation thresholds. Thus,

$$D_{m,t} + \epsilon_{m,t} > D^E_{N_{m,t}} 1(N_{m,t} > N_{m,t-1}) + D^C_{N_{m,t}} 1(N_{m,t} \leq N_{m,t-1})$$

$$D_{m,t} + \epsilon_{m,t} \leq D^E_{(1+N_{m,t})} 1(N_{m,t} \geq N_{m,t-1}) + D^C_{(1+N_{m,t})} 1(N_{m,t} \leq N_{m,t-1})$$

Following Collard-Wexler (2014) I define the gap between entry and continuation thresholds as $\gamma^S(N) \equiv D_N^E - D_N^C$. I will also represent $D_N^E \equiv \sum_{k=1}^{N} h(k)$, where $h(k)$ is the increment in demand thresholds between $k-1$ and k firms[9].

To reduce the number of parameters to be estimated, I will present estimates where the difference between entry and exit thresholds is either (i) constant, i.e. $\gamma^S(N) = \gamma_0^S$, or (ii) linearly varying with demand $\gamma^S(N) = \gamma_0^S + \gamma_1^S N$. To accommodate multiple demand components, such as population and construction employment, I use a single index of demand $D_{m,t} = \mathbf{X}_{m,t}\beta$.

Thus, the threshold becomes:

$$\begin{aligned} \epsilon_{m,t} &\geq -\mathbf{X}_{m,t}\beta + 1(N_{m,t} > N_{m,t-1})\gamma^S(N_{m,t}) + \sum_{k=1}^{N_{m,t}} h(k) \equiv \overline{\pi}(N_{m,t}, N_{m,t-1}, \mathbf{X}_{m,t}, \boldsymbol{\theta}) \\ \epsilon_{m,t} &< -\mathbf{X}_{m,t}\beta + 1(N_{m,t} \geq N_{m,t-1})\gamma^S(N_{m,t}) + \sum_{k=1}^{1+N_{m,t}} h(k) \equiv \underline{\pi}(N_{m,t}, N_{m,t-1}, \mathbf{X}_{m,t}, \boldsymbol{\theta}) \end{aligned} \tag{6}$$

where the parameter vector is denoted $\boldsymbol{\theta} \equiv \{\beta, \gamma^S(.), h(.)\}$. This means that my estimating equations will compute the probability that $\epsilon_{m,t}$ is in between $\overline{\pi}$ e $\underline{\pi}$, that is:

$$Pr(N_{m,t}, N_{m,t-1}, \mathbf{X}_{m,t}, \boldsymbol{\theta}) = \begin{cases} Pr(\underline{\pi}(N_{m,t}, N_{m,t-1}, \mathbf{X}_{m,t}, \boldsymbol{\theta}) \leq \epsilon_{m,t} < \overline{\pi}(N_{m,t}, N_{m,t-1}, \mathbf{X}_{m,t}, \boldsymbol{\theta})) \text{ if } N_{m,t} > 0 \\ Pr(\epsilon_{m,t} < \overline{\pi}(N_{m,t}, N_{m,t-1}, \mathbf{X}_{m,t-1}, \boldsymbol{\theta})) \text{ if } N_{m,t} = 0 \end{cases}$$

[9] This change in variables is mainly done because there is a larger variance in the demand thresholds, but the increments of these demand thresholds are precisely estimated

$$(7)$$

It will be convenient to assign $\underline{\pi}(N_{m,t}, N_{m,t-1}, \mathbf{X}_{m,t}, \boldsymbol{\theta}) \equiv -\infty$ if $N_{m,t} = 0$, then I do not have to keep two separated cases, just look at $Pr(\underline{\pi} \leq \epsilon_{m,t} < \overline{\pi})$.

If one assumes $\epsilon_{m,t}$ in an independently and identical distributed variable that is distributed as a $\mathcal{N}(0,1)$, then this model can be estimated by maximum likelihood almost as if it were an ordered probit. Truly, equation (7) differs from an ordered probit, such as is used in Bresnahan e Reiss (1991) only in the inclusion of the $\gamma^S(.)$ term.

The likelihood will be based on the probability of a sequence of $\boldsymbol{\epsilon}_m \equiv \{\epsilon_{m,t}\}_{t=0}^T$:

$$Pr(\{N_{m,t}\}_{t=0}^T | \{\boldsymbol{X}_{m,t}\}_{t=0}^T, \boldsymbol{\theta}) = \int_{\mu_m,0} Pr(\{N_{m,t}\}_{t=0}^T | \mu_{m,0}, \{\boldsymbol{X}_{m,t}\}_{t=1}^T, N_{m,0}, \boldsymbol{\theta}) Pr(\mu_{m,0} | N_{m,0}, \boldsymbol{X}_{m,0}, \boldsymbol{\theta}) d\mu_{m,0} \tag{8}$$

where $Pr(\{N_{m,t}\}_{t=0}^T | \mu_{m,0}, \{\boldsymbol{X}_{m,t}\}_{t=1}^T, N_{m,0}, \boldsymbol{\theta})$, which I will refer to as the "ordered probit" component, is given by:

$$\begin{aligned} Pr[\underline{\pi}(N_{m,1}, N_{m,0}, \boldsymbol{X}_{m,1}, \boldsymbol{\theta}) \leq \epsilon_{m,1} < \overline{\pi}(N_{m,1}, N_{m,0}, \boldsymbol{X}_{m,1}, \boldsymbol{\theta}), ..., \\ \underline{\pi}(N_{m,T}, N_{m,T-1}, \boldsymbol{X}_{m,T}, \boldsymbol{\theta}) \leq \epsilon_{m,T} < \overline{\pi}(N_{m,T}, N_{m,T-1}, \boldsymbol{X}_{m,T}, \boldsymbol{\theta}) | \mu_{m,0}] \end{aligned} \tag{9}$$

Notice that equation (8) incorporates both the ordered probit components in equation (9) and the initial conditions distribution $Pr(\mu_{m,0} | N_{m,0}, \boldsymbol{X}_{m,0}, \boldsymbol{\theta})$, the probability of the initial unobservable $\mu_{m,0}$ given the initial demand level and number of firms.

5.2 Demand Process

I estimate the demand process for observable demand $Q[D_{m,t} | D_{m,t-1}]$ from the data, using $d_{m,t} = log(D_{m,t})$ (log construction employment):

$$d_{m,t} = \beta_0 + \beta_1 d_{m,t-1} + \eta_{m,t}^d \tag{10}$$

where $\eta_{m,t}^d \sim (0, \sigma_0 + \sigma_1 d_{m,t})$. Q is estimated by maximum likelihood and Table 4 presents estimates of the demand process. Columns I and II show that the coefficient on lagged demand is essentially 1, i.e., a unit root process for demand. There is substantial variation in demand from year to year since the estimated variance is 0.27, but this variation is more important in small markets since log construction employment reduces the variance of η. For the counterfactual, and to simulate the initial conditions distribution, we use the demand process estimated in column I.

5.3 Likelihood and GHK

The likelihood for this model is given by $\mathcal{L}(\theta) = \Pi_{m=1}^M Pr(\{N_{m,t}\}_{t=1}^T | \{\mathbf{X}_{m,t}\}_{t=1}^T, \theta)$. Given the AR(1) process with independently and identically distributed shocks in this equation, the sequence of $\epsilon_m = \{\epsilon_{m,t}\}_{t=1}^T$ has a $\mathcal{N} \sim (0, \sum)$ distribution. Thus, we

Table 4 – Estimated Demand Transition Process

Dependent variable: Log construction employment		I	II
Last year	Log construction employment	0.930	0.969
		(0.02)	(0.03)
	Constant	0.092	0.045
		(0.05)	(0.08)
Variance σ_η	Constant	0.274	0.371
		(0.03)	(0.04)
	Log concrete employment		-0.096
			(0.001)
Observations		4583	4583
Log-likelihood		- 6973.87	- 6959.00

approximate the probability using the GHK algorithm, as a truncated multivariate normal [10].

6 Results

Table 5 presents the estimation results of equation (9). We normalize the coefficient on ready-mix concrete employment to 1, which allows me to show the entry and continuation threshold in terms of ready-mix concrete employment. Panels B and C present the entry and continuation thresholds.

Column I shows the estimates where $\gamma^S(N) = 0$ and therefore is comparable to Bresnahan e Reiss (1991) —henceforth, BR. In Column II shows the estimates of the LIFO model. The difference between the two models while BR predicts market structure, the second (I.I.D.) predicts changes in market structure. Columns III and IV show estimates with an AR(1) process for the unobservable. We will discuss the estimates of entry thresholds, the gap between entry and exit thresholds, and the magnitude of unobservable shocks.

[10] While GHK is most commonly used for correlated binary probit models, the logic behind the procedure is applicable to any multivariate normal that is truncated, such as an ordered probit.

Table 5 – Estimation of Entry and Exit Thresholds

Dependent variable	BR	I.I.D.	AR(1)	
Number of Plants	I	II	III	IV
Panel A. Estimates				
Entry parameter (($h(1)$)	-0.605	-0.954	-1.794	-8.073
	(0.097)	(0.066)	(0.151)	(0.042)
First Competitor (($h(2)$)	-0.399	-0.621	-1.211	-5.711
	(0.094)	(0.061)	(0.153)	(0.027)
Second Competitor (($h(3)$)	-0.283	-0.435	-0.823	-4.271
	(0.075)	(0.063)	(0.145)	(0.0233)
Third Competitor (($h(4)$)	-0.244	-0.362	-0.653	-3.460
	(0.081)	(0.074)	(0.141)	(0.022)
Fourth Competitor (($h(5)$)	-0.283	-0.419	-0.725	-3.443
	(0.063)	(0.048)	(0.049)	(0.012)
Competitors above 4 (($h(6)$)	-0.104	-0.401	-0.431	-2.572
	(0.000)	(0.067)	(0.056)	(0.098)
Gap entry-continuation γ_1^S		1.812	1.824	6.495
		(0.028)	(0.016)	(0.029)
Unabservables				
σ_η (independently and identically distributed shock)			2.098	4.344
			(0.038)	(0.042)
σ_ζ (AR(1) shock)				3.751
				(0.097)
ρ			1.258	1.057
			(0.012)	(0.009)
Observations	3900	3900	3900	3900
Markets	260	260	260	260
Log likelihood	5,031	4,617	3,673	2,692
Panel B. Entry threshold				
One firm	605	954	1,794	8,073
Two firm	1,005	1,574	3,005	13,784
Three firm	1,288	2,009	3,828	18,054
Four firm	1,531	2,372	4,481	21,514
Five firm	1,814	2,791	5,207	24,957
Panel C. Continuation threshold				
One firm		-858	-30	1,578
Two firm		-237	1,181	7,288
Three firm		198	2,005	11,559
Four firm		560	2,658	15,019
Five firm		979	3,383	18,462

Note: Columns I and II show estimates with an independently and identically distributed process for ϵ, while columns III and IV show an AR(1)— with independently distributed shocks— process for ϵ. The coefficient on construction employment in thousands was normalized to 1. Thus, using column III's estimates, an entry parameter $h(1)$ of 1.794 implies that the entry threshold is 1,794 construction employees. In addition, $\sigma_\eta = 2.098$ would imply that the independently and identically distributed shock has a variance of 2,098 construction employees.

The entry threshold for a monopolist, $h(1)$, in column III is 1.794. In other words, it takes 1,794 construction employees for the first firm to enter the market. However, for the second firm to enter, it needs 1,211 employees more. Thus, the level of demand necessary to induce two firms to enter the market is less than twice the level of demand needed to support a single entrant. To induce a third and fourth firm, construction employment must rise by an additional 823 and another 653 employees, respectively.

Comparing the entry threshold estimates between columns II and III, we find that the increments to the demand thresholds $h(k)$ are about 50 percent higher in column III's AR(1) estimates with a serially correlated unobservable than in column II's estimates with an independently and identically distributed unobservable.

The magnitude of the stasis zone has a direct impact on the persistence of the effects of changes in market structure. If the stasis zone is zero, then an exit only has an impact for a single period, and likewise, if the stasis zone is infinite, then an exit permanently alters the market structure. In column III, we estimate the magnitude of the stasis zone at 1,812 construction employees. This means that the level of demand required to induce a monopoly entrant $D_1^E = 1,794$ is in between the level of demand needed to maintain two or three competitors (since $D_2^C = -1,181$ and $D_3^C = 2,005$). These large estimated stasis zones are not too surprising since there is evidence of large sunk entry costs in the ready-mix concrete industry.

The independently and identically distributed unobservable η is quite large in column IV, at 4,344 construction employees. The majority of the unobservable is serially correlated, not independently and identically distributed. This serially correlated unobservable is quite persistent as well, with an estimated autocorrelation coefficient of 1.258 and 1.057 in columns III and IV, respectively. Two examples of these highly persistent differences are the size of building constructions, which use a large amount of concrete and are likely to take more than one year to be built.

To perform the counterfactual we will need to simulate the evolution of D over time which includes the evolution of both observable and unobservable demand. Thus, getting the right time-series process for unobserved demand ϵ is key.

7 Counterfactual

7.1 Goodness of Fit

We examine the fit of the LIFO estimates on several different metrics to explore the appropriateness of the approach here. Table 6 compares these predictions with the data. The entry and exit rates in the data are 25.3 percent and 14.8 percent, respectively, the independently and identically distributed model predicts entry and exit rates of 42.7 percent and 41.6 percent, and the AR(1) model predicts a 21.22 percent entry rate and a 14.4 percent exit rate. Thus, the I.I.D. specification of the models overestimates entry and exit rates. However, The AR(1) model's predictions are way better than the I.I.D. model and are more reasonable with the data. The entry and exit in the Brazilian Ready-mix industry are very large in comparison with the same industry in developed countries where these rates can be three times smaller [11].

[11] For detail see Collard-Wexler (2013) and Collard-Wexler (2014).

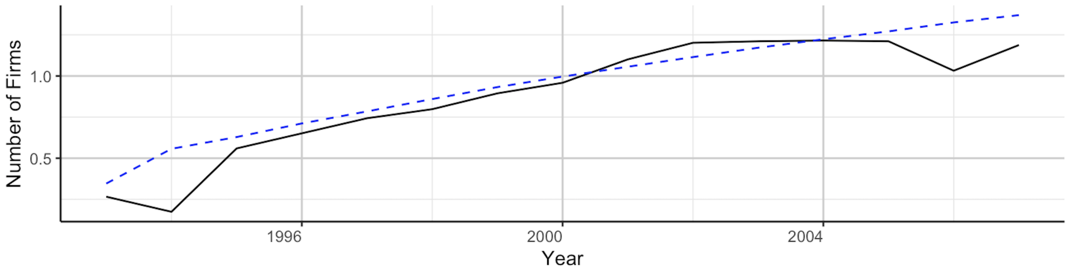
Table 6 – Goodness of Fit

Variable	Data	I.I.D	AR(1) model
Mean number of firms	1.08	0,86	0,97
Entry rate	25.3%	42.7%	21.22%
Exit rate	14.8%	41.6%	14.4%

To understand the model's long-run forecast for market structure, starting with the number of firms in 1993, we simulate the evolution of markets for the next 15 years. This is an important check for the counterfactual since it is important to check that the model accurately predicts the path of a market. Figure 3 plots the evolution of the number of firms in the market in the data (shown in solid blue), and compares this to the forecast from the AR(1) model (shown in dotted red). This evolution is broken out by the number of firms in the initial period, the year 1993.

Notice that over 15 years, there is a large amount of variation in the number of firms in a market. Moreover, the AR(1) model does a good job of replicating the time series pattern of the number of firms in the market, as evidenced by the proximity of the model's prediction to the path in the data.

Figure 3 – Matching the Path of Market Structure



Note: The graph shows the average number of plants in a market in 1993, respectively, both for the actual number of plants in a market (solid) and the predicted number of plants by the model (dotted), using the average of 10,000 simulation draws

However, the AR(1) model does a middling job of matching the transition matrix of the market structure. Table 7 shows the ten-year transitions of market structure, for the data and the AR(1) specification, respectively. The AR(1) predicts less volatility of market structure than what is observed in the data. These specifications predict mean reversion in market structure, to the mean in the data of one firm per market.

Table 7 – Ten-Year Predicted Transitions of Market Structure

Data	Plants this year				
Plants ten years ago	0	1	2	3	4
0	49.12	28.50	9.82	3.89	2.53
1	16.18	24.07	20.33	12.03	4.98
2	8.47	20.33	16.10	10.17	11.02
3	0.00	17.24	6.89	10.34	8.62
4	0.00	9.52	14.28	0.00	3.57

AR(1) model	Plants this year				
Plants ten years ago	0	1	2	3	4
0	43.35	25.35	7.57	2.00	0.44
1	4.42	49.78	2.38	0.94	0.32
2	1.37	2.02	12.34	15.27	2.47
3	0.22	0.45	6.89	7.34	4.82
4	0.13	0.22	0.12	0.00	0.00

7.2 Simulations

From 2007 onwards, Brazil experienced rapid construction growth, with fast development in the country's infrastructure. Fueled by a combination of economic growth, increased investment, and government initiatives, construction projects flourished across the country.

Two major policies are helping to boost construction growth: the Growth Acceleration Program (*PAC*) and *Minha Casa, Minha Vida* — (My House, My Life). The PAC was launched by the Brazilian government in 2007 as a strategic initiative to stimulate economic development and improve infrastructure throughout the country. This ambitious program aimed to address several critical areas, including transportation, sanitation, energy, and housing, through significant investments and streamlined project execution. With a focus on promoting social inclusion and reducing regional disparities, the PAC played a critical role in driving Brazil's economic growth, especially during the global financial crisis. It facilitated the construction of highways, ports, airports, and urban infrastructure, helping to create jobs, improve connectivity, and raise living standards for millions of Brazilians. The government spent approximately US$240 billion on the policy over 4 years.

Meanwhile, *Minha Casa, Minha Vida* was launched in 2009 as a flagship housing program to address Brazil's housing deficit and provide affordable housing solutions for low-income families. This initiative sought to address the challenge of housing accessibility by offering subsidies and financing options to facilitate home ownership. By partnering with private developers and leveraging government resources, *Minha Casa, Minha Vida* facilitated the construction of millions of housing units in urban and rural areas, providing dignified living spaces for those in need.

Figure 4 – Construction Employees per Year in Brazil

Note: This represents only the formal construction sector. The Industrial policy *PAC* lasted from 2007 to 2011.

Figure 4 shows the number of construction employees and the growth after the industrial policies were implemented. From 2007 to 2011 the number of construction employees grew on average 16%. These policies are reflected in the growth of demand for cement and concrete the dynamics of ready-mix concrete plants, in number of firms, and entry and exit rates.

Given the context that both cartel breakdown and increasing demand for construction happened in 2007, we need to separate this event to get the effect of dismantling the cartel on the market. Therefore, we simulated an exogenous shock on the number of construction employees, an increase of 16%, the size of growth of the market from 2007 to 2011— boom of construction in Brazil. And simulate the evolution of the market for 11 years, after 2007, from 2008 to 2018. In this regard, we obtain the evolution of the markets with the operation of the cartel and the boom of the civil construction sector. The effect of dismantling the cartel is obtained by the difference between the evolution of the markets with an exogenous shock and what happened with the real data. The real data after the cartel period contains the economic shock and the effect of dismantling the cartel while the simulated contains the economic shock in the presence of the cartel.

7.3 Simulation Results

Table 8 shows the effect of cartel dismantling on the expected number of firms, entry and exit rates in the industry over time, and their comparison with the real data. Notice that the average effect of the cartel breakdown increases the average number of plants to 0.20 per market in an 11-year window. The mechanism for this growth in the number of plants is the bigger decrease in exit rate than the entry rate.

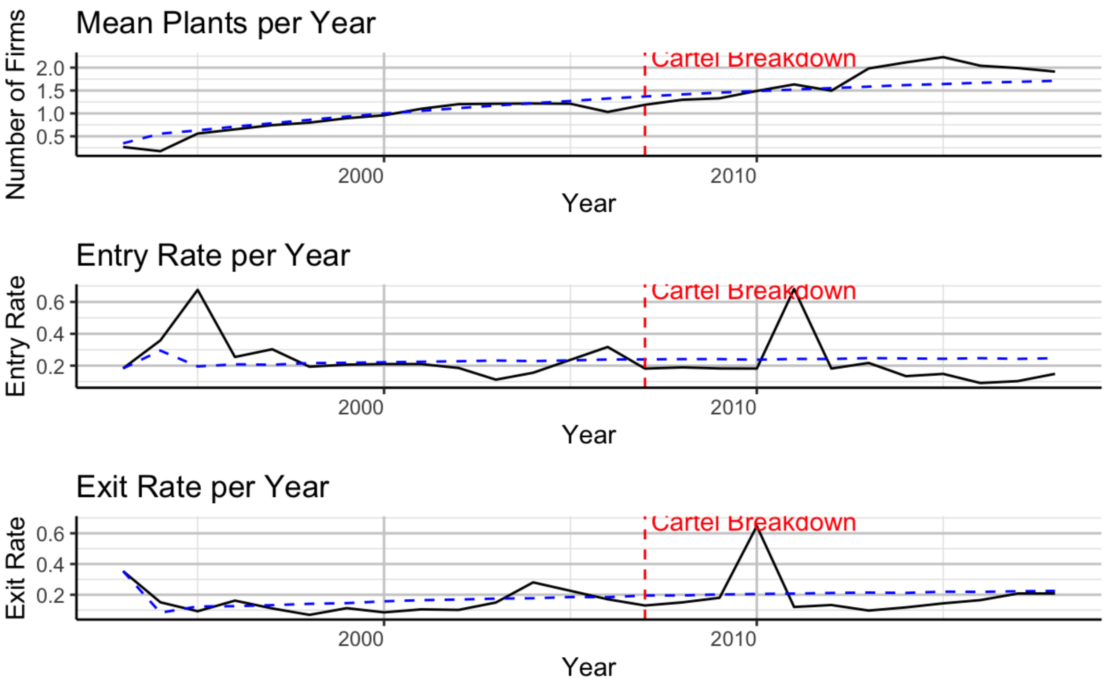
Table 8 – Effects Post Cartel

Variable	Data	Simulation	Effect of Cartel Breakdown
Mean number of firms	1,77	1.57	0.20
Entry rate	20.54%	24.33%	-3.79%
Exit rate	19.63%	21.22%	-1.59%

The effect of the cartel breakdown decreases the entry and exit rate by 3.79 and 1.59 percentage points. That is, entry became less likely to happen after the cartel and the exit is also less likely to happen. The magnitude of the effect of entry rate reduction is larger than the exit rate.

Figure 5 shows the behavior of the actual evolution of the market and the predictions from 1993 to 2018 using the dynamic simulation algorithm with the AR(1) estimates of the model.

Figure 5 – Effects Post Cartel



Note: The graph shows the average number of plants in a market and the entry and exit rate for both actual (solid) and predicted (dashed) numbers.

The results are consistent with the theory that once a cartel raises prices and profits, it can attract uncooperative entrants (STARC; WOLLMANN, 2022). However, after cartel dismantling, entry decreased as a result of lower profits. The dismantling of the cement cartel in the upstream sector— cement sector, may have affected the ready-mix concrete market, once the upstream collusion in the presence of a vertically integrated firm would benefit the downstream integrated firm from a raising-rivals'-costs effect (NORMANN, 2009). In this case, the elimination of the cartel in the upstream market makes firms more likely to face competitive prices against their vertically integrated rivals, thus decreasing the exit rate. Finally, the presence of sunk costs plays a significant role in decreasing the exit rate, as firms with high sunk costs may be reluctant to exit markets (BRESNAHAN; REISS, 1994).

8 Conclusion

This paper examines the aftermath of a cartel breakdown in the long run, focusing on the competitive dynamics within isolated ready-mix concrete markets. By employing a simple dynamic model of entry and exit, we shed light on the nuanced effects of this significant event.

Our model estimates reveal the presence of a substantial stasis zone, denoting a notable gap between the entry and exit thresholds in response to market demand. This underscores the importance of accounting for unobservable market heterogeneity, as evidenced by the reduction in the size of the stasis zone when serial correlation of the unobservables is included.

After the dissolution of the cartel, our results indicate a notable shift in market dynamics. On average, we observe a remarkable increase of 0.20 plants per market, indicating a noticeable expansion of market competition. In addition, our analysis identifies a 3.79 percentage point annual decline in the entry rate and a 1.59 percentage point annual decline in the exit rate.

Taken together, these findings suggest that the dissolution of the cartel has led to an improvement in market conditions. Despite the reduction in entry rates, the overall landscape has become more competitive, with an increase in the number of market participants and a mitigated exit rate. This underscores the central role of competition in enhancing market efficiency and consumer welfare, and highlights the detrimental impact of cartels on economic vitality and market integrity.

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