Building New Plants or Entering by Acquisition? Estimation of an Entry Model for the US Cement Industry *

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Abstract

In many industries, firms usually have two choices when expanding into new markets: They can either build a new plant (greenfield entry) or they can acquire an existing incumbent. The U.S. cement industry is a clear example. For this industry, I study the effect of two policies on the entry behavior and industry equilibrium: An asymmetric environmental policy that creates barriers to greenfield entry and an antitrust policy that creates barriers to entry by acquisition. In the U.S. cement industry, the comparative advantage (e.g., TFP or size) of entrants versus incumbents and the environmental regulatory entry barriers to the construction of new plants are important factors that determine the means of expansion. To model this industry, I use a perfect information static entry game. To estimate the supply and demand primitives of my model, I apply a recent estimator of discrete games of complete information to a rich database of the US Census of Manufactures for the years 1963-2002. In my counterfactual analyses, I find that if there is an increase of approximately 25% in the entry barriers to construction of new plants, the number of acquired plants increases by 11.8%. Also, a similar increase in the barriers to entry by acquisition increases greenfield entry by 25%. Additionally, I demonstrate how my estimates change when I apply the approach in the entry literature where entry by acquisition is not considered. Finally, I consider how my estimates change when using a simple OLS estimation.

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1 Introduction

The importance of firm expansion is well-recognized in the economics literature and has several interesting dimensions to study. One specific dimension of interest is the type of expansion. For instance, firms can expand by selling products in new markets or by diversifying their activities to offer new products. Another interesting dimension is the way in which this expansion occurs because firms can expand internally (by building new facilities, which is usually called greenfield investment in manufacturing industries) or externally (by acquiring an existing firm in the market[1]).

There are many examples of industries where expansion by acquisition or by building new facilities can be observed[2]. When the banking industry was deregulated in 1994, regional banks were allowed to operate nationwide and many regional banks tried to expand to other markets by acquiring small regional banks or by opening new branches[3]. The cement industry is another clear example because acquisitions of plants almost doubled the construction of new plants for the period 1963-2002; and the construction of new plants was rare during the 1990s. An extreme example is the U.S. wireless industry where, due to regulation constraints and the limited capacity of spectrum, it is impossible to enter into new markets by building a new wireless network (unless there is an spectrum auction). Thus, acquisition of existing firms with spectrum licenses is virtually the only means of geographical expansion.

The U.S. cement industry has many interesting properties that facilitate understanding the reasons behind various means of expansion. First, the market for cement has a limited geographical scope (a reasonable approximation is to consider that the size of the market is a U.S. state) therefore to expand to new markets, firms necessarily must have production facilities in those markets. Second, cement is a very homogeneous product, and since differentiation is very low in this market, cost advantages, and therefore productivity, are important determinants of expansion. Finally, there are asymmetric environmental regulations (such as the 1990 Clean Air Act) that create important barriers to the construction of new plants as well as antitrust regulations that prevent firm expansion by acquisition.

[1] Since expansion can occur in many dimensions, in my paper I focus only on the geographic expansion of firms to other markets. Firm expansion to other geographic markets implies that a firm needs to have production facilities to cover new markets (for example, because transportation costs to send the product from other markets is too expensive).

[2] Depending on the industry, there are many reasons why a firm may decide upon one method of entry instead of another. To cite a few, we have competitive reasons (building a new plant in the market is increasing the number of competitors in the market), the intensity of entry barriers (regulatory barriers, scarcity of a basic input like technology or patents, etc) and comparative advatange aspects (the ability of entrants to extract more profits from the assets of incumbents).

[3] According to the Federal Deposit Insurance Corporation, from 1994 to 2005 the number of acquisitions of bank branches more than doubled the number of new branches opening. For the build or buy decision in the banking industry see Ruffer and Holcomb (2001).

Since firms have two margins of expansion, there is a substitution effect in the sense that when one of the margins of expansion becomes more expensive, there should be a substitution from the more expensive to the relatively less expensive method of expansion. For example, given the characteristics of the cement industry, an interesting economic question would be to determine the magnitude of this substitution effect in the industry equilibrium when the entry barriers in the cement industry are changed: How many incumbent plants would be acquired if there is an asymmetric environmental regulation that increases the cost of building new plants but not the cost of the existing incumbents? How many new plants would be built if entry by acquisition is more expensive due to antitrust barriers? What would the implications be in terms of average productivity, total welfare or prices in the market?

To answer these questions, I propose an entry game model that consists of four stages. In the first stage, all potential entrants make strategic decisions among three different choices: to enter by greenfield investment, to enter by acquisition or to stay out of the market. In the second stage, greenfield entrants decide how much capital they invest in the new plant. In the third stage, the identities of the acquired incumbents are determined using a sequential acquisition game. Finally, in the fourth stage all firms compete in the market. In my model, the decision to enter by acquisition or greenfield entry is driven by several factors. These include: a) the importance of costs of greenfield entry (such as sunk entry costs, or costs of building new capital); b) differences in characteristics (e.g. productivity or size) between entrant firms and incumbent plants; and c) the intensity of competition. For example, if sunk entry costs are too high, entry by building a new plant may simply be unprofitable. Also, when an incumbent plant is bought by an entrant firm, the acquired plant has now a new owner with different characteristics from the previous owner of that plant. Therefore, firm-level differences between the potential entrants and the incumbents determine this acquisition. Finally, intensity of competition affects the decision to buy or build a new plant. Building a new plant impacts the market in that another competitor is added to the markets and profits decrease with more intense competition.

For my estimation, I use a recent estimator from Bajari, Hong and Ryan (2008) to estimate the parameters of the model. This estimator uses an equilibrium selection rule as part of the model primitives to deal with the existence of multiplicity of equilibria. The estimation method requires the calculation of all equilibria, so it is computationally demanding. I use a rich plant-level data set from the U.S. Census of Manufactures (CM) database which is available every five years for the period 1963-2002.

My results show that if there is a 25% increase of the entry barriers to construction of new plants, the number of acquisitions increases by 11.8%, and the number of greenfield entrants decreases by 92%. A similar increase in the barriers to acquisitions generates approximately a 25% increase in the number of new plants built and a 94% decrease in the number of acquired plants.

Another result I demonstrate is that since entry by acquisition is a very common phenomenon in many markets, neglecting to consider entry by acquisition leads to an inaccurate representation of many industries, such as the U.S. cement industry. As a consequence, we may incorrectly estimate the key parameters that are driving entry into these markets. For example, a firm that enters into a market by buying an incumbent is choosing this option not only because this is more profitable than staying out of the market, but also because greenfield entry is a less profitable option (which may be suboptimal, but still be a better option than staying out of the market). In my estimation results, I demonstrate how my estimates change when assuming that entry by acquisition is not an available choice for entrants and find a 31% bias in the estimation of the own-quantity parameters of the demand function. I also discuss the differences in my estimates when I use simple OLS and find very high differences.

The outline of this paper is as follows: In the next section I present literature related to my paper. Then, I present the general characteristics of the U.S. cement industry and propose a model for this industry and explain the estimation strategy that I use. Finally, I show the estimation results and I use the estimated parameters to make counterfactual policy experiments that affect greenfield entry and entry by acquisition. The appendix contains results of my estimations, counterfactual experiments and details about the US cement industry.

2 Literature review

Although entry by acquisition is a very common method of expansion, the study of the various ways in which expansion occurs has received limited attention in the industrial organization field, specifically in the empirical literature. The closest theoretical reference to this topic in the industrial organization literature is Gilbert and Newbery (1992), who are the first to study this question using a simple entry game.

Concerning the empirical IO literature, we have structural empirical entry models, either static (starting with the Bresnahan and Reiss framework) or dynamic (Ericson and Pakes framework), that implicitly assume that all firms enter into markets by building new plants. These models do not consider the idea that there is usually another margin of entry into markets by buying an existing firm. Also, these models assume that when a plant exits a market, it receives an exogenous scrap value for its assets; and when a firm builds a new plant, it pays an exogenous sunk entry cost. However, since incumbents always have the possibility of selling the plant to leave the market and entrants can also buy an existing plant to enter the market, these entry and exit values now can be endogenous because they are endogenously determined in the process of acquisition between buyer and seller.

Since I consider that mergers are merely another means of entering into markets, my research also builds upon the merger literature. The empirical and theoretical literature related to mergers is very extensive. A well known question centers upon determining if mergers are driven by efficient reallocation of assets or by other reasons (such as conflicts of interest between managers and the owners of the firm). This question is usually difficult to answer because indicators of efficiency at plant level are usually difficult to measure because there is no data available. Maksimovic and Phillips (2001) answer this question using TFP plant-level data from the Census of Manufactures and they find that productivity (measured as TFP) increases significantly after assets change ownership on average (for the entire sample) about 2%. Concerning a more structural empirical approach to mergers, we have few examples. Gowrisankaran (1999) adapts the Ericson and Pakes (EP) framework to consider that firms can also merge horizontally in every market. Gowrisankaran numerically solves the set of equilibria and finds interesting insights but he does not apply his framework to a real industry to obtain estimates of the primitives of the model. More recently, Benkard et al. (2009) apply the two-step estimator from Bajari et al. (2007) to study horizontal mergers in the airline industry. Also, Akkus and Hortacsu (2007) and Park (2008) use two-sided matching models to study the sorting of characteristics between buyers and sellers in the banking and the mutual fund industry respectively[4].

In the cement industry, a paper closely related to mine is Ryan (2009), who studies entry into the cement market for the period 1980-1999 and estimates the increases in sunk entry costs due to environmental regulations using a two-step estimator applied to a dynamic game. Ryan does not focus upon the fact that entry can be accomplished through acquisition of plants and this is very important in the cement industry: Changes of plant ownership in this industry have been about twice the number of greenfield entries.

[4] Finally, another related body of literature is the extensive international trade literature on foreign direct investment (FDI). Part of this literature focuses upon why different modes of entry (greenfield entry or entry by acquisition) of multinational firms exist when these firms expand to other countries. Conceptually, the topic addressed in these papers is similar to my paper but the authors apply different macroeconomic methodologies. One close example to my paper is Nocke and Yeaple (2008) who use an assignment model to study what factors determine each firm's decision.

3 The US Cement Industry

3.1 General characteristics

The cement industry has unique characteristics that make it ideal to use in this project. Cement is a fine mineral dust with useful properties that makes it the key ingredient of concrete, which is mainly used in construction. Producing cement requires limestone, among other materials, and heat in enormous quantities. Limestone is a very common material that is virtually ubiquitous, thus, it is easily found in most states. Usually, limestone comes from a quarry located next to the cement plant. Large quantities of limestone are ground and sent in combination with other materials like clay to large rotary kilns. Very high temperatures cause chemical reactions that convert these combined materials into cement.

The relative high ratio of transportation costs to price makes cement a commodity that is usually transported in short distances. According to the Commodity Flow Survey, the average transportation distance for cement was 64 miles (with a standard deviation of 5.12 miles) in 1992, and 82 miles in 1997 (standard deviation of 5.9). Of course, there are exceptions as in the case of plants located close to the Mississippi River or in the Great Lakes area[5]. Given these facts, it is a good approximation to consider a U.S. state as the definition of a market in this paper. This market definition is also used in recent papers on the cement industry (such as Ryan (2009)). Furthermore, due to the local properties of the market, even smaller market definitions have been used (BEA's economic areas in Hortacsu and Syverson (2007)).

Concerning imported cement, imports have been relatively low for the period 1963-1982 (they were less than 5% of total production, see appendix) due in part to the high transportation costs. Although, imports have increased significantly recently due to the constant reduction of transportation costs, the consumption of imported cement is usually constrained to coastal states because the subsequent use of terrestrial transport would increase the final cost significantly.

Although there are several types of cement produced, in 1992 about 85% of the value of all cement produced was portland type[6] and this percentage has been approximately constant over the years. There are five different types of portland cement depending on the special constituents used. However, most of portland cement sold in the U.S. was of type I or II (for 1992, about 80% of the value corresponds to type I or II, with type I cement accounting for more than 60%). Therefore, although the production of cement is

[5] The use of barges decreases the cost of transportation significantly, so cement plants in these locations can inexpensively transport cement to distant areas.

[6] Cement Manufacturing, 1997 Economic Census, Industry Series

not as homogeneous as some extreme cases like ready-mix concrete, it is reasonable to consider that most cement produced is roughly of the same type.

This characteristic of cement as an homogenous product implies that product differentiation in this market is very small. Since firms basically offer the same product and they cannot significantly change the product's quality or characteristics, firms basically compete in prices[7]. Therefore, cost advantages by firms are critical to increase profitability and survival in this industry. We can identify three sources of cost advantages in this industry. First cost advantage is given by technological improvements in the manufacturing of cement. For example, Colson (1980) comments on innovations in the production of cement such as the use of more energy efficient processes (dry production) or the increasing use of computers to control the functioning of the kilns. A second cost advantage is given by the scale economies. Several authors (Norman (1979), Scherer et al. (1975) and McBride (1981)) have found significant scale economies, with minimum efficient scale levels between 1 and 2 million short tons per year. This efficient scale is probably much higher presently[8]. However, the use of scale economies as a source of cost advantage is limited by the high transportation costs and limited demand in the local market. Even if a larger plant could be more profitable, the limited size of certain markets and the high transportation costs can prevent maximization of this advantage. Finally, a third cost advantage is given by better managerial skills as noted in Lucas (1978) in the sense that some firms can manage certain assets more efficiently than others.

Due to the high transportation costs, cement cannot be easily transported to other markets, so firm growth has to be based on the production of cement in facilities located in markets where firms want to expand. Therefore, firm growth in the cement industry is based on the operation of multiple plants in the U.S. market. The fact that cement firms operate multiple plants in many markets could be a source of extra profitability as noted in Scherer et al. (1975). However, contrary to other markets where multi-market presence may give significant economic advantages[9], the cement industry is not likely to have strong multi-plant economies. Although some economies of multi-plant operation may exist in the cement industry, there is no persuasive evidence that they are as significant as the FTC (1966) comments in its report. Possible sources of multi-plant operation, other than access to capital, are difficult to identify. Product promotion offers few opportunities to savings because cement is, for the most part, an undifferentiated

[7] This does not preclude the existence of spatial differentiation. Actually, this is a reasonable hypothesis in the cement industry so I consider a differentiated demand in my model.

[8] Holcim is currently building a cement plant in Ste. Genevieve, Missouri, with an annual capacity of 4 million tons (about 5% of the total production in U.S., one of the biggest plants in the world) that will be open in 2009.

[9] For example, in the wireless industry there are strong demand-side network economies because consumers have a high willingness to pay for national coverage plans provided by carriers (see Bajari, Fox and Ryan (2008)). In the supply side, there is evidence of strong density economies in the discount retailing industry (Jia (2008)).

product sold to specification and sales promotion primarily involves "on the spot" efforts by salesman. Therefore, economies associated with large scale advertising and product differentiation are unlikely.

Moreover, as explained in the following section, the U.S. cement industry has been highly fragmented over the years, which is evidence that these multi-plant economies are low. If there were significant economics derived from the presence in multiple markets, we would have observed a clear process of consolidation in the U.S. but we have not. In addition, the process of expansion of the multi-plant firms does not have a clear geographic pattern. I studied the geographic pattern of multi-market firms and I did not observe significant clustering in the way the firms cover the markets.

The last remarkable characteristic is the important environmental issue related to this industry. It is well known that the cement industry is an industry with a high environmental impact because of the high emissions of pollutants and use of energy resources. Diverse environmental regulations in the U.S. like the Clean Air Act (CAA, 1970) and successive amendments in 1977 and 1990 have increased fixed and variable costs of operation as well as the sunk costs of building new facilities[10]. This had a great impact in the industry because environmentally inefficient plants had to exit the market because it was not profitable for them to pay for the necessary renovations to comply with the law. It also affected the entry of new plants because of the increasingly high entry costs necessary to build cement plants in the market. In fact, there is a well documented asymmetry between environmental regulations applied to the new sources and to the existing sources of pollution so new cements plants are subjected to more stringent regulations than the existing plants (what is usually called grandfather vs new source regulations[11]). Finally, a number of entry barriers are due not to specific environmental regulations but to social and political pressure by lobbies, neighbors or city officers to prevent the construction of a new cement plants in a certain area.

In summary, the cement industry can be characterized by the following: markets are local, product is very homogenous, cost advantages are critical for survival and profitability, economics of multi-market operation are small and environmental issues considerably affect entry and profitability.

[10] For example, Becker and Henderson (2000) finds a lower birth rate of plants in counties with more stringent environmental regulations for a number of industries, whereas Ryan (2009) studies specifically the effects of the CAA on the entry in the cement industry.

[11] See for example Levinson (1999) or Nash and Revesz (2007).

3.2 Structure of the market and patterns of firm expansion

The structure of the U.S. cement industry has been relatively stable for the last 40 years. Although the number of plants has decreased significantly, the number of firms and concentration levels have not had significant variations in this period (see appendix). In the period of study, the largest firm in the market rarely had more than 15% of the total number of plants in the industry and about half of the firms were single-plant firms. There were several industry leaders, but there has been a relatively fast variation in the identity of these leaders. For example, well known leaders in the industry during the 1960s and 1970s like Ideal Cement, Lone Star and Marquette Cement, were substituted by foreign firms like Holcim and Heidelberg that entered into the market in the 1970s and quickly expanded, or by diverse old incumbents like Ash Grove or Southwestern Cement that had been producing cement in U.S. for many years.

As a consequence of this low concentration in the U.S. market, most firms have a limited presence in the U.S. markets and about half of all cement producers are single-plant firms (see appendix).

Considering the means of expansion, using the CM database there have been 134 new plants build and about twice as much changes of ownership of plants. Therefore, entry by acquisition was a more common way of entering in the market than greenfield entry[12]. The construction of new plants has decreased over the years, and this effect is especially strong during the 1990s after the 1990 amendments to the Clean Air Act (CAA). The number of plants acquired has increased over the years, but mergers have been specially high in the 1980s and in the late 1990s. Also, during this period the number of plants that were closed almost doubled the construction of new plants. This explains the progressive reduction in the number of plants in the industry over the years.

These patterns of firm expansion by greenfield entry or by acquisition can be explained by a number of facts.

First, I observe correlation between exit of plants and greenfield entry in those markets. For example, in the 1960s and 1970s many small inefficient plants closed and this was an opportunity for new efficient and larger plants to enter into these markets.

Second, increasing environmental concern during the 1980s and 1990s created high entry barriers to the construction of new plants and it is a well known fact that the construction of new plants slowed

[12] Most of these acquisitions correspond to acquisitions of single-plant firms or to partial acquisitions of multi-plant firms. For example, a typical acquisition to a multi-plant firm in a census year would be a firm that closes part of its plants, sells part of its plants to one or more firms and keeps the remainder of the plants functioning under its control for at least one or more census years.

significantly during those years, particularly after the CAA 1990 amendments.

Third, these greater entry barriers to the construction of new plants together with the lack of competitiveness of the U.S. cement industry were significant incentives to foreign firms (more efficient and modern than the U.S. cement plant owners) to launch massive acquisitions of U.S. plants during the 1980s and 1990s[13].

In summary, these patterns of expansion by building new plants or by buying local incumbents is correlated with the exit of incumbents (which increases the rents in the markets), the entry barriers to greenfield investment and to the relative efficiency of potential entrants with respect to local incumbents.

3.3 Importance of comparative advantage in expansion by acquisition

The relationship between relative efficiency of potential buyers and sellers and the acquisition of assets is found in the merger literature in Maksimovic and Phillips (2001)[14]. Using the accounting procedure used by Syverson (2004) and Hortacsu and Syverson (2007) to calculate TFP values, I found similar qualitative results using the CM database (see appendix) comparing the TFP of the acquired plant during the census year with the previous census year. For example, I find that the relative TFP of firms (relative to the average TFP level in U.S. for that year) that are acquired increases between 1.4% and 2.2% with respect to the relative TFP level of the previous census year. Also, I find a positive relationship equal to 0.33 between the increase of TFP of a plant after an acquisition and the difference of TFP between the buyer firm and the acquired plant during the census year before the acquisition. This increase in the productivity of plants when they change ownership suggests that the new owners of the plant have the ability to add more value to the acquired assets due to better managerial practices, better production techniques, and better technology, etc. The idea that the new owners of the plant pass their superior skills to the acquired plant, as it is reflected in the higher TFP after acquisition, is shown in my model of entry that I use to estimate this industry (see section below).

Finally, in the context of the well known economic question in regard to the reasons for mergers (usually divided in two categories: by efficiency reasons or by market power reasons), these results suggest that

[13] Compared to the U.S, firms, many of these foreign firms had more efficient technology, more integrated divisions and had run global operations for years. Their technological, financial and managerial advantages were an opportunity to acquire the relatively more inefficient U.S. cement firms. See Mabry (1998) for an excellent analysis of the U.S. cement industry in the last century.

[14] The authors use the census' Longitudinal Research Database and using all industries and years find increases of productivity (from year -1 to year +2 around the acquisition)between 2% and 14% depending on the case (multidivision firm, single segment firm, partial firm acquisitions, etc.)

mergers are driven by efficiency reasons and not by market power reasons. Moreover, I rarely observe mergers within the same market between different firms: Most of the mergers in this market are completed by firms that try to expand their presence in other geographical markets, and not to increase their market share within a market[15].

4 Data

My primary source of information is the United States Census of Manufactures (CM). This is a well known database that contains a wealth of information on every plant's production activities in the manufacturing sector for the years 1963, 1967, 1972, 1977, 1982, 1987, 1992, 1997 and 2002. The database includes firm ownership information, revenues by type of product, quantity of output produced, variable costs by input (materials, energy, labor), quantity of inputs used, capital expenditures, book value of assets, etc. Since I study the cement industry, I only use plants with primary SIC code equal to 3241[16].

Since I study greenfield entry and entry by acquisition, I need to obtain very accurate measures of construction of new plants, closings and changes of ownership of existing plants as well as characteristics of the owners of these plants. Fortunately, the rich database of the U.S. Census of Manufactures provides this information. To study greenfield entry and closings of plants, I use the Permanent Plant Number (PPN) from the CM database, which is a variable created by the census specifically designed to make longitudinal linkages of plants and accurately determine exits and entries of new plants in the market. Contrary to other variables, like the CFN (Census File Number) which is a plant identifier for the Census that may change from year to year, the PPN is supposed to remain constant during the entire life of the plant. Using this variable, I determine closings and openings of new plants using the following definitions:

- A new plant is built in year T if it has a PPN that did not exist in the CM of year T-1
- A plant with a PPN in year T-1 is closed in year T if the PPN does not exist anymore in the CM of year T

Concerning the measures of changes of ownership, I use the variable FIRMID that identifies common ownership of plants in my database. Using this variable, I determine changes of ownership of plants using

[15] Antitrust regulations could play an important role in this fact. FTC (1966) is an excellent reference to assist in understanding the behavior of the Federal Trade Commission during the early stages of this industry.

[16] These cement plants also basically produce cement: A very high percentage of the products produced correspond to cement.

the following definition: A plant changes ownership in year T if it has a different FIRMID in year T-1.

Also, I use the observed revenues, quantities and the observed expenditures in materials, energy and labor to build measures of prices and variable marginal costs. I also use the book value of assets deflated by capital deflators to obtain a measure of capital used by the plants.

Finally, I have used other external sources to add demographic and economic data about the markets. I use demographic data from the U.S.Census and for construction activity I use data at the state level on earnings (wages and proprietors' income, deflated using GDP deflators) for the construction sector from the Regional Economic Information System of the Bureau of Economic Analysis (BEA). The reason I used income information instead of labor data is because there is no public data on employment by sector at the state level since 1963. However, I compared the income data with the labor data for late years and they have a very high correlation.

5 A Model of Entry by Acquisition or Greenfield Investment

5.1 Introduction

Based on the characteristics of the U..S. cement industry presented in previous sections, I present a static model of entry by acquisition or greenfield entry for this industry. A simple explanation of the mechanics of the equilibrium of this model would be the following: Entry barriers (sunk entry costs of building new facilities) directly affect the profitability of greenfield entry, and the comparative advantage of potential entrants with respect to incumbents (measured by TFP or size) affects the profitability of entrants by acquisition. Therefore, for some constant value of greenfield entry costs, more productive potential entrants will be more likely to enter by acquisition; and for a fixed comparative advantage of potential entrants, a lower greenfield entry cost will increase the probability of greenfield entry. Also, the size of the market will affect the number of plants that can make positive profits in the market, therefore the number of greenfield entrants.

The idea previously noted about how the buyer firm increases the productivity of the acquired assets by adding better technologies or better managerial skills is shown in my model in a simple way: When a potential entrant buys an incumbent, the acquired plant now has different firm-level characteristics because the plant belongs to a different mother firm. Therefore, I assume that in the acquisition, the firm "passes" its exogenous characteristics (TFP and size) to the acquired plant.

5.2 Assumptions of the model

I assume there are N markets. In every market n, there is an static entry game of perfect information with the following characteristics:

- Types of firms: There are two types of firms in every market: Firms can be potential entrants that want to enter in a market, or they can be incumbents that are already established in the market.
  - Entrants: There are e potential entrants in every market. Let denote the set of entrants $E = \{1, 2, ..., e\}$
  - Incumbents: There are ι incumbents in every market. Let denote the set of incumbents $I = \{1, 2, ..., \iota\}$.
- Actions of entrants: Entrants can choose between not entering in the market, entering by acquisition (matching to some incumbent plant according to certain assignment rule μ_a) or entering by greenfield investment (by building a new plant). I denote by $a_j \in \{0, g, m\}$ the action of every entrant j and $a = \{a_1, a_2, ..., a_e\}$ the vector of actions of all entrants. Let denote $E_G^a = \{j \in E | a_j = g\}$ the set of greenfield entrants, $E_M^a = \{j \in E | a_j = m\}$ and $E_D^a = \{j \in E | a_j = 0\}$ the set of entrants that do not enter in any market. Therefore, $E = E_G^a \cup E_M^a \cup E_D^a$.

This entry game has four stages:

1. First stage: The E entrants choose some actions a (therefore, G^a firms decide to enter by greenfield entry, M^a firms decide to enter by acquisition and D^a firms don't enter in the market (where $G^a = \#E_G^a$, $M^a = \#E_M^a$ and $D^a = \#E_D^a$).
2. Second stage: The set of firms E_G^a that decide to enter by greenfield entry choose an optimum level of capital.
3. Third stage: A simple sequential acquisition game assigns each of the firms in E_M^a to one of the incumbents in I. It could be the case that some firms in E_M^a are not assigned to any incumbent. In that case, the unassigned entrants pay an arbitrarily small merger cost c_M and stay out of the market.

4. Fourth stage: All active plants in the market compete in quantities (Cournot competition). Active plants in the market are incumbents (some of them may have been acquired) and greenfield entrants. Therefore, the number of active plants is equal to $G^a + \iota \equiv A^a$

5.3 Profit expression for the firms

5.3.1 Introduction

When entrants enter in a market, they choose to build a new plant with some level of capacity (greenfield entrants) or they choose to buy an incumbent with some existing level of capacity (entry by acquisition). The model is static so I assume that entrants choose some initial level of capacity to start operations and they stay with that level of capacity for the entire life of the plant. This is most likely a good approximation of the cement industry because in the cement industry it is rare to significantly change the capacity level of the kiln due to high adjustment costs. Given this fixed level of capital, the firms generate variable profits that are equal to revenues minus operating costs (which are equal to cost of labor, energy and materials). To denote the variable nature of this profit (for a given fixed level of capital) I use the term Cash Flow which is often used in the finance and accounting literature:

$$CashFlow = Revenues - OperatingCosts$$

where

$$OperatingCosts = MaterialCosts + LaborCost + EnergyCost$$

Firms also have to consider the cost of buying a firm or building the initial capital level. Therefore, I obtain the total long-run profits of entrants as the total cash flows minus the cost of buying the capital which is the cost building the new plant or the cost of acquiring an existing incumbent:

$$\text{Total Profit Greenfield Entry}: \ \Pi_j = CashFlow_j - CapitalCost_j$$

$$\text{Total Profit Entry by Acquisition}: \Pi_j = CashFlow_j - AcquisitionCost_j$$

Therefore, in my entry model cash flows represent some measure of total variable profits obtained during the total life span of the plant.

Also, note that in my model capital is completely variable for the greenfield entrant, but not for the entrants by acquisition:

- Greenfield entrants: They build a new plant so they can select the optimum level of capital that maximizes the total profit which is equal to the cash flows minus the cost of capital. The level of optimum capital is obtained using an investment rule function that I estimate (this investment rule function is closely related to the the investment policy function of Ryan (2009)).
- Entrants by acquisition: I assume that when a firm buys a plant, it cannot adjust the level of capital. Therefore, the level of capital of the plant that was bought equals the level of capital it had before the acquisition. This is a reasonable assumption as in the cement industry capital is lumpy[17]. When a firm buys a cement plant, it may change some aspects of the plant, but the special characteristics of the cement industry suggest that the changes will likely be small.

5.3.2 Primitives of the model

Production technology I assume that operating costs of production of every plant depend linearly on the quantity produced

$$C_O(Q; X^{MC}, Y, Z, \varepsilon^{MC}) = MC(X^{MC}, Y, Z, \varepsilon^{MC}) \cdot Q$$

where MC is the constant marginal cost of production that depends on market-level variables (vector X), plant-level variables (vector Y), firm-level variables (vector Z) and a plant-specific unobserved (for the econometrician) error term ε^{MC} with distribution $N(0, \sigma^2_{MC})$. Market-level variables are variables that are constant for all plants in the same market (such as input prices). Plant-level variables are variables that are specific to every plant (such as capital). Finally, firm-level variables are variables that are specific to the firm that owns the plant (like firm-level TFP or firm size). These variables are particularly relevant when there is an acquisition: When a plant is acquired by an entrant, the firm-level characteristics of the acquired plant change to the firm-level characteristics of the entrant, whereas the plant-level and market-level characteristics do not change.

[17] The basic production element in a cement plant is the kiln, which is a large-scale piece of industrial equipment that needs years of planning to be installed.

For example, I assume the following variables in my model

$$X^{MC} = [YEAR, SALARY, FUEL, ELECT]$$
$$Y = [CAP]$$
$$Z = [FIRMSIZE, TFP]$$

I assume a multiplicative expression for the marginal cost:

$$MC(X^{MC}, Y, Z, \varepsilon^{MC}) = e^{\varepsilon_j^{MC}} \cdot e^{\beta_0} \cdot e^{\beta_1 YEAR} \cdot FIRMSIZE_j^{\beta_2} \cdot TFP_j^{\beta_3} \cdot CAP_j^{\beta_4} \cdot SALARY^{\beta_5} \cdot FUEL^{\beta_6} \cdot ELECT^{\beta_7}$$

Demand function To model the spatial differentiation effects of plants in this industry, I consider a differentiated demand function and I assume a functional form where the price of every plant depends linearly on market and plant characteristics and on the quantities produced in the market[18]:

$$p(Q_j, Q_{-j}; X^D, \varepsilon_j^P) = A(X^D, \varepsilon_j^P) - \alpha_1 \cdot Q_j - \alpha_2 \cdot \sum_{i \neq j} Q_i$$

where $A(X^D, \varepsilon_j^P)$ is the plant-level intercept, α_1 is the effect of the plant production in the plant price level, and α_2 is the effect of the competitors' production on the price of the plant.

The intercept depends on a vector of market-level variables (X^D) and an unobserved plant-specific error term (ε_j^P). The demographics variables I use in my model are

$$X^D = [CONSTRUCTION, YEAR, MARKET]$$

where $CONSTRUCTION$ represents construction activity in the market and $YEAR$ and $MARKET$ are fixed effects.

I assume that the intercept has a linear form equal to

$$A(X^D, \varepsilon_j^P) = \alpha_0 + \alpha_{const} \cdot CONSTRUCTION + \alpha_{year} \cdot YEAR + \varepsilon_j^P$$

[18] The main reason I choose a linear demand is because it gives a closed form solution for a Cournot game with heterogeneous firms.

where ε_j^P is the plant-specific unobserved (for the econometrician) error term with distribution $N(0, \sigma_P^2)$.

Using these functional forms for supply and demand, I obtain cash flows of every plant are obtained by subtracting variable costs from revenues

$$CashFlow(Q_j, Q_{-j}; X, Y_j, Z_j, \varepsilon_j^P, \varepsilon_j^{MC}) = p(Q_j, Q_{-j}; X^D, \varepsilon_j^P) \cdot Q_j - C_O(Q_j; X^{MC}, Y_j, Z_j, \varepsilon_j^{MC})$$

where $X = [X^D \; X^{MC}]$.

Investment cost The greenfield entrants have to pay a cost of building new capital (capital cost, C_K). This cost consists of a fixed part (λ_0) that represents a sunk entry cost, and a variable part (λ_k) that depends on the amount of capital:

$$C_K(CAP_j; \lambda) = \lambda_0 + \lambda_k \cdot CAP_j$$

where CAP_j is the capital of the plant and λ are parameters to be estimated.

6 Stages of the game

6.1 Fourth stage: Competition in the market

In the last stage, all the active plants in every market compete. The active plants are the incumbents (some of them may have been acquired by some of the entrants) and the new greenfield entrants.

Every firm chooses the optimum level of production in a Cournot game and a vector of Nash equilibrium quantities for all plants in the market $(Q_1, ..., Q_A)$ can be obtained by solving this simple Cournot game. The equilibrium production in the economy $Q^* = [Q_1^*, ..., Q_A^*]$ can be solved with the standard Nash-Cournot conditions that maximize the cash-flows of every plant given the quantities produced by the other plants in the market:

$$\max_{Q_j} CashFlow(Q_j, Q_{-j}^*; X, Y_j, Z_j, \varepsilon_j^P, \varepsilon_j^{MC}) \;\; \nabla j$$

Due to the linearity of the demand function, this game has a unique closed-form interior solution (see appendix) denoted by Q^*. This solution depends on the plant-level and firm-level characteristics of all plants competing in the market. Let denote Y, Z, ε^P and ε^{MC} the vectors of all plant-level and firm-level observed and unobserved (for the econometrician) characteristics of all plants competing in the market. We can define the solution of this Cournot game as

$$Q^*(X, Y, Z, \varepsilon^P, \varepsilon^{MC})$$

Therefore, the equilibrium cash flows for every plant j can be written as $CashFlow^*(X, Y, Z, \varepsilon^P, \varepsilon^{MC})$ defined as

$$CashFlow_j^*(X, Y, Z, \varepsilon^P, \varepsilon^{MC}) \equiv CashFlow(Q_j^*, Q_{-j}^*; X, Y, Z, \varepsilon^P, \varepsilon^{MC})$$

This expression has a closed form solution that is shown in the appendix.

6.2 Third stage: Sequential acquisition game

6.2.1 Approaches in the literature to model mergers

In this stage, given a set of actions chosen in the first stage a, there are G^a firms that enter by greenfield investment and M^a firms that choose to acquire a firm. I model a sequential acquisition game where the M^a potential buyers bid for the I incumbents. There are different appraches to modeling mergers in industrial organization. For the case of horizontal mergers, there is a well known extensive literature to model mergers, either cooperatively (like cooperative bargaining games of Hart and Kurz (1983)) or non-cooperatively (Kamien and Zang (1990) and Salant et al. (1983) among others). A common problem in this literature is the existence of a vast multiplicity of equilibria. In this paper, I consider non-horizontal mergers because I am interested in modeling expansion of outsiders within alternative geographical markets and I consider the acquisition of only one incumbent by every outsider.

To model non-horizontal, market-extension acquisitions by outsiders (which is the case I am studying), the theoretical literature is less extensive, perhaps because some of the problems present in horizontal mergers are not present when outsiders buy a single firm in a market. A possible way of modeling mergers is using a two-sided matching approach where one side of the market are the buyers (potential entrants) and the other side of the market are the sellers (the incumbent plants). Roth and Sotomayor (1990) is the standard reference to study the theory of matching games. Some recent applications of this framework to mergers are Akkus and Hortacsu (2007), Fox (2008) or Park (2008). A matching game with the possibility of transferring utility between players using money would be an appropriate way of modeling mergers (Shapley and Shubik (1971)).The difficulty of applying this to the present framework is that the matching literature considers a payoff between any two possible partners that is independent of the identities of the rest of the matches of the market. However, in simple oligopoly games where plants compete in the market, the equilibrium profit function depends on all characteristics of all plants competing in the market[19]. Therefore, this is a matching game with externalities that has been studied by Sasaki and Toda (1996) which has a number of technical difficulties like the multiplicity of the possible assignments in the transferable utility matching game[20].

Due to the fact to the difficulties arising from the existence of multiplicity of equilibria in matching games with externalities and the fact that this is still an open research field in the matching literature, I have adopted a simple non-cooperative sequential acquisition game to model mergers.

6.2.2 Sequential acquisition game model

Every potential entrant that chooses to enter by acquisition has a number of characteristics that are added to the incumbents whenever there is an acquisition. When a plant is bought by a firm, the plant belongs now to a new mother company that has a number of different characteristics different from the former mother company. In the cost function, the firm-specific observed and unobserved characteristics of an incumbent plant i, $Z_i = [FIRMSIZE_i, TFP_i]$ and ε_i^{MC} are changed by the characteristics of the buyer j, Z_j and ε_j^{MC} if the acquisition takes place. The total cost effect of the outsider $e^{\varepsilon_j^{MC}} \cdot FIRMSIZE_j^{\beta_2} \cdot TFP_j^{\beta_3}$ interacts with the plant characteristics of the acquired incumbent (CAP, capital) which is plant specific and the rest of the market specific variables (salaries, fuel and electricity prices). Similarly, in the demand function the plant-specific shifter of the incumbent i, ε_i^P, is changed by the characteristic of the buyer j, ε_j^P if the acquisition takes place.

The game proceeds as follows: Every entrant j chooses an incumbent plant i to buy and makes a bid (denoted by $b_{j,i}$). To simplify the computation of this acquisition game, I assume that only the decision of what incumbent to buy is part of the strategy set of every entrant. I also assume tthat bids are "fixed" and equal to the reservation value of the incumbent plant (this reservation value is what the incumbent would

[19] For example, a simple Cournot-Nash game with constant marginal costs and heterogenous firms gives a profit function for every plant that depends on the own-marginal cost and the average marginal cost of all plants competing in the market.

[20] For example, if there is a strong negative externality of every match on the others, we may have many multiple stable payoffs that correspond to assignments where one couple match and the rest of the agents in the market remain unmatched.

make in the market if it would not be acquired by the entrant)[21]. Also, I model this perfect information acquisition game sequentially: There is a predefined order of bidding for the entrants, and every entrant can only make one bid.

Sequentiality helps to eliminate potential multiple equilibria and facilitates the calculation of bids. In order to determine who bids first, I consider that the biggest firms (the firms with highest value of the variable $FIRMSIZE$) bid first. This represents some first-mover advantages of the biggest firms, which are more likely to be have better managerial resources to participate more aggressively in the market for acquisition.

Definition 1 *An equilibrium of the acquisition game is a set of bids of every entrant j for an incumbent plant i, $b^*_{j,i}$, where no entrant j wants to deviate by choosing a different incumbent.*

I obtain the equilibrium of this simple game by solving the subgame perfect equilibrium using the payoffs obtained from substracting the bids (equal to the reservation value of every incumbent) to the cash flows from buying the plant. It is easy to see that this game has a solution and that this solution is unique.

The following result is also important for my estimation:

Proposition 1 *In the entry game where firms can enter by acquisition or greenfield investment, I find that*

1. *There can not be equilibria where more entrants than incumbents choose to enter by acquisition in the first period.*
2. *There can not be equilibria where at least one entrant by acquisition is not assigned to any incumbent*
3. *In equilibrium, all solutions of the Cournot game played in the last stage of the game must be interior*

Proof. *First, if more entrants than incumbents available in the market choose to enter by acquisition in the market, then at least one of the entrants does not buy an incumbent. Since all firms pay an arbitrarily small merger cost c_M, the firm that does not buy an incumbent plant can profitably deviate by choosing not to enter in the market and make 0 profits instead of $-c_M$.*

[21] This acquisition game is simple. However, solving a more realistic game where entrants can choose continuous bids and the identity of the incumbent to bid for would significantly slow the computation speed of my estimation procedure.

Second, using a similar argument, there cannot be equilibria where one of the entrants by acquisition does not buy any incumbent (because for instance, it is not efficient enough to buy it). In that case, the entrant is better off not entering into the market.

Finally, if there is a solution that is not interior, it means that one of the entrants has a marginal cost too high to make a profit in the market, so it produces zero. But in that case it can profitably deviate by not entering into the market (because it can save either the merger cost c_M or the sunk entry cost from entering greenfield). ■

If in the equilibrium I find that one or more entrants do not buy any incumbent, then this can not be an equilibrium in the entire game (see previous proposition).

To solve the entire game, the solution of the acquisition game has to be done for every possible vector of strategies in the entry game: Given a number of greenfield entrants and firms that enter by acquisition in the market represented by the vector of strategies a, the outcome of the game is represented by an equilibrium assignment function $\mu_a^*(j; X, Y, Z)$ and a set of equilibrium bids from the successful bidders denoted by $b^*(a, \mu_a)$. Also, I denote by $Z^*(\mu_a^*)$ the vector of firm-level characteristics present in the market after the acquisition game (the game reallocates firm-level characteristics of some entrants by acquisition to some incumbents).

The assignment function represents the plant bought by buyer j. For example $\mu_a^*(j; X, Y, Z) = i$ means that buyer j acquires the plant of incumbent i. Therefore $\mu_a^*(j; X, Y, Z)$ is a function that maps every buyer with with an elements in the set of all possible incumbents.

6.3 Second stage: Investment by greenfield entrants

I use a similar approach to Ryan (2009): I assume that greenfield entrants choose the optimum initial level of capital CAP^* according to some investment function that depends on the firm-level characteristics of the greenfield entrant and on the number of plants in the market (given by the number of new greenfield entrants plus the number of incumbents I). Let denote this investment rule as

$$\begin{aligned} CAP_j^* &= \kappa(a, Z_j, \varepsilon_j^K; \gamma) \\ &= \gamma_0 + \gamma_1 \cdot \left[I + \sum_{i=1}^{e} 1[a_i = g] \right] + \gamma_2 \cdot Z_j + \varepsilon_j^K \end{aligned}$$

where CAP_j^* is capital expressed in logs, Z are firm-level variables, ε_j^K is an unobserved (for the econometrician) error term with distribution $N(0, \sigma_K^2)$ and γ are parameters to be estimated.

6.4 First stage: Entry in the market

Finally, the entry game is solved in the first stage taken into account the optimal solutions of the assignment and competition stages.

Let X denote the vector of market characteristics. Let Y denote the vector of plant-level characteristics (capital) in the market. Since we are in the first stage, this corresponds to the capital already present in the market (from existing incumbents). Finally, let Z denote the vector of firm level characteristics of entrants and incumbents.

I define the vectors $Y^*(a, Z, \varepsilon^K; \gamma)$ and $Z^*(\mu_a^*)$ which are obtained by solving the investment and acquisition stages.

First, $Y^*(a, Z, \varepsilon^K; \gamma)$ is the vector of capital levels of new greenfield entrants in the market. Therefore $Y^*(a, Z, \varepsilon^K; \gamma)$ is equal to

$$Y^*(a, Z, \varepsilon^K; \gamma) \equiv [\kappa(a, Z_{i_1}, \varepsilon_{i_1}^K; \gamma) ... \kappa(a, Z_{i_G}, \varepsilon_{i_G}^K; \gamma)]$$

where

$$i_1, ..., i_G \in E_G^a$$

Second, $Z^*(\mu_a)$ is the vector of firm characteristics present in the market after the acquisition game (this game reallocates firm-level characteristics of some entrants that enter by acquisition to some incumbents).

Using those vectors, I can define the long-run profit function of entrant firm j when it enters by greenfield investment. This long-run total profit is equal to the cash flow minus the cost of capital. I denote this profit by $\Pi_j(a_j = g, a_{-j}; \mu_a, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K)$ where μ_a is the assignment function of the acquisition game given the strategies of all firms and $\kappa(a, Z_j)$ is the investment rule:

$$\Pi_j(a_j = g, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K) =$$
$$CashFlow_j^*(X, Y^*(a, Z, \varepsilon^K; \gamma), Z^*(\mu_a^*), \varepsilon^P, \varepsilon^{MC}) - C_K(\kappa(a, Z_j, \varepsilon_j^K; \gamma); \lambda)$$

Note that the levels of capital and the characteristics of firms in the market will depend on the actions of players because capital and characteristics of firms depend on the investment and assignment stages.

Similarly, I can define the long-run profit function of entrant firm j when it enters by acquisition:

$$\Pi_j(a_j = m, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K) =$$
$$CashFlow_j^*(X, Y^*(a, Z, \varepsilon^K; \gamma), Z^*(\mu_a^*), \varepsilon^P, \varepsilon^{MC}) - b^*([m, a_{-j}], \mu_a)$$

Given these profit expressions, I define the necessary and sufficient conditions for the equilibrium in every market are the following:

- The entrant j will prefer acquisition of incumbent i to greenfield entry or to not entry if and only if

$$\Pi_j(a_j = m, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K) \geq \Pi_j(a_j = g, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K)$$
$$\Pi_j(a_j = m, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K) \geq 0$$

- Similarly, entrant j chooses greenfield entry g instead of buying incumbent i (where $\mu_a(j) = i$) if

$$\Pi_j(a_j = g, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K) \geq \Pi_j(a_j = m, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K)$$
$$\Pi_j(a_j = g, a_{-j}; \mu_a^*, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K) \geq 0$$

Using these necessary and sufficient inequalities I can solve for the equilibrium of the entry game.

7 Estimation: Simulated method of moments estimator

7.1 Overview

The estimation discrete games have been recently applied to diverse topics in empirical microeconomics like labor participation, entry, product differentiation or advertising. The existence of multiplicity of equilibria in these games is a well known problem because there is not a unique correspondence between the outcomes of the game and the primitives of the model, introducing difficulties for the identification and estimation of the game. Several solutions have been applied to deal with this problem. In this paper, I use the estimator of Bajari, Hong and Ryan (2008) for the case of perfect information static games. Their estimator requires the calculation of all equilibria of the game and, to deal with the existence of multiplicity of equilibria, an equilibrium selection mechanism is included as a part of the primitives of the model that have to be estimated.

There are few papers where the econometrician observes revenue or cost data and uses it in the estimation method. One of the first examples is Berry and Waldfogel (1999) for the radio industry. More recently, Ellickson and Misra (2008) and Nishida (2008) have used revenue data in the retail industry. The advantage of using revenue or cost data is twofold: First, by using extra data, revenue and cost parameters from the profit function can be separately identified. Second, since we use a richer data set, we can obtain more efficient estimates. Since in my CM database I observe a wealth of plant-level data on revenues, prices, quantities, costs, I use part of this information in my estimation method.

7.2 The simulated method of moments estimator

To summarize the characteristics of the model presented, the predicted (left hand side) observed variables of my model are:

- a (vector of actions of potential entrants with $a_i \in \{0, 1, 2\}$), m (assignment between entrants and incumbents), CAP (initial capital of greenfield entrants), MC (observed marginal costs of all firms in the market), P (prices of all firms in the market) and Q (observed quantities of all firms in the market).

The exogenous (right hand side) variables are:

- X (market-level variables like input prices, construction activity, etc.), Y (plant-level variables: existing capital of incumbents) and Z (firm-level variables: TFP and size of firms).

The unobserved (for the econometrician) error terms (all error terms are independently distributed) are:

- ε^{MC} (marginal cost), ε^{P}(demand) and ε^{K} (new capital for greenfield entrants).

  (Remark: Note that in the error terms we have match specific terms when firm j buys plant i (given by ε_{ij}^{MC} and ε_{ij}^{P})

And finally, the parameters to be estimated are:

- α (demand parameters), β (marginal cost parameters), γ (new investment parameters), λ (cost of capital parameters) and δ (equilibrium selection rule parameters).

To estimate the model I use a simulated method of moments (SMM) estimator. Given a weighting matrix W and a vector of size $r \times 1$ of sample moments $\widehat{m}(X, Y, Z; \theta)$ that depend on the exogenous variables and the vector of parameters to be estimated $\theta = (\alpha, \beta, \gamma, \lambda, \delta)$, the SMM estimator $\widehat{\theta}$ is based on the minimization of the following expression

$$\min_{\theta} \widehat{m}'(X, Y, Z; \theta) \cdot W \cdot \widehat{m}(X, Y, Z; \theta)$$

I use two types of moments. As in Bajari, Hong and Ryan (2008), I use moments corresponding to the observed equilibrium decisions: At the true values of the parameters, it has to be that the population moment corresponding to the equilibrium outcome k is equal to[22]

[22] More formally:

$$\begin{aligned}
&E\left[(1(a_i = k) - \Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)) \cdot \omega(X, Y, Z)|X, Y, Z\right] \\
&= E\left[(1(a_i = k) - \Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta))\,|X, Y, Z\right] \cdot \omega(X, Y, Z) \\
&= (E[1(a_i = k)||X, Y, Z] - \Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)) \cdot \omega(X, Y, Z) \\
&= 0 \cdot \omega(X, Y, Z) = 0
\end{aligned}$$

and by the law of iterated expectations

$$\begin{aligned}
&E\left[(1(a_i = k) - \Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)) \cdot \omega(X, Y, Z)\right] \\
&= E_{X,Y,Z}\left[E\left[(1(a_i = k) - \Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)) \cdot \omega(X, Y, Z)|X, Y, Z\right]\right] \\
&= E_{X,Y,Z}\left[0\right] = 0
\end{aligned}$$

$$m_k = E\left[(1(a_i = k) - \Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)) \cdot \omega(X, Y, Z)\right] = 0$$

where $\omega(X, Y, Z)$ is an interaction function of the exogenous variables.

However, since I also observe other variables like prices, quantities, investment or marginal costs, I can construct moments corresponding to some of these observed outcomes:

$$m_O = E\left[(O_i - E[O_i|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta]) \cdot \omega(X, Y, Z)\right] = 0$$

where O_i is some observed outcome in the market.

7.3 Moments for observed strategies

These moments require the calculation of $\Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)$. To calculate this probability we need to solve all the equilibria of the entire game using the equilibrium conditions from the previous section and the analitical profit expressions from the Cournot competition (shown in the appendix).

More formally, let denote by $\epsilon(X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K; \alpha, \beta, \gamma, \lambda)$ the set of all possible equilibria obtained given the observed variables and the unobserved error term. Let denote $\lambda(eq; \epsilon(.), \delta)$ the equilibrium selection rule (I assume it has some parametric form) that depends on the equilibrium eq, the set of equilibria $\epsilon(.)$ and the equilibrium selection parameter δ. This probability can be expressed as

$$\begin{aligned}
&\Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta) \\
&= \int \left\{ \sum_{eq \in \epsilon(.)} 1[k = eq] \cdot \lambda(eq; \epsilon(X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K; \alpha, \beta, \gamma, \lambda), \delta) \right\} dF(\varepsilon^P, \varepsilon^{MC}, \varepsilon^K)
\end{aligned}$$

Note that here we are including all possible error terms, including the match specific error terms (the error terms when firm j buys plant i are given by ε_{ij}^{MC} and ε_{ij}^P, etc.).

$\lambda(eq; \epsilon(.), \delta)$ is the parametric form of the equilibrium selection function that depends on the equilibrium selection parameters $\delta:$ it represents the probability that some equilibrium eq is played among the set of all possible equilibria $\epsilon(.)$. Therefore, by definition

$$\sum_{eq\in\epsilon(.)} \lambda(eq;\epsilon(X,Y,Z,\varepsilon^P,\varepsilon^{MC},\varepsilon^K;\alpha,\beta,\gamma,\lambda),\delta)=1$$

Like in Bajari, Hong and Ryan (2008), I can assume some parametric model of λ (logit expression), equal to

$$\lambda(eq;\epsilon(.),\delta)=\frac{\exp(\delta\cdot y(\Pi,eq))}{\sum\limits_{eq'\in\epsilon(.)}\exp(\delta\cdot y(\Pi,eq'))}$$

where δ is a vector of parameters that determine the equilibrium selection to be estimated and $y(\Pi,eq)$ a vector of dummy variables that satisfy some criteria. In this case, I just consider a simple equilibrium rule where the equilibrium selected is the one with highest total profits. This is a straightforward characteristic of the selected equilibrium in an entry game in pure strategies that has been already suggested by Berry (1992) and Ciliberto and Tamer (2008). In this case, the vector $y(\Pi,eq)$ is:

$$y(\Pi,eq)=\begin{cases}1 & \text{if } eq \text{ is the equilibrium that maximize total profits}\\ 0 & \text{otherwise}\end{cases}$$

This probability do not have an analytical expression and has to be estimated by simulation. Let denote this simulated probability $\widehat{\Pr}(a|X,Y,Z;\alpha,\beta,\gamma,\lambda,\delta)$. Then, the simulated probability can be written as

$$\begin{aligned}&\widehat{\Pr}(a|X,Y,Z;\alpha,\beta,\gamma,\lambda,\delta)\\ &=\frac{1}{S}\sum_{s=1}^{S}\left\{\sum_{eq\in\epsilon(.)}\lambda(eq;\epsilon(X,Y,Z,\varepsilon_s^P,\varepsilon_s^{MC},\varepsilon_s^K;\alpha,\beta,\gamma,\lambda),\delta)\cdot 1[a=eq]\right\}\end{aligned}$$

where $\{\varepsilon_s^P,\varepsilon_s^{MC},\varepsilon_s^K\}_{s=1,\ldots,S}$ are random draws of the unobserved error terms.

The main computational difficulty of my estimation procedure is the calculation of $\widehat{\Pr}(k|.)$ because the set of all pure strategy must be computed[23]. Moreover, the calculation of all equilibria must be done at every stage of the optimization routine, which renders the estimation procedure extremely slow[24]. In my

[23] Bajari, Hong and Ryan (2008) calculate all equilibria of the game, including mixed equilibria. The calculation of mixed equilibria is computationally much more demanding than the calculation of pure strategies in a discrete game because it involves the calculation of solutions to system of polynomials (see Judd (1998) for a good introduction to the topic).

[24] The authors try to reduce the computational burden of their estimation by using recent importance sampling techniques

case, I reduce the computational burden by not considering mixed equilibria and using a not too high number of entrants (which is a good representation of the industry.

Given this expression, the sample expression of the moment m_k is

$$\widehat{m}_k = \frac{1}{N}\sum_{i=1}^{N}\left[\Big(1(a_i = k) - \widehat{\Pr}(k|X_i, Y_i, Z_i; \alpha, \beta, \gamma, \lambda, \delta)\Big) \cdot \omega(X_i, Y_i, Z_i)\right]$$

7.4 Moments for observed outcomes

Let denote $O(eq, X, Y, Z; \alpha, \beta, \gamma, \lambda, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K)$ the outcome variable generated for one (of the potentially multiple) equilibrium eq. Then, the expected value of observing some outcome variable can be constructed in a similar way to $\Pr(k|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)$:

$$\begin{aligned} &E[O/X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta] \\ &= \int \left\{ \sum_{eq\in\epsilon(.)} O(eq, X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K; \alpha, \beta, \gamma, \lambda) \cdot \lambda(eq; \epsilon(X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K; \alpha, \beta, \gamma, \lambda), \delta) \right\} dF(\varepsilon^P, \varepsilon^{MC}, \varepsilon^K) \end{aligned}$$

Like in the case of the simulated probability of the previous section, this expected value do not have an analytical expression. Let denote the simulated expression $\widehat{E}(O|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta)$. Then, the simulated expected value of the outcome variable can be written as:

$$\begin{aligned} &\widehat{E}(O|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta) \\ &= \frac{1}{S}\sum_{s=1}^{S} \left\{ \sum_{eq\in\epsilon(.)} O(eq, X, Y, Z, \varepsilon_s^P, \varepsilon_s^{MC}, \varepsilon_s^K; \alpha, \beta, \gamma, \lambda) \cdot \lambda(eq; \epsilon(X, Y, Z, \varepsilon_s^P, \varepsilon_s^{MC}, \varepsilon_s^K; \alpha, \beta, \gamma, \lambda), \delta) \right\} \end{aligned}$$

where $\{\varepsilon_s^P, \varepsilon_s^{MC}, \varepsilon_s^K\}_{s=1,\ldots,S}$ are random draws of the unobserved error terms.

Given this expression, the sample expression of the moment m_O is

$$\widehat{m}_O = \frac{1}{N}\sum_{i=1}^{N}\left[\Big(O_i - \widehat{E}(O|X_i, Y_i, Z_i; \alpha, \beta, \gamma, \lambda, \delta)\Big) \cdot \omega(X_i, Y_i, Z_i)\right]$$

used in industrial organization (see Ackerberg (2009)) that allow them to calculate the set of all equilibria only once. Unfortunately, the importance sampling approach is not feasible in this complex game I am considering because the importance density does not have an easy analytical expression in this multistage complex game.

To build my moments, I use as O_i the observed average price in the market, the observed total quantity produced, the observed new total capital invested and the observed average marginal cost.

7.5 Distribution of the SMM estimator

The vector of moments used in the estimation is formed by all the moments corresponding to the observed outcomes and to the observed strategies (see details about all the moments I use in the appendix):

$$\widehat{m}(X,Y,Z;\theta) = \begin{bmatrix} (\widehat{m}_k(X,Y,Z;\theta))_k \\ (\widehat{m}_O(X,Y,Z;\theta))_O \end{bmatrix}$$

For this estimator I use the usual efficient optimum GMM estimator where I use the identity matrix as the weighting matrix W in a first optimization stage and then I use the inverse of the sample covariance matrix of the moments (calculated at the estimated parameters in the first stage) as the weighting matrix in a second optimization stage. Following McFadden (1989) and Pakes and Pollard (1989), given this choice of the weighting matrix and for a fixed number of simulations S, the estimator of the parameters $\widehat{\theta}$ is consistent and asymptotically normal as $N \to \infty$ and has a limit normal distribution equal to

$$\sqrt{N}(\widehat{\theta} - \theta) \to N(0, (1 + S^{-1})(G'\Lambda^{-1}G))$$

where $G = E[\nabla_\theta m(X,Y,Z;\theta)]$ and $\Lambda = E[m(X,Y,Z;\theta) \cdot m(X,Y,Z;\theta)']$.

The reported standard errors in my estimations are obtained by using the sample expressions of the the expected value of the gradient of the moments, G, and the covariance matrix of the moments, Λ. To see details about the behavior of this estimator and the computational difficulties, see section below.

7.6 Estimation without considering mergers

To show the difference with the traditional entry models where entry by acquisition is not considered, I try to obtain estimates assuming a simple standard entry game where acquisitions are not considered. Therefore, I consider a new entry game where there are only two choices, $\widetilde{a} = 0$ (no entry) and $\widetilde{a} = g$

(greenfield entry) where these choices are related with the observed "true" choices, a, as follows:

$$\widetilde{a} = 0 \text{ if and only if } a = 0 \text{ or } a = m$$

$$\widetilde{a} = g \text{ if and only if } a = g$$

This simpler entry game has only three stages instead of four: entry decision, investment and competition. There is no acquisition game because mergers are ignored.

For the estimation, I use an identical estimator to the estimator used previously (case of the entry game with mergers)[25]. The only difference is that the number of moments for the observed strategies is smaller (because this is a game with two actions instead of three). Fortunately, this estimation is much less computationally intensive than the one where mergers are considered because the modified entry game does not have an acquisition subgame and also the number of entry choices is reduced significantly (with 5 entrants we have $2^5 = 32$ choices instead of $3^5 = 243$ choices)

7.7 Remarks about the variables used in my estimation

To estimate the model I measure changes in ownership and new plant openings for the cement industry using census data. I use 9 years of the CM database: 1963, 1967, 1972, 1977, 1982, 1987, 1992, 1997 and 2002. I use a U.S. state as a geographic measure of a market[26] (this is a good approximation because as I previously noted, cement is a product usually transported for short distances). This gives a total of 450 market-year observations. The observed greenfield entries for this entire period are 134 and the observed acquisitions are more than two hundred.

To make a fair comparison of the different nominal variables (costs, cement prices, input prices, revenues, etc.) for all markets, I deflate all nominal variables using price deflators.

The fact that I am using a panel instead of a cross section in my static entry model is problematic. However, since the U.S, cement industry has been relatively stable during the last 40 years (in terms of concentration levels and number of firms), I deflate all nominal variables and I use time trends to control for technological changes, therefore these potential negative effects are decreased.

[25] To facilitate the comparison between the two estimators, I also use the same potential entrants and the same errors.

[26] It is convenient to divide some big states (California, Texas, Pennsylvania and New York). This is also a practice which is commonly used in the USGS Reports about the cement industry.

One critical aspect when estimating entry games is the number of potential entrants I use. I rarely observe more than five entrants in every market-year. In fact, in many market-years there are zero or only one entrant. Therefore, I consider that five potential entrants is an accurate number to estimate the model. These potential entrants are selected randomly among all entrants in all other markets for the same year and I also include the entrants of that market if there are entrants in that market-year.

The observed firm characteristics of potential entrants that I consider are firm size and TFP values. To generate firm size I aggregate all the plant-level revenues of all manufacturing plants that are owned by every firm. I find substantial variation in this variable, because some firms are very small firms with few plants in the cement industry, and other firms are large conglomerates with interests in many industrial sectors.

To generate TFP values, I use the accounting method from Syverson (2004), explained in the appendix, to calculate TFP at plant level. Then, I obtain the weighted average TFP level for every firm by weighting TFP levels of every plant owned by every firm with the quantities produced. Although plant-level TFP values are different from firm-level TFP values, I have found that the dispersion of plant-level TFP of plants belonging to the same firm is relatively small, which means that highly productive firms also have highly productive plants with TFP values with relatively low deviation around the mean. All possible deviations of productivity around the firm-level TFP enter in the error term of the cost function.

7.8 Computational details

7.8.1 Computational difficulties

Like other related papers in the empirical industrial organization literature, the estimation procedure is computationally intensive because for every iteration step in the optimization routine of the objective function we need to solve the equilibrium of all markets considered. In addition, my model has the additional complexity of the calculation of the equilibrium assignment function which has to be calculated for every possible vector of strategies a.

The fast computation of equilibria in my model is the most difficult computational part. Moreover, this difficulty is even higher if we consider the fact that my entry game has three possible actions to be played by every agent (enter greenfield, enter acquisition or do not enter, with a nested acquisition game), the number of pure strategy possible equilibria is significantly higher than in the normal case of enter/do not enter considered by the previous entry literature (for example with 9 potential entrants, there are $19,683 = 3^9$ possible pure strategy equilibria in my model, but only $512 = 2^9$ pure strategy equilibria in the traditional entry/no entry models, so about forty times less pure strategy equilibria). If we consider mixed equilibria, these numbers increase exponentially. For example, according to McKelvey and McLennan (1997), the maximum number of totally mixed equilibria in a game with 9 agents and two actions is $133,496$ and $1.6 \cdot 10^{12}$ for the case of three actions[27]. Given all these difficulties, I have been able to maximize the speed of estimation of my model by adopting a number of computational strategies:

First, I have constrained the calculation of equilibria to the case of pure strategies. This greatly simplifies the estimation because mixed equilibria require solving a system of polynomial equations[28].

Second, I try to take advantage of the structure of the game to eliminate all possible sets of actions that cannot be equilibria because they are strictly dominated by other actions. For example, since I am assuming that firms pay an arbitrarily small fixed merger cost c_M, there cannot be equilibria where more entrants than incumbents enter in the acquisition game. This simplifies the computation greatly because the number of possible matching outcomes increases exponentially with the number of entrants. Since the number of incumbents in my database is relatively small (on average there are less than 3 or 4 plants in every market and the maximum number rarely exceeds 8), the computational difficulty is relatively small.

Third, I use a reasonable number of potential entrants (five potential entrants in every market). The use of a low number of potential entrants is convenient but it is not an unrealistic assumption in the cement industry. As we can see from the tables in the appendix, the total number of firms in the cement industry varies between 40 and 50. Also, on average there is less than one entry in every market-year (either by acquisition or greenfield entry). This means that it is an accurate approximation to consider a low number of potential entrants in the market. This may come with a cost, because a low number of potential entrants would decrease the variation of entrant-firm characteristics and this would decrease the capacity of the model to explain the industry equilibrium.

Finally, all these solutions to increase the speed of computation would be irrelevant with non-efficient programming techniques. I use Matlab in my estimations, and this is a programming language that is particularly fast when using matrix and vector operations but it can be very slow if too many programming

[27] Although the existence of mixed equilibria is more likely to exist in my model with three actions than in other traditional entry models that consider two actions, in the trade-off between using a high number of entrants and pure strategies and a low number of entrants and both mixed and pure strategies, I chose the first option.

[28] In the simulated estimation method I use I have found that the number of markets without pure strategy equilibrium (that is, markets where there is only mixed strategy equilibria) is small (about 5% of the markets).

loops are used. Certain calculations that use matrix operations or indexing techniques can be more than one hundred times faster than using programming loop operations. Therefore, I optimize the speed of the estimation in my Matlab programs by minimizing the use of loops and maximizing the use of efficient matrix operations.

7.8.2 Behavior of the estimator

The estimator uses a very high number of moments which means that the weighting matrix has a high dimensionality. I observe that the solution from the optimization in the first stage does not change greatly in the second stage after the new weighting matrix has been calculated from the first stage.

Also, to check the behavior of the estimator, I have done preliminary Monte Carlo experiments and I have found reasonable results.

8 Estimation results

In the appendix I show my estimations for the case of the entry by acquisition model, the traditional entry game with no mergers, and also I show the results when using simple OLS estimation.

I first analyze the case of the estimations of the "true" model. In most cases, the results have low standard errors and have intuitive signs. In the case of the demand parameters, this market is likely to have significant spatial differentiation, so we find a relatively small effect of the competitors' quantity on the demand compared to the own-quantity effect. The ratio of own-firm effect to competitors effect is about 14 which is relatively high.

For the case of the investment rule, the initial investment if affected positively by the size of the firm and negatively by the number of plants in the market, which are intuitive results. However, a surprising result is that more productive firms invest less.

In the estimation of the marginal cost parameters, I find intuitive signs of the variables (positive effect of input prices on the marginal cost, negative effect of the capital and the TFP, etc.) and reasonable values for the parameters that represent weights of every factor of production. For example, I find that in this industry that intensively uses energy to produce cement, the weight of the fuel is about 30%, three times bigger than the weight of salaries. Also, I find that the decrease in costs is about 3% for every census year and that capital and TFP reduce the variable costs of production.

For the case of the entry cost, I find a sunk cost of entry in the market for new greenfield plants of 76.4 million dollars. Of course, this result has to be rescaled with the typical lifespan of a plant because we are considering a static model where entrant firms are assumed to live for only one period.

Second, I show the biases arising when we consider the "wrong" model where entry by acquisition is not considered, and when we assume a simple OLS estimation of the primitive functions for demand, marginal cost and investment. The biases when we assume OLS are very high and may show high selection bias. Also, compared with the "true model" the biases by assuming no mergers are much smaller for all parameters except for the own-quantity demand parameter (about 30% higher). The intuition for this result is the following: It is easy to check that a higher own-quantity demand parameter implies smaller profits (see Cournot profit expressions in appendix). Therefore, the estimations from the "wrong model " imply that entry is less profitable than in the "true model". The reason we obtain this result is because in the "wrong model" low greenfield entry implies low profitability. However, in the "true model", low greenfield entry does not necessarily imply low profitability (or to be more precise, not such low profitability) because some of the entrants may find it more profitable to enter by acquisition (because they are more efficient than the incumbents) rather than greenfield entry (where greenfield entry could be more profitable than not entering).

9 Counterfactual policy experiments

I use my estimates to find interesting implications of counterfactual policy experiments. We can determine the effect of policies that affect every type of entry on the industry equilibrium and find the substitution effect in the means of expansion when one of the ways of expansion becomes more expensive. There are two types of policies that I consider.

First, we have policies that affect the construction of new plants. In this industry where environmental aspects are so controversial, an environmental regulation is a good candidate for policies that increase the cost of greenfield entry.

Second, we have policies that affect entry by acquisition. This is the case of antitrust policies that make it more difficult for firms to acquire other firms.

In both cases, a relatively more expensive way of entering into a market by building a new plant makes it relatively less expensive to enter by acquiring an incumbent due to this substitution effect. This has interesting effects on the market in terms of structure of the market, concentration, variations in productivity, prices, quantities produced, welfare changes and others.

9.1 Impact of an asymmetric environmental regulation that increases the entry cost of new plants

There is an increasing concern about the environmental impact of cement plants. Aspects like CO_2 emissions, energy use or other environmental impacts have been considered in the last decades in terms of governmental regulation (see for example the recently proposed American Clean Energy and Security Act of 2009 and also the Clean Air Act of 1990 already studied by Ryan (2009) for the cement industry). An important aspect to consider in these environmental regulations is that they are asymmetric because they set more stringent regulations upon the construction of new plants with respect to existing plants. This is what is usually called "grandfather" rules versus new source regulations[29]. Recently, the Bush Administration has revised some environmental regulations making this asymmetry even stronger[30].

Also, the great environmental impact of the cement plants has created an increasing public concern in the last decades, creating other types of barriers to entry like social and political pressure by lobbies, neighbors or city officers to prevent the construction of a new cement plant in a certain area. There is well documented evidence of these difficulties (see for example Grancher (2003) and Grancher (2005)) such that greenfield entrants spend years and millions of dollars to overcome these difficulties.

Therefore, this asymmetry in the environmental regulations together with other types of social barriers introduces great difficulties to the construction of new plants. To consider the effects of these policies, I consider an arbitrary increase in the sunk entry cost of 25 million dollars (one third of the estimated entry costs) that makes greenfield entry more costly than the estimated entry cost in the industry.

[29] See for example Levinson (1999) or Nash and Revesz (2007).

[30] According to Nash and Revesz (2007), in December 2002 and October 2003, the Bush Administration adopted regulatory revisions that significantly extended the grandfathering of old plants. For example, the authors cite regulations such as "more flexibility in determining the baseline against which changes in pollution emissions levels are measured" or "a regulation that provides a safe harbor for modifications and renovations of grandfathered plants that cost less than twenty percent of the replacement cost of a grandfathered unit".

9.2 Impact of a tougher antitrust policy that affects entrants by acquisition

The effect of an antitrust policy on an industry is a question widely studied in microeconomics with very clear policy implications and usually different antitrust policies depending on the ideology of the administration in the Federal Government[31].

There has already been some policy debate in antitrust about the possible negative effects of expansion by acquisition in the U.S. cement industry (see for example FTC (1966)). If entry by acquisition is more costly for firms (because firms are more uncertain about the antitrust barriers, possible time delays, sunk expenditures in legal actions, etc.), firms may decide to enter by greenfield investment, but this may have interesting results in terms of inefficiencies of investment (overinvestment) or even negative environmental consequences.

I fornulate an experiment where I impose a fixed merger cost to every acquisition that takes place in the market. This cost shows some sunk costs derived from the process of acquisition like the obligation to divest part of the assets acquired, losses from the litigation process with antitrust authorities, the opportunity cost for the buyers due to delays in the merger process, etc. To facilitate comparison, I assume a cost identical to the environmental experiment: I consider an arbitrary merger cost of 25 million dollars imposed to every acquisition of a plant that takes place in the market.

9.3 Results from counterfactual experiments

In the appendix I show the results of the two proposed counterfactual policies. I have also simulated the industry with the estimated parameters (without changing any parameter) to compare the actual situation with the counterfactual situation.

To obtain these numbers I solve the equilibria for a high number of simulations. Since there is multiplicity of equilibria, I have averaged the different equilibria according to the equilibrium selection rule estimated and then I have averaged these values across all simulations. Also, in the equilibrium variables shown in my results, some variables (like total revenues) are aggregated across markets and other results are averaged across markets (like maximum TFP).

As expected, both policies negatively affect the average price and quantity produced in the market.

[31] Contrary to the former George W. Bush administration, the new Barack Obama administration is giving clear signs about amore stringent future antitrust policy (see Varney (2009)).

Also, both policies negatively affect the TFP value in the industry as now some efficient firms cannot acquire inefficient incumbents or build new plants due to the higher entry barriers.

Concerning the number of entrants, as we would expect we have a significant direct effect of the environmental policy on the number of new greenfield entrants and a smaller indirect effect on the number of mergers (due to the substitution effect: some firms used to enter by greenfield entry because it was more profitable than entering by acquisition, but now they find it more profitable to enter by acquisition due to the higher entry barriers to the construction of new plants). We observe that under the environmental policy the number of greenfield entrants decreases from 238.7 to 19.8, a 92% decrease, whereas the number of acquisitions increases from 312.2 to 349.8, a 11.8% increase. This increased number of acquisitions has a similar interpretation to the "new source bias" (see Levinson (1999)) referred in the literature regarding the fact that "grandfather" rules create an incentive for firms to maintain existing capital instead of investing in new capital. In the case of my entry model, firms have an incentive to buy the existing capital of incumbents rather than building new greenfield plants.

We can make a similar reasoning for the antitrust policy concerning the number of entrants: A more restrictive antitrust policy decreases mergers from 312.2 to 17.2, a 94% decrease, whereas the number of greenfield entries increases from 238.7 to 298.4, a 25% increase. It is also interesting to show the increase in investment of new plants when there are antitrust barriers that make acquisitions more difficult: This new investment increases by 28% due to the substitution effect.

An a priori surprising result is the increase of consumer surplus under an antitrust policy. The reason I obtain a higher net consumer surplus is because the higher antitrust policy increases the number of plants in the market. Since I am considering a differentiated demand, this increases the number of varieties (plants) offered in the market. The price is a slightly higher but this negative effect is compensated by the higher number of varieties.

10 Concluding remarks

This paper proposes and estimates an empirical entry model where entrants can expand into markets by building new facilities or by acquiring local incumbents. I formulate a multistage entry model where entrants sequentially decide the type of entry, the quantity of new capital to be built and the incumbent to acquire. Sunk entry costs to construction of new capital and comparative advantage of entrants with respect to local incumbents are important determinants of the mode of expansion. By using a recent estimator by Bajari, Hong and Ryan (2008), I can estimate the primitives of the model and compare these estimates to the estimates obtained by the traditional approach of the entry literature where acquisitions are ignored. Finally, I apply my model to determine the effects of different policies that increase the barriers to greenfield entry and entry by acquisition on the industry equilibrium.

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A Cournot Competition with Linear Differentiated Demand and Heterogeneous Firms

I show the interior solution to the Cournot problem with linear differentiated demand and n heterogenous firms. Every firm j has cost function equal to:

$$C_j(Q) = MC_j \cdot Q$$

and a linear expression for the demand for firm j:

$$P_j = p(Q_j, Q_{-j}) = A_j - \alpha_1 \cdot Q_j - \alpha_2 \cdot \sum_{i \neq j} Q_i$$

The profit maximization condition is:

$$\max_{Q_j} p(Q_j, Q_{-j}) \cdot Q_j - C_j(Q_j)$$

First order conditions are:

$$A_j - \alpha_2 \sum Q_j - MC_j = (2\alpha_1 - \alpha_2) Q_j \quad j = 1, ..., n$$

Aggregating all equations for every firm, we obtain

$$\sum A_j - \alpha_2 NQ - \sum MC_j = (2\alpha_1 - \alpha_2) \sum Q_j$$

From here, we can obtain the expression of total optimum quantity produced:

$$Q^* \equiv \sum Q_j = \frac{\sum A_i - \sum MC_i}{2\alpha_1 + (n-1)\alpha_2}$$

The optimum prices, quantities, margins and cash flows are

$$P_j^* =$$

$$\frac{A_j\alpha_1(2\alpha_1+\alpha_2(n-2)) + MC_j(2\alpha_1^2-\alpha_2^2(n-1)+\alpha_1\alpha_2(n-2)) + \alpha_1\alpha_2(\sum_{i\neq j} MC_i - \sum_{i\neq j} A_i)}{(2\alpha_1-\alpha_2)(2\alpha_1+\alpha_2(n-1))}$$

$$Q_j^* = \frac{(2\alpha_1+\alpha_2(n-2))\cdot(A_j-MC_j)+\alpha_2(\sum_{i\neq j} MC_i - \sum_{i\neq j} A_i)}{(2\alpha_1-\alpha_2)(2\alpha_1+\alpha_2(n-1))}$$

$$P_j^* - MC_j = \frac{\alpha_1\left((2\alpha_1+\alpha_2(n-2))\cdot(A_j-MC_j)+\alpha_2(\sum_{i\neq j} MC_i - \sum_{i\neq j} A_i)\right)}{(2\alpha_1-\alpha_2)(2\alpha_1+\alpha_2(n-1))}$$

$$CashFlow_j \equiv (P_j^*-MC_j)Q_j^* = \frac{\alpha_1\left((2\alpha_1+\alpha_2(n-2))\cdot(A_j-MC_j)+\alpha_2(\sum_{i\neq j} MC_i - \sum_{i\neq j} A_i)\right)^2}{(2\alpha_1-\alpha_2)^2(2\alpha_1+\alpha_2(n-1))^2}$$

B Calculation of plant-level productivity values

I use the accounting method of Syverson (2004) also used in Hortacsu and Syverson (2007). They measure productivity using a standard TFP index. Plant-level TFP for every plant-year, TFP_{it}, is computed as the log of the physical output minus a weighted sum of the log values of labor, capital, materials and energy inputs:

$$TFP_{it} = q_{it} - \alpha_{lt}l_{it} - \alpha_{kt}k_{it} - \alpha_{mt}m_{it} - \alpha_{et}e_{it}$$

where the weights α represent input elasticities that are industry specific. Syverson (2004) uses industry specific cost share as the measure of the input elasticities. These cost share are computed from reported industry-level labor, materials and energy expenditures from the CM database.

The plant level quantities of the final product, q_{it}, and the number of production hours are available in the CM database. The number of materials and energy used (m_{it} and e_{it}) are obtained by dividing the reported expenditures on materials and energy by their respective industry-level deflators from the NBER Productivity Database.

Finally, the most problematic step is probably the measure of capital. Syverson (2004) use reported book values of buildings and machineries and deflate it by the book-real value ratio for the corresponding three-digit industry (obtained from published Bureau of Economic Analysis data).

C Moments used in the estimation

For the case of moments for observed strategies, since there are 5 potential entrants and three actions, there are in total 3^5 possible strategies that I can use. However, since the probabilities of all strategies must sum to one, one of these probabilities will be linearly dependent on the others, so there are effectively $3^5 - 1 = 242$ strategies to be used. For the function of interaction, I use the identity function (no interaction), the construction activity in the market, and the year in the market. Therefore, there is a total of $242 \times 3 = 726$ moments for the case of observed strategies.

For the case of moments for observed outcomes, I use the average price, the total quantity produced, the observed new total capital invested and the observed average marginal cost in every market. As in the case of observed strategies, I use the identity function (no interaction), the construction activity in the market, and the year in the market. Therefore, I have in total $4 \times 3 = 12$ moments.

Therefore, in my estimation I use $726 + 12 = 738$ moments.

In the case of the estimation when I assume a "wrong" entry model, I build the moments in a similar way. Since the entry game has 2 choices, we have $2^5 - 1 = 31$ possible strategies, so the total number of moments used is $31 \times 3 + 4 \times 3 = 104$ moments.

D The US Cement Industry (1963-2002)

D.1 Structure of the market

Table 1: The US Cement Industry (1963-2002)

Year	Plants	Firms	Production	Imports
1963	181	46	66.6	0.7
1967	188	49	70.5	1.1
1972	175	47	79.5	3.2
1977	168	49	74.8	2.3
1982	149	44	63.2	2.4
1987	130	39	76.2	14
1992	121	43	70.1	4.9
1997	116	39	81.3	15.9
2002	114	40	85.2	24.1

Source: USGS Minerals Year Book and Census of Manufactures

Table 2: Leaders in the US cement industry (1963-2002)

	1st leader		2nd leader		3rd leader		4th leader		5th leader	
Year	Name	Plants	Name	Plants	Name	Plants	Name	Plants	Name	Plants
1963	Ideal	18	Lone Star	15	Marquette	13	Lehigh	13	US Steel	10
1967	Ideal	16	Lone Star	15	Marquette	11	Lehigh	11	US Steel	9
1972	Ideal	16	Marquette	12	Lone Star	11	US Steel	10	Marietta	10
1977	Ideal	14	Lone Star	12	Marquette	9	Marietta	9	General	8
1982	Lone Star	17	Ideal	12	Heidelberg	8	Marietta	8	General	7
1987	Lone Star	14	Holderbank	10	Lafarge	9	Heidelberg	8	Ash Grove	7
1992	Holderbank	15	Ash Grove	9	Lone Star	8	Lafarge	8	Heidelberg	8
1997	Holderbank	14	Ash Grove	9	Heidelberg	9	Lafarge	8	Lone Star	8
2002	Lafarge	15	Holderbank	13	CEMEX	12	Heidelberg	11	Ash Grove	9

Source: USGS Minerals Year Book, PCA Plan Information Summaries and other industry reports

Table 3: Multiplant and multimarket firms (1963-2002)

	single/multiplant firms		single/multimarket firms		
Year	Single plant	Multi plant	Single market	Multi market	Total number firms
1963	23	23	25	21	46
1967	24	25	26	23	49
1972	21	26	23	24	47
1977	23	26	24	25	49
1982	20	24	22	22	44
1987	15	24	17	22	39
1992	24	19	25	18	43
1997	22	17	22	17	39

Source: Census of Manufactures

D.2 Mergers and productivity

Table 4: Changes in TFP level

Relative change of TFP	(1)	(2)	(3)
changeownership	0.0141	0.0213	0.0228
	(0.0081)	(0.010)	(0.0107)

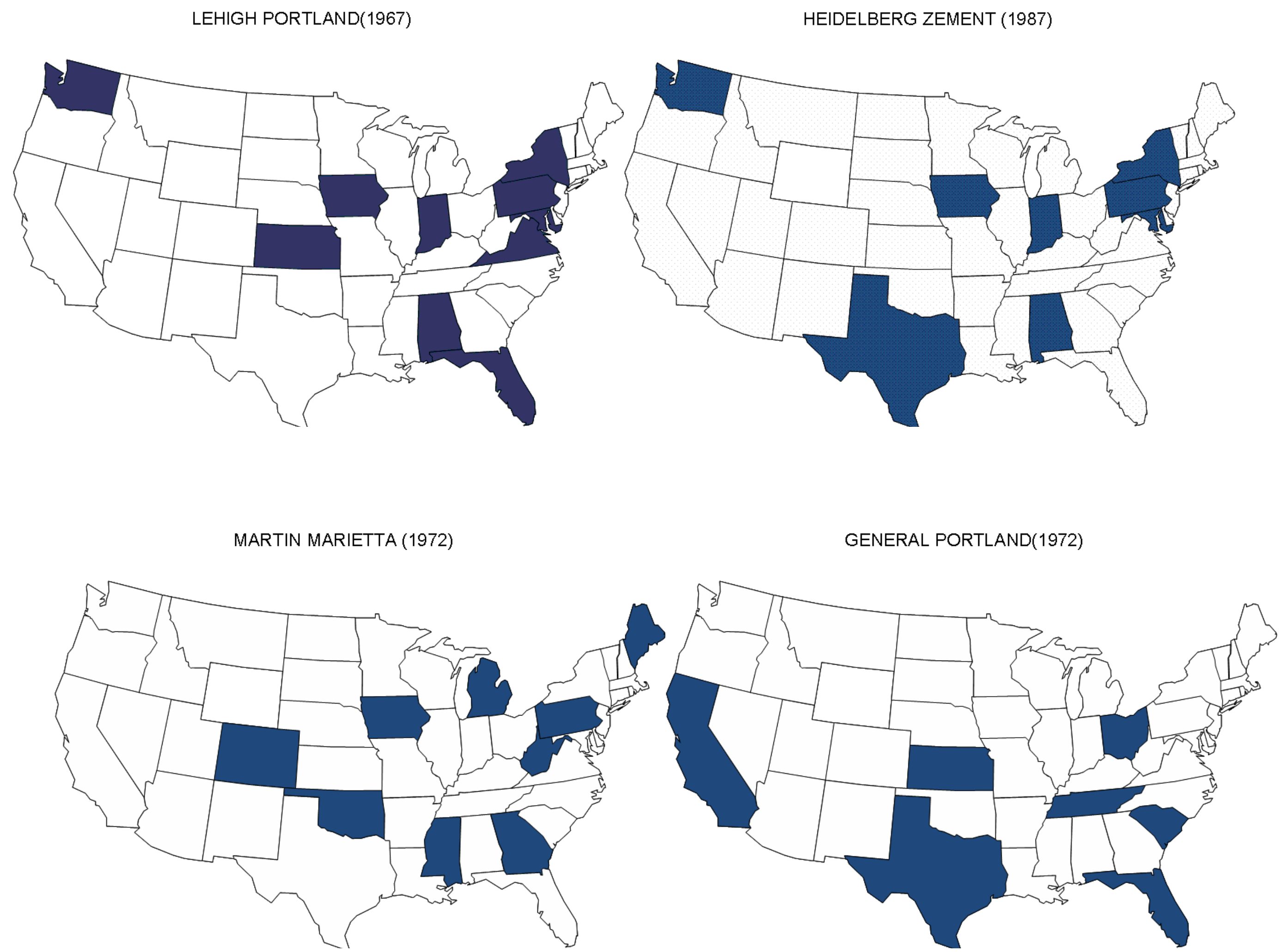
Notes: (1): No dummies. (2):Year dummies. (3):Year and market dummies. Relative change of TFP: Change of TFP level (relative to the average TFP level in the country) with respect to previous census year.

Table 5: Changes in TFP level between buyers and sellers

Change of TFP	(1)	(2)
Difference TFP buyer-seller	0.3515	0.3639
	(0.1044)	(0.1359)

Notes: (1): No dummies. (2):Year dummies. 92 plants used. Change of TFP: Change of TFP level of the acquired plant at the year of the acquisition with respect to the TFP level at the census year before the acquisition. Difference TFP buyer-seller: Difference between TFP of buyer firm and the acquired plant at the census year before the acquisition. Standard errors in parenthesis

E Maps of some industry leaders



Source: USGS (Years 1963-2002), PCA (Years 1977-2002) and other industry reports.

F Estimation results

Table 6: Estimates of the model

	SMM (true model)	SMM (wrong model)	OLS
Demand parameters:			
Quantity	-14.234	-18.67	-9.42
	(0.62)	(0.87)	(1.22)
Quantity of competitors	-0.919	-0.904	-0.874
	(0.039)	(0.105)	(0.040)
Construction activity	0.1369	0.1388	0.0592
	(0.005)	(0.035)	(0.1302)
Standard deviation of price	8.805	8.635	12.201
	(0.828)	(1.605)	
Optimum investment parameters:			
Log of size	0.483	0.460	0.564
	(0.030)	(0.065)	(0.097)
TFP	-1.324	-1.369	-1.297
	(0.181)	(0.3006)	(0.330)
Log of number of plants in market	-1.267	-1.227	-0.109
	(0.252)	(0.320)	(0.357)
Standard deviation of error term	0.732	0.742	2.229
	(0.011)	(0.023)	
Marginal cost parameters:			
Size	-0.0173	-0.0177	-0.0366
	(0.0010)	(0.00482)	(0.0134)
TFP	-0.1073	-0.1104	-0.2028
	(0.00253)	(0.00749)	(0.0517)
Year trend	-0.0304	-0.03052	-0.0293
	(0.00246)	(0.0047)	(0.0122)
Capital	-0.1271	-0.1247	-0.04676
	(0.00473)	(0.0220)	(0.0104)
Wages	0.0816	0.0807	0.3069
	(0.00338)	(0.0228)	(0.1458)
Fuel price	0.2957	0.2944	0.539
	(0.0527)	(0.0764)	(0.1174)
Electricity price	0.1077	0.1110	0.0923
	(0.0184)	(0.0259)	(0.07801)
Constant (marginal cost)	5.8693	5.9708	4.4595
	(0.537)	(1.4065)	(0.4579)
Standard deviation of error term	0.15802	0.1549	0.3604
	(0.0151)	(0.0151)	
New capital cost parameters:			
Capital variable term	0.2131	0.2132	
	(0.0406)	(0.0381)	
Sunk entry cost (in m. dollars)	76.43	77.36	
	(10.791)	(11.154)	
Equilibrium selection rule:			
Profit maximizing equilibrium	1.736	1.766	
	(0.369)	(0.293)	

Notes: Standard errors in parenthesis. Prices expressed in deflated dollars per million of short ton of cement. Construction activity measured in deflated billion dollars (measured as personal income). Marginal costs expressed in deflated dollars. Capital expressed in deflated dollars.

Table 7: Biases from the true model (in percentage deviation from the estimations of the true model)

	SMM (wrong model)	OLS
Demand parameters:		
Quantity	31.16%	-33.82%
Quantity of competitors	-1.63%	-4.90%
Construction activity	1.39%	-56.76%
Standard deviation of price	-1.93%	38.57%
Optimum investment parameters:		
Log of size	-4.76%	16.77%
TFP	3.40%	-2.04%
Log of number of plants in market	-3.16%	-91.40%
Standard deviation of error term	1.37%	204.51%
Marginal cost parameters:		
Size	2.31%	111.56%
TFP	2.89%	89.00%
Year trend	0.39%	-3.62%
Capital	-1.89%	-63.21%
Wages	-1.10%	276.10%
Fuel price	-0.44%	82.28%
Electricity price	3.06%	-14.30%
Constant (marginal cost)	1.73%	-24.02%
Standard deviation of error term	-1.97%	128.07%
New capital cost parameters:		
Capital variable term	0.05%	
Sunk entry cost	1.21%	
Equilibrium selection rule:		
Profit maximizing equilibrium	1.73%	

Table 8: Counterfactual policy experiments

	Estimated values	Antitrust policy	Environmental policy
Price (median of weighted average market price)	63.61	68.75	71.04
Total production (m. short tons)	1,260.7	897.3	678.6
Total net consumer surplus (b. dollars)	91.35	112.07	75.87
Total variable cost (b. dollars)	28.48	15.25	17.66
Total revenues (b. dollars)	72.33	36.00	34.56
Total average of maximum TFP value	5.07	5.04	4.99
Total new capital (b. dollars)	18,79	24.19	1,44
Total number of greenfield entrants	238.7	298.4	19.8
Total number of acquisitions	312.2	17.2	349.8

Notes: Simulated results from equilibrium. Case 1: Equilibrium in the industry with the estimated parameters. Case 2: A cost of 25 m. dollars is imposed to every merger. Case 3: Increase of 25 m. dollars in the sunk costs of building new plants. Number of simulations used in every experiment= 50