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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. In the U.S. cement industry, the comparative advantage (e.g., TFP or size) of entrants versus incumbents and regulatory entry barriers are important factors that determine the means of expansion. Using a rich database of the U.S. Census of Manufactures (1963-2002), an entry game is proposed to model this decision and estimate the supply and demand primitives to determine the importance of these factors. Two policies that affect the entry behavior and industry equilibrium are considered: An asymmetric environmental policy that creates barriers to greenfield entry and a policy that creates barriers to entry by acquisition. In the counterfactual analysis it is found that a less favorable environment for acquisitions during the Reagan-Bush administration would decrease the acquired plants by 90% and increase greenfield entry by 21%. Also, the Clean Air Act Amendments of 1990 increased the number of acquisitions by 3.5%. Furthermore, my simulations suggest that regulations that create barriers to greenfield entry are less favorable in terms of welfare than regulations that create barriers to entry by acquisition. Finally, it is shown how the parameter estimates change with the traditional approach in the entry literature where entry by acquisition is not considered, and when using a simple OLS estimation.

JEL classification: L13, L40, L61
Bank classification: Productivity; Market structure and pricing; Econometric and statistical methods

Résumé

Dans de nombreuses branches d'activité, les entreprises qui se développent sur de nouveaux marchés ont habituellement deux possibilités : construire une usine (nouvel apport) ou acquérir un établissement. Dans le secteur du ciment aux États-Unis, l'avantage – au chapitre, p. ex., de la productivité totale des facteurs ou de la taille – des entreprises entrantes comparativement à celles en place et les barrières réglementaires à l'entrée sont des facteurs importants dans le choix du moyen d'expansion. Pour modéliser cette décision et estimer les primitives de l'offre et de la demande qui permettent de déterminer l'influence de ces facteurs, l'auteur propose un jeu fondé sur une riche banque de données, tirée du recensement des entreprises industrielles américaines (1963-2002). Il examine deux politiques qui ont une incidence sur le type d'entrée privilégié et sur l'équilibre sectoriel : une politique environnementale asymétrique qui entrave les nouveaux apports, et une politique freinant les entrées par acquisition. L'analyse contrefactuelle menée indique qu'un environnement moins favorable aux acquisitions aurait induit une chute de 90 % des acquisitions d'usines et une hausse de 21 % des nouveaux apports durant les années Reagan-Bush. Les modifications apportées à la *Clean Air Act* en 1990 ont fait monter de 3,5 % le nombre d'acquisitions. En outre, d'après les résultats des simulations de l'auteur, les règlements qui créent des barrières à l'encontre des nouveaux apports sont plus préjudiciables pour le bien-être que ceux qui freinent les entrées par acquisition. Enfin, l'auteur montre comment les estimations des paramètres changent lorsqu'il applique la méthode traditionnellement suivie dans la littérature liée aux modes d'entrée (qui fait abstraction des entrées par acquisition) et lorsqu'il emploie une simple méthode des moindres carrés ordinaires.

Classification JEL : L13, L40, L61
Classification de la Banque : Productivité; Structure de marché et fixation des prix; Méthodes économétriques et statistiques

1 Introduction

The importance of firm expansion is well-recognized in the economics literature and has several dimensions. 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 dimension is the way in which this expansion occurs; firms can expand internally (by building new facilities, 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 is observed. When the U.S. 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.[2] The cement industry is another clear example because acquisitions of plants almost doubled the construction of new plants for the period 1963-2002. In figure 1 in the appendix we observe that acquisition of plants was a very common phenomenon, particularly in the late 1970s and 1980s, whereas the construction of new plants was rare during the 1990s. Furthermore, the question I am addressing has been of great interest in the international trade literature.[3]

What drives a firm's decision to expand by greenfield or acquisition? There are many possibilities. To cite a few, there are competitive reasons (building a new plant in the market increases the number of competitors in the market); intensity of entry barriers (regulatory barriers, scarcity of a basic input like technology or patents, etc); and comparative advantage aspects (the ability of entrants to extract more profits from the assets of incumbents). I propose an entry model that includes many of these trade-offs, and estimate it using data from the U.S. cement industry to delineate the determinants of this decision.

Although the cement industry is relatively important to the U.S. economy[4], my interest in cement is not to study the industry per se, but rather to use it as an example (due to the interesting properties of this industry and the data available) in order to understand the determinants of every type of entry. The

[1] Since expansion can occur in many dimensions, this paper focuses only on the geographic expansion of firms to other markets. Firm expansion across 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] 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).

[3] A extreme example would is the U.S. wireless industry. Due to regulatory constraints and the limited capacity of spectrum, there is not free entry of new firms in this industry. Therefore, in absence of new spectrum available through spectrum auction, the acquisition of existing firms with spectrum licenses is virtually the only means of geographical expansion.

[4] In 2007, the total value of the cement sold was 10.6 billion dollars, according to the U.S. Economic Census.

U.S. cement industry is characterized by certain properties that make it an ideal industry to study. 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 the expansion of firms across U.S markets offers a source of variation that helps identify these determinants. Second, cement is a homogeneous product, therefore, cost advantages, and thus productivity, are important determinants of competition and firm 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.

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. Determining the magnitude of this substitution effect in the industry equilibrium will alow us to answer questions such as: 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 and to better understand the economic mechanism behind the expansion decisions of firms, I propose a structural entry model that is rich enough to capture the main trade-offs that govern these decisions. This entry game 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 to invest in the new plant built. In the third stage, the identities of the acquired incumbents are determined using a simultaneous acquisition game. Finally, in the fourth stage all firms compete in the market. The decision to enter by acquisition or greenfield entry is driven by several factors that are included in the primitives. These include: a) entry barriers to greenfield entry (such the cost of building new capital) and to entry by acquisition (such as antitrust barriers); b) differences in characteristics (e.g. productivity or size) among all firms (entrants 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 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 market and profits decrease with more intense competition.

For my estimation, I use a recent estimator from Bajari et al. (2010) to estimate the demand and supply primitives 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. Therefore, as opposed to other more indirect two-step estimators, I use a full solution method that requires the calculation of all equilibria, which is computationally demanding. To estimate the parameters, 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.

In my counterfactual analysis, I find that eliminating the benefits to entry by acquisition during the Reagan-Bush administration would decrease mergers by 90% and increase the number of new plants built by 21%. Also, I find that the Clean Air Act (CAA) 1990 Amendments increased entry barriers to greenfield entry so the number of mergers increased by 3.5% and the number of greenfield entrants decreased by 81%. My results suggest that regulations that create barriers to greenfield entry are less favorable in terms of welfare than regulations that create barriers to entry by acquisition.

An important result of the paper is that neglecting to consider entry by acquisition leads to an inaccurate representation of many industries where entry by acquisition is a common phenomenon, 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. Finally,the richness of the data allows me to estimate the primitives of the model using simple ordinary least squares (OLS) and compare them with the structural estimates.

The outline of this paper is as follows. In the next section I present the literature most closely related to this 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. Finally, I show the estimation results and counterfactual policy experiments that affect greenfield entry and entry by acquisition. Tables and figures are collected in the appendix.

2 Literature review

Although entry by acquisition is acommon 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 is Gilbert and Newbery (1992), who are the first to study this question using a simple entry game.

Concerning the empirical IO literature, there are 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 mergers as merely another means of entering into a market, my research also builds upon the merger literature. The empirical and theoretical literature related to mergers is extensive. A well known question centers upon determining if mergers are driven by efficient reallocation of assets, by market power reasons, or other reasons (such as conflicts of interest between managers and the owners of the firm). To show that mergers increase efficiency of assets acquired, Maksimovic and Phillips (2001) use plant-level data from the U.S. Census to show that productivity (measured as TFP) increases significantly (about 2% on average for the entire sample) after manufacturing plants change ownership. Using the same database, Schoar (2002) finds similar results. These results suggest that the new owner of the plant can increase the productivity of the acquired assets by addying to them a number of positive characteristics that increase their performance. I capture this mechanism suggested by the literature in my structural merger model.

In the structural empirical literature, a number of papers have studied the merger decisions of firms. There are different approaches to model this decision. Some authors borrow from the theoretical endogenous merger literature to model horizontal mergers as a non-cooperative game. In this literature, the competitive interaction between firms is key to determine the outcome of the horizontal merger process. Gowrisankaran

(1999) adds a horizontal merger stage to the the Ericson and Pakes (EP) framework. Gowrisankaran numerically solves the dynamic model and characterizes the set of equilibria without making estimations. Recent advances in the estimation of dynamic models have facilitated the empirical application of these dynamic models. For example, Benkard et al. (2009) apply the two-step estimator from Bajari et al. (2007) to study horizontal mergers in the airline industry. More recently, instead of using this non-cooperative approach to mergers, some authors model mergers as the outcome of a cooperative matching game where buyer and seller characteristics interact in the production function of the merged firm. For example, Akkus and Hortacsu (2007) and Park (2008) study the sorting of characteristics between buyers and sellers in the banking and the mutual fund industry, respectively. This matching approach to mergers does not consider the competitive interaction from firms, which is at the core of the endogenous merger literature. In my model, I use a non-cooperative merger game that captures the competitive effect between firms. The model also emphasizes the importance of buyer and seller characteristics as a key determinant of the outcome of this merger process.[5]

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 which is very important in the cement industry: Changes of plant ownership in this industry have been about twice the number of greenfield entries, as we can see in figure 1 in the appendix.

Compared to some of the commented structural papers, my empirical structural model is static and uses a full solution estimation method that calculates all equilibria. My paper focuses on the determinants of entry of firms into new markets, emphasizing the importance of firm characteristics in this expansion process as suggested by the merger literature.

[5] 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 study entry. 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).[6] Given these facts, it is a good approximation to consider a U.S. state as the definition of a market.[7] This market definition is also used in recent papers on the cement industry (such as Ryan (2009)).[8]

Concerning imported cement, imports have been relatively low for the period 1963-1982 (they were less than 5% of total production, see table 1 in appendix). In last years, imports have increased due to the constant reduction of transportation costs, but the consumption of imported cement, if any, is usually constrained to coastal states because the subsequent use of terrestrial transport would increase the price significantly.

Although there are several types of cement produced, in 1992 about 85% of the value of all cement produced was portland type and this percentage has been approximately constant over the years.[9] There are five different types of portland cement depending on the special constituents used. However, most of portland cement sold in the U.S. is 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

[6] Of course, there are exceptions as in the case of plants located close to the Mississippi River or in the Great Lakes area. The use of barges decreases the cost of transportation significantly to distant areas.

[7] In order to make this market definition more accurate, I aggregate same small states in the east cost in a single market, and I divide some big markets like California and Texas.

[8] Even smaller market definitions have been used in the literature (BEA's economic areas in Hortacsu and Syverson (2007)).

[9] 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 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[10]. 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, there can be 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 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[11]. 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 (e.g. Scherer et al. (1975)). However, contrary to other markets where multi-market presence may give significant economic advantages, the cement industry is not likely to have strong multi-plant economies.[12] 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

[10] 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.

[11] 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.

[12] 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 et al. (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 provides 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.

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 (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[13]. This had a great impact in the industry because environmentally inefficient plants had to exit the market since it was not profitable for them to pay for the necessary renovations to comply with the law. It also substantially 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 cement plants are subjected to more stringent regulations than the existing plants (what is usually called grandfather vs new source regulations). 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 homogenous, cost advantages are critical for survival and profitability, economics of multi-market operation are small and environmental issues considerably affect entry and profitability.

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 substantially, the number of firms and concentration levels have not had significant variation in this period (see table 1 in appendix). In the period of study, the largest firm in

[13] 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 construction of new plants in the cement industry.

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 these have changed over time. 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 table 3 in appendix).

Considering the means of expansion, using the CM database there have been 134 new plants built and about twice as many changes of ownership. Therefore, entry by acquisition was a more common way of entering in the market than greenfield entry. 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) (see Ryan (2009)). The number of plants acquired has increased over the years, but mergers have been especially 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.

It is important to remark that the observed acquisitions in these industry can be well approximated as individual decisions made on a plant-level basis by every potential buyer as opposed to a scenario where big firms buy complete big firms. This idea of individual decisions on acquisition of every plant is a good approximation for two reasons: First, many of these acquisitions correspond to acquisitions of single-plant firms (and single-plant firms are very common in this industry). Second, there are many partial acquisitions of multi-plant firms[14]. This behavior together with the insignificance multi-plant economies allows me to model the entry behavior in every market independently as I show later in my model.

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

First, I observe a 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.

[14] An example of the behavior of a seller 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.

Second, increasing environmental concern during the 1980s and 1990s created high entry barriers to the construction of new plants and the construction of new plants slowed 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.

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 profits from entering into 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

A clear example of the importance of comparative advantage in the expansion by acquisition is the case of the massive acquisition of U.S. cement plants by foreign firms. Compared to the U.S, firms, many of these foreign firms had more efficient technologies, 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. This superior advantage is cited by some authors as the main reason for these acquisitions[15] but there are probably also other reasons[16].

The relationship between relative efficiency of potential buyers and sellers and the acquisition of assets has been studied by Maksimovic and Phillips (2001)[17]. 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 tables 4, 5 and 6 in the 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

[15] See Mabry (1998) for an excellent analysis of the U.S. cement industry in the last century and Bianchi (1982) to understand the comparative advantages of european cement firms.

[16] Some authors attribute the merger waves in the 1980's to the Reagan's administration permissive antitrust policy (see Baldwin (1990)). The relaxation of previous antitrust enforcement standards is shown in the Department of Justice's merger guidelines of 1982 and 1984. However, other factors could be also considered, like changes in the tax laws in the 1980's (see Scholes and Wolfson (1990)).

[17] 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 (multi-division firm, single segment firm, partial firm acquisitions, etc.)

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 than the previous owners due to better managerial practices, better production techniques, 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.

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 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[18].

4 Data

My primary source of information is the CM database. 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[19].

The CM database has accurate measures on the construction of new plants, closings and changes of ownership of existing plants as well as characteristics of the owners of these plants. 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 Bureau 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

[18]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.

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

CFN (Census File Number) which is a plant identifier in the CM database 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[20]
- 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 which identifies common ownership of plants. Using this variable, I determine changes of ownership of plants using 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, 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 going back to 1963. However, I compared the income data with the labor data for the later years and they have a very high correlation. In order to consider the dynamics of the entry decision by firms, I use the average construction activity over the 10 years after the year of entry.

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 rich enough to capture the main trade-offs and observed facts that drive the decision of greenfield entry, or entry by acquisition for this industry.

[20] There are special cases of plants that receive a new PPN without being strictly a new built plant. This is the case of plants that have received a major renovation, typically after being closed for several years. From the census data, I can't determine if a plant is new or fully renovated but in many cases, the magnitude of these renovations makes the plant virtually a brand new plant.

The game is conceptually straightforward: A set of potential entrants want to enter a market, and they play an entry game with three initial choices: Enter by building a new plant, enter by acquiring an existing plant, or not enter in the market. The game has subsequent stages to determine the amount of greenfield capital built (second stage), the identity of the acquired firm by every entrant by acquisition (third stage) and the prices and quantities in equilibrium.

A simple explanation of the mechanics of the equilibrium of this model are as follows: Entry barriers in the construction of new facilities (like higher asymmetric environmental entry costs) directly affect the profitability of greenfield entry. Relative comparative advantage of potential entrants and incumbents (measured by TFP or size) and differences of entry barriers to the acquisition of incumbents, affect the profitability of entrants by acquisition. Therefore, for some constant value of greenfield entry costs, more productive potential entrants or changes in merger regulations will increase the probability of entry by acquisition; and for a fixed comparative advantage of potential entrants or merger regulations, a lower greenfield entry cost will increase the probability of greenfield entry. Also, other aspects will affect this decision, like the size of the market (will positively affect new greenfield entry) and the degree of competition in the market (a more competitive market decreases the profitability of a new greenfield entrant, but affects much less entry by acquisition because the number of plants remains constant).

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, size or experience in the cement industry) to the acquired plant.

5.2 Assumptions of the model

I assume there are N markets. In every market n, there is a perfect information static entry game 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, or they can be incumbents that are already established.
  - Entrants: There are e potential entrants in every market. I denote the set of entrants as $E = \{1, 2, ..., e\}$

- Incumbents: There are ι incumbents in every market. I denote the set of incumbents as $I = \{1, 2, ..., \iota\}$.

- Actions of entrants: Entrants can choose between not entering, 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. $E_G^a = \{j \in E | a_j = g\}$ is 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 by acquisition or greenfield. 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 $D^a = \#E_D^a$)[21].

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 simultaneous acquisition game assigns each of the firms in E_M^a to zero, one or more of the incumbents in I.

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 $G^a + \iota \equiv A^a$

Here the greenfield entry decision is done before the entry by acquisition decision. This assumption captures the fact that building a new plant requires an enormous amount of planning so greenfield entrants need to commit for greenfield entry early enough. Also, I simplify my model by not considering exit of the market by existing incumbent plants. Many of the exitors of the market are very old and small plants with obsolete technology and high difficulties to compete in the market, so this decision can be considered, to a certain extent, as exogenous.

[21] In order to discard same unreasonable equilibria, I assume an infinitely small fixed amount paid by every entrant in the market c_M (see proposition 2 below).

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). 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:

$$CashFlow = Revenues - Operating\ Costs$$

where

$$OperatingCosts = Material\ Costs + Labor\ Cost + Energy\ Cost$$

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 of building the new plant or the cost of acquiring an existing incumbent:

$$\text{Total Profit Greenfield Entry}: \ \Pi = CashFlow - Capital\ Cost$$

$$\text{Total Profit Entry by Acquisition}: \Pi = CashFlow - Acquisition\ Cost$$

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

Also, in the model capital is completely variable for the greenfield entrant, but not for the entrants by acquisition. The greenfield entrants can select the optimum level of capital that maximizes the total profit (using an investment rule function that I estimate) whereas the entrants by acquisition cannot adjust the level of capital. Therefore, the level of capital of the plant that is acquired equals the level of capital it had before the acquisition. This is a reasonable assumption as in the cement industry capital is lumpy[22].

[22] 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.

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[23]

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

where MC is the constant marginal cost of production. This marginal cost depends on variables that I have classified between observed market-level variables (X^{MC}), observed plant-level variables (Y^{MC}), observed firm-level variables (Z^{MC}) 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 (input prices and a year trend). Plant-level variables are variables that are specific to every plant (capital, age and a binary variable equal to one if the plant is built in that year). Finally, firm-level variables are variables that are specific to the firm that owns the plant (firm-level TFP, firm size and a binary variable equal to one if the firm is a new firm in the cement industry)[24].

In summary, I assume the following variables in my model

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

The intuition for using these variables as determinants of the operating cost is the following. At market level, input prices should clearly have a significant effect on the variable costs (specially the cost of energy, because the cement industry is very intensive in energy), and to control for possible technological changes over the years, I use a year trend. At plant level, we expect that plants with more capital should have lower variable costs because the substitution between capital and the variable factors of production[25]. Also, we should expect that new plants or younger plants have smaller costs of production because they have a state of the art or more modern technology. Finally, at firm level I have introduced variables that may

[23] This implies that if we double production of cement, the variable cost of producing cement doubles. This is a good approximation for the cement industry where a number of inputs like materials and energy are used in fixed proportions.

[24] As we will see later, the classification used for the variables used 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.

[25] This represents a scale effect that I mentioned as a driver of cost advantages: Bigger, highly capitalized plants have lower variable costs.

affect the cost of producing cement. Firm level TFP should have an obvious effect on the cost function. Also, firm size (where I use the size of the firm in the manufacturing sector) and the experience of the firm in the cement industry may affect the operating costs because these variables measure the experience of firms in the manufacturing industries which may significantly affect its capability to successfully enter and compete in the cement industry.

I assume a multiplicative expression for the marginal cost:

$$MC(X^{MC}, Y^{MC}, Z^{MC}, \varepsilon^{MC}) = e^{\varepsilon^{MC}} \cdot e^{\beta_0} \cdot e^{\beta_1 YEAR} \cdot FIRMSIZE^{\beta_2} \cdot TFP^{\beta_3} \cdot INSIDER^{\beta_4} \cdot BIRTH^{\beta_5} \cdot CAP^{\beta_6} \cdot AGE^{\beta_7} \cdot SALARY^{\beta_8} \cdot FUEL^{\beta_9} \cdot ELECT^{\beta_{10}}$$

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[26]:

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

where $A(X^D, Y^D, \varepsilon^P)$ 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), plant level variables (Y^D) and an unobserved plant-specific error term (ε^P). The demographics variables I use in my model are

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

where $CONSTRUCTION$ represents construction activity in the market and $YEAR$ is a year trend.

The plant level variable I consider is just a binary variable equal to one if the plant is built in that year[27]

$$Y^D = [BIRTH]$$

[26] A linear demand gives a closed form solution for a Cournot game with heterogeneous firms.

[27] As Foster et al. (2010) show, new manufacturing plants start with a considerable demand deficit with respect to existing plants (for example growth of a customer base or building a reputation take considerable time to play out).

I assume that the intercept has a linear form equal to

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

where ε^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 by subtracting variable costs from revenues

$$CashFlow(Q_j, Q_{-j}; X, Y, Z, \varepsilon^P, \varepsilon^{MC}) = p(Q_j, Q_{-j}; X^D, Y^D, \varepsilon^P) \cdot Q_j - C_O(Q_j; X^{MC}, Y^{MC}, Z^{MC}, \varepsilon^{MC})$$

where $X = [X^D \ X^{MC}]$, and $Y = [Y^D \ Y^{MC}]$.

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:

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

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

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.

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 plants.

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 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:

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

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. I denote Y, Z, ε^P and ε^{MC} as 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: 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 in every market. To determine what incumbents are acquired by every entrant, I model a simultaneous acquisition game where the M^a potential buyers bid for the I incumbents in the market.[28]

To model acquisitions of the incumbents by the entrants, a possible way of modeling it is using a

[28] 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.

two-sided matching model where one side of the market are the buyers (potential entrants) and the other side of the market are the sellers (the incumbent plants).[29] Some recent applications of this framework to mergers are Akkus and Hortacsu (2007) or Park (2008). A transferable utility matching game could be an appropriate way of modeling mergers (Shapley and Shubik (1971)).This 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 choosing strategically the quantities in a Nash equilibrium setting, the equilibrium profit function depends on all characteristics of all plants competing in the market. Hence, controlling for this would require to solve a matching game with externalities (see Sasaki and Toda (1996)) which has a number of technical difficulties like the multiplicity of the possible assignments in the transferable utility matching game[30]. Due to these difficulties, I have adopted a simple non-cooperative simultaneous perfect information acquisition game to model mergers that has a unique outcome and is easy to compute.

6.2.2 Transfer of firm-level characteristics from the buyer to the seller

Based on the facts commented previously, a key feature of my acquisition model is the transfer of firm-level characteristics from the buyer to the seller. What happens when an entrant firm buys one incumbent plant? When a plant is bought by an entrant firm, the plant belongs now to a new firm that has a number of characteristics that could be very different from the former owner of the plant[31]. Therefore, if the acquisition takes place, the supply firm-specific observed characteristics of the seller are replaced by the firm-specific observed characteristics of the buyer : the characteristics of the cost function of an incumbent plant i, $Z_i = [FIRMSIZE_i, TFP_i, INSIDER_i]$ are replaced by the characteristics of the buyer firm j, Z_j. Hence, the total cost effect brought by the entrant firm $FIRMSIZE_j^{\beta_2} \cdot TFP_j^{\beta_3} \cdot INSIDER_j$ interacts with the plant specific characteristics of the acquired incumbent that do not change (capital and age[32]) and the rest of the market specific variables (salaries, fuel and electricity prices). The error term from the match ij, ε_{ij}^{MC}, is plant-firm specific so every potential firm-plant match ij has a unique error term

[29] Roth and Sotomayor (1990) is the standard reference to study the theory of matching games.

[30] 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 remainder of the agents in the market remain unmatched.

[31] To understand this better, we can think of an extreme case, like the acquisition of a plant owned by a small firm by a big multinational like CEMEX. Certainly, the acquired plant is going to be now under the control of a very different organization, with different managerial practices, technology, etc.

[32] Although the age of a plant obvioulsy can not be changed, there are some concerns that capital remains constant after an acquisition. However, since capital is a lumpy investment in this industry, it is a good approximation to consider that capital remains constant after an acquisition. On the other side, I have found evidence that some firms make major renovations of acquired cement plants, but in that case the plant needs to be closed for several years, and if the renovations are very important the plant is basically a new greenfield plant that is considered as a new plant by the U.S. Census.

(and this error term replaces the incumbent plant i error term ε_i^{MC}). Similarly, since my demand does not consider firm-level characteristics, after the acquisition the plant-specific shifter of the incumbent i in the demand function, ε_i^P, is replaced by the plant-firm specific unobserved error term of the firm-plant match ij, ε_{ij}^P.

6.2.3 Simultaneous acquisition game model

In this perfect information acquisition game every bidder (every entrant firm) can buy one or more incumbents[33]. Therefore, every entrant j submits a bid for every incumbent plant i (denoted by $b_{j,i}$). The firm with the highest bid buys the incumbent (provided that the bid is greater than the valuation of the incumbent). Here, I denote valuation as the cash-flow expresion from the Cournot competition in the last stage[34].

In order to simplify the computational burden of the estimation of this game, I need to make the assumption that if one entrant buys more than one incumbent, this entrant does not internalize the effects of the quantities produced in other owned plants when optimizing the quantities produced in the Cournot game[35].

Definition 1 *In this game, I differentiate between the equilibrium of the game, and the outcome of the game:*

- ***Equilibrium:*** *A Nash equilibrium of the acquisition game is a set of bids of every entrant j for every incumbent plant i, $b_{j,i}^*$, where no entrant j can profitably deviate by choosing a different bid given the bids of the other entrants.*
- ***Outcome:*** *The outcome of the acquisition game is given by the identity of the firm that buys every incumbent and the equilibrium bid paid for every incumbent if acquired.*

[33] I allow for multiple acquisition for two reasons: First, I observe it in my data (although this is not frequent). And second, this game is computationally much simpler to calculate than other acquisition games were there can be only one acquisition by every entrant.

[34] Since the error terms ε_{ij} are plant-firm specific and they have a continuous distribution, valuations have continuous support and therefore, ties are events of probability zero.

[35] This implies that the same usual single-plant Cournot first order conditions are applied to all the plants owned by the same firm in the same market. A simple justification of this assumption would be that a multiplant firm has independent managers that independently optimize production in every plant within the same market. Of course, the total profit from the firm that enters in the market is equal to the aggregation of all profits of the acquired plants (but the first order conditions are obtained "independently").

I make explicitly this difference because the outcome is what I use in my estimation. Also, given the assumptions considered, it turns out that the outcome of this game (the identity of the firm that buys every incumbent and how much it pays) has a solution and that this solution is unique.

Proposition 1 *The outcome of this acquisition game is unique, and it is such that an incumbent i is acquired by the firm j with the highest valuation for that incumbent, and the bid paid $b^*_{j,i}$ is equal to the second highest valuation among all firms in the market.*

Proof. *For every incumbent i, the cash-flows of every entrant j when they buy any incumbent can be calculated solving the Cournot equilibrium and ranked using the firm-specific effects of every entrant, as explained before. I denote by $V_{j_1,i}$ and $V_{j_2,i}$ the highest and second highest valuation (i.e. cashflows) of the incumbent among all firms in the market (note that the incumbent is also considered, so $j_1 = i$ in case the incumbent has the highest valuation among all entrants).*

First, I show that $b^*_{j_1,i} = V_{j_2,i} + \epsilon$ (with $\epsilon > 0$ infinitely small) and $b^*_{j,i} \leq V_{j_2,i}$ for any $j \neq j_1$ (with equality if $j = j2$) is an equilibrium. Note that the payoff of the winner firm is $V_{j_1,i} - V_{j_2,i} > 0$ (strictly inequality because there can not be identical valuations since the error terms are drawn from continuous distributions) and the payoffs of all other firms are 0. The winner firm j_1 does not increase payoffs by setting a higher bid $b^{'}_{j_1,i} > b^*_{j_1,i}$ because $V_{j_1,i} - b^{'}_{j_1,i} < V_{j_1,i} - b^{*}_{j_1,i}$. If j_1 sets exactlty $b^{'}_{j_1,i} = V_{j_2,i}$, it increases by ϵ infinitely small the margin, but since now a lottery assigns the object with probability 1/2, j_1 is worse off. And if $j1$ sets a lower bid, it does not buy the incumbent and makes 0. Also, firm $j2$ does not profitably deviate by setting a lower bid (it still makes 0), or a higher bid (it makes negative profits with positive probability).

Second, I show that this outcome is unique. There can not be equilibria where $V_{j_2,i} < b^*_{j_2,i} < b^*_{j_1,i}$ because firm j_1 can set $b^*_{j_1,i} = b^*_{j_2,i} - \epsilon$ and can increase profits. Also $V_{j_2,i} < b^*_{j_1,i} \leq b^*_{j_2,i}$ can not be an equilibrium because firm j_2 makes negative profits with positive probability and can make 0 by decreasing the bid. Also, any situation where $b^*_{j_1,i} \leq b^*_{j_2,i} < V_{j_2,i}$ can't be an equilibrium because j_1 can profitably deviate by setting $b^*_{j_2,i} < b^*_{j_1,i}$. Same logic applies to equilibria where $b^*_{j_2,i} \leq b^*_{j_1,i} < V_{j_2,i}$.

Finally, these arguments can be extended to every incumbent acquired. Although the Cournot cash-flow expression shows that the acquisitions of other incumbents affect the profitability of every entrant that is buying an incumbent, the rank of valuations within entrants bidding for the same incumbent is not affected. Therefore, we can apply the same previous arguments and obtain the same outcome independently for every *incumbent.* ■

Note that this result has the same intuition as the classical Bertrand price competition with heterogeneous firms or to a second price auction. Note also that the outcome is unique, but not the equilibrium (because there is an infinituum of equilibrium bids of the firms that do not win the auction), but this is not an inconvenience, because the outcome is what we need to solve the entry game.

To solve the entire game, the solution of the acquisition game has to be solved for every possible vector of strategies in the entry game: Given a number of greenfield entrants and firms that enter by acquisition from the first stage (represented by the vector of strategies a), the unique outcome of the acquisition game is represented by an equilibrium assignment correspondence $\mu_a^*(j; X, Y, Z, \varepsilon^P, \varepsilon^{MC})$ that assigns every entrant j to one or more incumbents, 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 correspondence represents the incumbent plants bought by every buyer j. For example $\mu_a^*(j; .) = i$ means that buyer j acquires the incumbent plant i.

Finally, to have a more realistic acquisition game, I introduce a fixed merger cost that is added to the equilibrium bid[36]. This fixed merger cost is estimated with the rest of the primitives of the model and is constant across firms, markets and years.[37]

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

[36] This fixed cost can be interpreted as 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. Therefore, these are rents dissipated from the surplus of the acquisition.

[37] To represent variation of entry barriers to acquisition during the Reagan administration, I consider that this merge cost is different for years 1982-1992.

entrants plus the number of incumbents I). I denote the 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 solution of the game can be obtained by determining the equilibrium entry decisions in the first stage taking into account the solution of the last stages of the game.

Let X denote the vector of market characteristics. Let Y denote the vector of plant-level characteristics (capital and others) in the market. Finally, I denote Z as the vector of firm level characteristics of entrants and incumbents.

I define the vectors $Y^*(\mu_a^*, a, Z, \varepsilon^K)$ and $Z^*(\mu_a^*)$ that summarize the plant and firm level characteristics present in the market by every competitor which are obtained by solving the investment and acquisition stages explained previously.

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:

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

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[38]:

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

Given these profit expressions, 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 non-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 after solving for the last stages of the game.

Finally, the following result is also important to simplify the calculation of the equilibria of the game at the first stage:

Proposition 2 *In the first stage of my game where firms can enter by acquisition or greenfield investment, I find that*

[38] In case that an entrant buys more than one incumbent, the expression would include the cashflows and bids of all the acquired plants. Also, the fixed acquisitions cost is included in b^*

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 in the market choose to enter by acquisition, then at least one of the entrants does not buy an incumbent. By assuming an infinitely small fixed amount paid by every entrant in the market* 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* $-c_M$*.*

Second, using a similar argument, there cannot be equilibria where one of the entrants by acquisition does not buy any incumbent. 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 too high marginal cost to make a profit in the market, so it produces zero. But in that case it can profitably deviate in the first stage by not entering into the market (because it can save either the cost c_M *or the sunk entry cost from entering greenfield).*

The intuition for these results is clear: The can not be situations where firms enter in a market to not produce anything, or to not buying any incumbent. ■

Therefore, we can use this proposition to eliminate some set of actions that can not be equilibria in the entire game. This simplifies the numerical estimation of the parameters.

7 Estimation: Simulated method of moments estimator

7.1 Overview

Some of the main difficulties found in the literature of estimation of games is a consequence of the existence of multiple of equilibria. Since there is not a unique correspondence between the outcomes of the game and the primitives of the model, several difficulties appear in the identification and estimation of the game. A number of solutions have been proposed, and I adopt one proposed by Bajari et al. (2010) for the case of perfect information static games. Their estimator requires the calculation of all equilibria of the game and an equilibrium selection mechanism is included as a part of the primitives of the model.

The rich database from the U.S. Census contains information on prices, quantities, capital, etc, allowing me to include it in my estimation procedure. This information is usually not observed by the econometrician. 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. By using this extra data, revenue and cost parameters from the profit function may be separately identified.

7.2 The simulated method of moments estimator

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

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

where X are market-level variables, Y plant-level variables and Z firm-level variables.

I use two types of moments. As in Bajari et al. (2010), 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[39]

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

[39] 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

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

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 analytical profit expressions from the Cournot competition.

More formally, let $\epsilon(X, Y, Z, \varepsilon^P, \varepsilon^{MC}, \varepsilon^K; \alpha, \beta, \gamma, \lambda)$ denote the set of all possible equilibria given the observed variables and the unobserved error terms. Let $\lambda(eq; \epsilon(.), \delta)$ denote 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

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

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 δ : 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 et al. (2010), 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 paper, I just consider a simple equilibrium rule where the equilibrium selected is the efficient one (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 does not have an analytical expression and has to be estimated by simulation. Let $\widehat{\Pr}(a|X,Y,Z;\alpha,\beta,\gamma,\lambda,\delta)$ denote this simulated probability. Then, the simulated probability can be written as

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

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 strategies must be computed[40]. Moreover, the calculation of all equilibria must be done at every stage of the optimization routine[41].

[40] Bajari et al. (2010) 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)).

[41] The authors try to reduce the computational burden of their estimation by using recent importance sampling techniques 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 function does not have an easy analytical expression in this multistage complex game.

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

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

7.4 Moments for observed outcomes

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

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

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

$$\widehat{E}(O|X, Y, Z; \alpha, \beta, \gamma, \lambda, \delta) =$$
$$\frac{1}{S}\sum_{s=1}^{S}\left\{ \sum_{eq \in \epsilon(.)} O(eq, X, Y, Z, \varepsilon^P_s, \varepsilon^{MC}_s, \varepsilon^K_s; \alpha, \beta, \gamma, \lambda) \cdot \lambda(eq; \epsilon(X, Y, Z, \varepsilon^P_s, \varepsilon^{MC}_s, \varepsilon^K_s; \alpha, \beta, \gamma, \lambda), \delta) \right\}$$

where $\{\varepsilon^P_s, \varepsilon^{MC}_s, \varepsilon^K_s\}_{s=1,\dots,S}$ are random draws of the unobserved error terms.

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

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

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 Behavior 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.

The interactions I use for my moments are construction activity in the market, the year in the market and input prices (electricity, fuel and salary).

For the observed outcomes, I use the average price, the total quantity produced, the observed new total capital invested, the observed average marginal cost, and the total number of incumbents acquired in every market (see details in the appendix).

The use of a great number of outcomes and interactions, helps me identify the different primitives of the model and the parameters included in every primitive. The model I propose is substantially more complex than the entry models usually presented in the entry literature. However, the use of outcome information in my estimation should help identify these primitives. I leave for future work a more formal argumentation of the identification.

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 "greenfield-only" 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)[42]. 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 Estimation using ordinary least squares

Since I can observe in my rich database the plant-level prices, quantities, marginal costs, capital, etc. I want to use it as an opportunity to easily estimate the primitives of my model by regressing the corresponding variables. The demand and capital equations can be estimated immediately in a simple linear model, whereas the marginal cost equation just requires a log linearization in order to use OLS. This is an interesting comparison exercise because these variables are rarely observed in the data sets used in the structural entry models found in the literature. This exercise can be applied to the price, cost and investment primitives, but the estimation of other parameters (fixed greenfield costs, equilibrium selection, etc) require a structural approach. The biases found in my OLS regressions compared to the structural estimates show also the important selection problems present when trying to estimate these primitives

[42] I use the same outcomes in the moments for the estimation. Also, to facilitate the comparison between the two estimators, the same potential entrants in every market-year and the same errors for the simulation are used.

using simple regression methods.

7.8 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 with some exceptions[43] (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 of years instead of a cross section to estimate a static entry model could be 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. To control also for dynamic considerations in the entry decision by firms, I use as construction activity the value of income in the construction sector averaged over ten years after the entry.

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 firms in all other markets for the same year (I also add to the set of potential entrants the actual entrants of that market if there was entry in that market-year).

The observed firm characteristics of potential entrants that I consider are firm size, firm-level TFP and a binary variable equal to one if the firm is a new firm in the cement industry ("insider"). To generate firm size I aggregate all the plant-level revenues of all manufacturing plants in all manufacturing sectors that are owned by every firm. I find substantial variation in this variable, because some firms are very

[43] It is convenient to divide some large states (California, Texas, Pennsylvania and New York), which is a common practice in the USGS Reports about the cement industry. Due to its small size, it is also convenient to aggregate same contiguous states in the east coast (Rhode Island, Vermont, etc.)

small firms with few manufacturing plans, and other firms are large conglomerates with interests in many industrial sectors. This variable is a proxy variable for experience or some comparative advantage. Firms with high experience in the manufacturing sector may have a greater advantage to successfully enter and compete in the cement industry.

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.

7.9 Computational details

7.9.1 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 solution of the merger game, which has to be calculated for every possible vector of strategies a.

The fast computation of all equilibria in my model is the most challenging 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) instead of the two actions (enter, no enter) considered in the "standard" entry models. Therefore, the number of pure strategy possible equilibria is significantly higher. 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.

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[44].

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 (see proposition 2).

Third, I use a reasonable number of potential entrants (five potential entrants in every market). This is convenient but it is not an unrealistic assumption in the cement industry. As we can see from the table 1 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) and markets usually have a small number of plants, with some markets not having any plants. This means that it is an accurate approximation to consider five as the number of potential entrants in every 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 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.

8 Estimation results

The estimation results are presented in the appendix 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 estimated parameters have intuitive signs. In the case of the demand parameters, one extra million short ton of cement produced

[44] Although the existence of mixed equilibria is more likely 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.

by a plant decreases the price by almost 19 deflated dollars, whereas the effect of competitors is much smaller (which suggests a high degree of spatial differentiation[45]), and consistent with Foster et al. (2010), I find a "demand deficit" of new greenfield plants equal to -1.74 deflated dollars.

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 on the variable cost is about 27.9%, about four times bigger than the weight of salaries. Also, I find that the decrease in costs is about 6.4% for every census year (which a similar reduction when the plant is a greenfield plant) and that capital and TFP reduce the variable costs of production by 10% and 9.1% respectively. Finally, firms that have experience in the cement industry (insider firms) reduce costs by about 13.9%, a relatively high value, similar in magnitude to the effect of TFP in the reduction of costs.

For the case of the entry cost, I find a sunk cost of entry in the market for new greenfield plants of 27.8 million dollars with an additional cost of 10.58 million dollars for years 1992-1997. Of course, to fully understand the significance of this result, the estimated parameter has to be rescaled with the typical lifespan of a cement plant. This is because we are considering a static model where entrant firms are assumed to live for only one period. Also, I find a positive value in the equilibrium selection parameter, which shows that observed equilibria in the market are more likely to be the observed ones.

In the estimation of the fixed merger costs, I find a value equal to 20.5 million dollars with an additional negative value of -18.2 million dollars during the merger waves of years 1982-1992. This result shows how, other things equal (in particular, the comparative advantages of entrants with respect to incumbents), entry by acquisition was more favorable during the 1980's with a net fixed cost of mergers equal to 20.5-18.2=2.3 million dollars which explains the merger waves in those years. The Reagan administration had a relaxation of antitrust enforcement standards and this could be an important reason for this result, although there could be other reasons like changes of tax laws in the 1980's.

[45] This relatively small competitive effect suggests that the creation of a new competitor when an entrant firms wants to build a new plant is not an important effect to consider in its entry decision.

Finally, 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 high and may show the typical high selection bias present in these models. Also, as it would be expected, the biases by assuming no mergers are smaller than OLS. Comparing the two entry models, the bias is specially high for the sunk entry costs for 1992-1997. The intuition for this result is the following: The estimations from the "wrong model " imply that entry is less profitable than in the "true model" for those years. 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

In this section, I use the estimates of the model to conduct 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, there are policies that affect the construction of new plants. In this industry where environmental factors are quite controversial, an environmental regulation is a good candidate for policies that increase the cost of greenfield entry. Factors such as CO_2 emissions, energy use or other environmental impacts have been considered in the last decades in terms of governmental regulation (for example, see 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)[46]. Variation over the years of these policies could help explain the decrease in greenfield plants during the last decades.

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[47].

[46] Also, we have 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.

[47] Recently, the Bush Administration revised some environmental regulations making this asymmetry even stronger. Accord-

This is what is usually called "grandfather" rules versus new source regulations[48].

Second, there are policies that affect entry by acquisition. This is the case of antitrust or other policies that make it more difficult for firms to acquire other firms. 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 (over-investment in new plants) or negative environmental consequences. We observe variation of these policies due to changes in regulations, different approaches to mergers by different governments depending on the ideology of the administration in the Federal Government[49]. These observed variations could help partially explain the changes in merger waves over the years[50]. Also, in the cement industry there has already been some antitrust policy debate about the possible negative effects of expansion by acquisition in the U.S. cement industry (see for example FTC (1966)).

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, concentration, variations in productivity, prices, quantities produced, welfare changes and others.

The intuition for the effects of every type of policy on the market equilibrium can be explained as follows: A policy that makes entry by acquisition more expensive reduces the number of acquisitions in the markets. Therefore, it is more difficult for inefficient incumbents to be acquired by efficient entrants. As a result, the cost of production increases and prices increase. On the other hand, some entrants will enter by building new plants because now it is more profitable than entering by acquisition. This increases competition in the market and prices decrease. Hence, we have two opposite effects that will affect the structure of the market, prices, welfare, etc. We can apply a similar argument for a policy that makes greenfield entry more expensive. The counterfactual experiments will determine the relative importance of these effects given the estimated parameters of the cement industry shown in the previous section.

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ing 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 emission 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."

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

[49] For example, we observe clear swings in the antitrust policies in the last thirty years, like the cases of the Republican administration in the 1980s and the Clinton's administration. Contrary to the former George W. Bush administration, the new Barack Obama administration is giving clear signs about a more stringent future antitrust policy (see Varney (2009)).

[50] See Golbe and White (1988) for a study of the determinant of mergers in U.S. for the period 1948-1984.

I study three particular cases: First, I study the effects of the Clean Air Act Amendments of 1990 by eliminating the estimated sunk costs for the period 1992-1997. Second, I study the effects of more favorable policies for entry by acquisition during the Reagan-Bush years (1982-1992) by eliminating the estimated merger costs for the period 1982-1992. Finally, I study the behavior of the industry for the entire sample by changing the entry barriers to acquisition and to greenfield entry for the entire sample 1963-2002.

In the appendix (see tables 11-15), I show the results of the three proposed counterfactual policies. For every case, I show the results of the experiments and I compare them with the simulated case of the industry with the estimated parameters (without changing any parameter) to compare the actual situation with the counterfactual situation. I also show how these experiments change when I use the "wrong" estimated model where acquisitions are not considered.

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

9.1 Counterfactual experiment 1: Effect of CAA Amendments of 1990 (years 1992-1997)

To evaluate the effect of the CAA Amendments of 1990, I eliminate the estimated increase of sunk entry costs for greenfield entry of 10.58 million dollars for that period of time. By comparing the actual equilibrium and the counterfactual equilibrium, we observe that the CAA Amendments have a significant impact on the quantities produced (quantities would increase from 198 to 252 million short tons without the CAA Amendments), prices (from 51 to 50 dollars) and consumer surplus (from 2.3 to 3.1 billion dollars, a 34.7% increase). 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 previously entered by greenfield entry because it was more profitable than entering by acquisition, however it is now more profitable to enter by acquisition due to the higher entry barriers to the construction of new plants): The number of greenfield entrants is 81% smaller. On the other hand, the mergers increase with the regulation from 57 to 59 acquisitions for that period (a 3.5% 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.

9.2 Counterfactual experiment 2: Effect of Reagan-Bush years (years 1982-1992)

To evaluate the effect of the Reagan years on the market, I eliminate the estimated decrease of fixed cost of acquisition of -18.2 million dollars for that year. Concerning the number of entrants, as we would expect, we have a significant direct effect of the policy that favors mergers on the number of entrants by acquisition and a smaller indirect effect on the number of greenfield entrants (due to the substitution effect: some firms previously entered by acquisition because it was more profitable than greenfield entry, however, it is now more profitable to enter greenfield due to the higher entry barriers to acquisitions). As a consequence, the number of mergers decreases from 154 to 14 (a 90% decrease) and the number of greenfield entrants increases from 33 to 40 (a 21% increase). In addition, new investment increases from 0.4 to 0.5 billion dollars (a 25% increase). Also, prices decrease from 49 dollars to 47 but consumer surplus decreases from 7.0 to 6.1 billion dollars.

If we compare counterfactual experiments 1 and 2, we see that the environmental regulations in the 1990s had a stronger impact on welfare than during the Reagan years. The reason is that according to the estimated parameters, the competitive effect of a policy that introduces barriers to new entry is more important that the inefficiencies arising when inefficient incumbents can not be acquired because entry barriers to acquisition increase.

9.3 Counterfactual experiment 3: Effects of a general increase of entry barriers (years 1963-2002)

To consider the effects of these policies, I consider an arbitrary increase in the sunk entry cost of 25% that makes greenfield entry more costly than the estimated entry cost in the industry (equivalent to 6.8 million dollars). I also assume the same absolute increase of 6.8 million dollars for the fixed merger cost of every acquisition.

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

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.

We observe that under the environmental policy the number of greenfield entrants decreases from 110 to 38, whereas the number of acquisitions increases from 177 to 180 (this is the "new source bias" commented before).

Also, a more restrictive antitrust policy decreases mergers from 177 to 83,whereas the number of greenfield entries increases from 110 to 115. It is also interesting to show the increase in investment of new plants when there are merger barriers that make acquisitions more difficult: This new investment increases by 5.8% due to the substitution effect.

We observe that the consumer surplus decreases more in the case of barriers to greenfield entry than in the case of barriers to acquisition. The reason is that according to the estimated parameters, the competitive effect of a policy that introduces barriers to new entry is more important that the inefficiencies arising when inefficient incumbents can not be acquired because entry barriers to acquisition increase. This result suggests that assuming identical entry costs, a barrier to new entry is always more negative than a barrier to acquisition.

10 Conclusion and future applications

This paper proposes and estimates an empirical entry model where entrants have two choices to expand into markets: by building new facilities or by acquiring local incumbents. These are very common means of expansion in many industries, but the structural empirical entry literature has traditionally considered that greenfield is the only mean of entry. To model this dual entry decision, I formulate a multistage entry model where entrants sequentially decide upon the type of entry, the quantity of new capital to be built and the incumbent to acquire. Barriers to the construction and the acquisition of plants and comparative advantages of entrants with respect to local incumbents are important determinants of the mode of expansion. By using a recent estimator by Bajari et al. (2010), I 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 not considered, and also to OLS estimates. Finally, I use my model estimates to solve for the industry equilibrium in order to determine the effects of different environmental policies that have affected the barriers to enter by greenfield or by acquisition during the last 30 years. My results suggest that for this industry, regulations that create barriers to greenfield entry are less favorable in terms of welfare than regulations that create barriers to entry by acquisition because the competitive effects have a greater effect than the effect of reallocating assets from inefficient firms to more efficient entrants.

Finally, I conclude by noting that the main elements used in my model (efficiencies, entry barriers, competition, etc) and the mechanism that is driving the equilibrium in the markets can be easily found in many other industries. Therefore, the results from my analysis related with the specific case of the U.S. cement industry should not be as important as more general conclusions about the determinants of other types of entry in many other industries[51].

[51] For example, in a recent paper about the banking industry, Giannetti et al. (2010) found that the greenfield/merger entry decision by banks in European countries is affected by the type of credit register (private or public) in every country. This difference affects essentially the entry barriers to greenfield entry (or creates a different "demand deficit" as found by Foster et al. (2010)) that my model is taking into account.

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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

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

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 shares 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) uses reported book values of buildings and machineries and deflates 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, the year in the market and input prices (electricity, fuel and salary). Therefore, there is a total of $242 \times 6 = 1452$ 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, the observed average marginal cost, and the total number of incumbents acquired in every market. As in the case of observed strategies, I use the identity function (no interaction), the construction activity in the market, the year in the market and input prices (electricity, fuel and salary). Therefore, I have in total $5 \times 6 = 30$ moments.

Therefore, in my estimation I use $1452 + 30 = 1482$ moments.

In the case of the estimation when I assume a "wrong" entry model, I build the moments in a similar way (except using the number of acquired incumbents). Since the entry game has 2 choices, we have $2^5 - 1 = 31$ possible strategies, so the total number of moments used is $31 \times 6 + 4 \times 6 = 210$ 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 Facts about expansion

Table 4: Changes in TFP level

TFP level	(1)	(2)
changeownership	0.150	0.044
	(0.049)	(0.050)

Notes: OLS regression of changes of plant-level TFP (with respect to the previous census year) on plant changes of ownership. (1): No dummies. (2):Year dummies. Standard errors in parenthesis.

Table 5: Changes in Relative TFP level

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

Notes: OLS regression of relative change of plant-level TFP (relative to the average TFP level in the country, change with respect to previous census year) on plant changes of ownership (1): No dummies. (2):Year dummies. (3):Year and market dummies. Standard errors in parenthesis.

Table 6: 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)

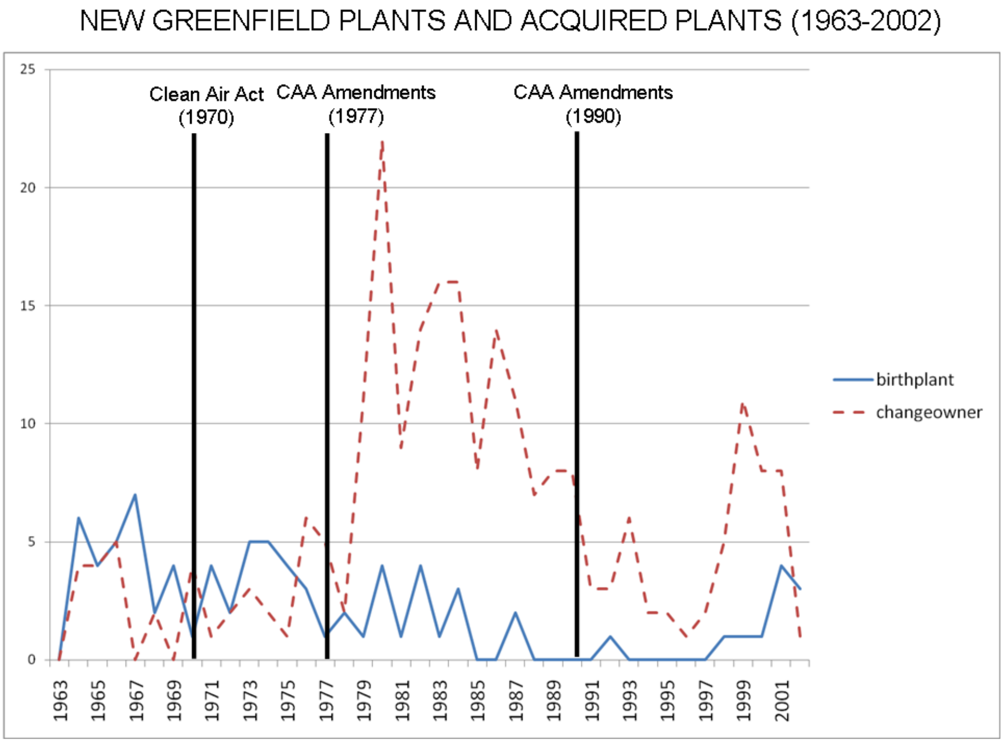
Notes: OLS regression of changes of TFP levels on TFP differences between buyers and sellers. (1): No dummies. (2):Year dummies. 92 plants used. Change of TFP: Change of plant-level TFP of the acquired plant at the year of the acquisition (with respect to the previous census year). Difference TFP buyer-seller: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

Table 7: Construction of new plants

Construction of new plant	
Construction activity	0.0382
	(0.0087)
Years 1992-1997	-0.315
	(0.135)

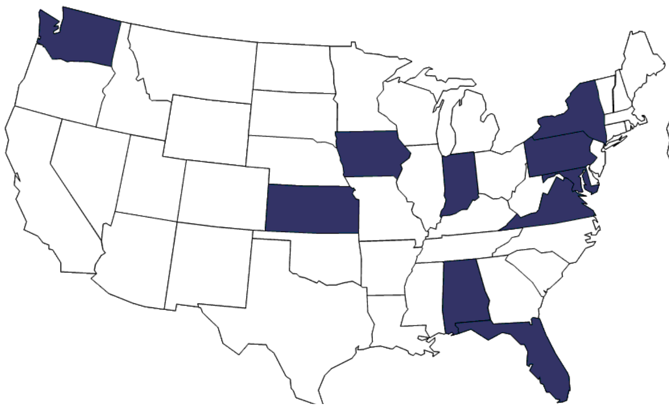
Notes: Probit regression. Construction activity in billion dollars. Standard errors in parenthesis.

E New plants and number of mergers in the industry

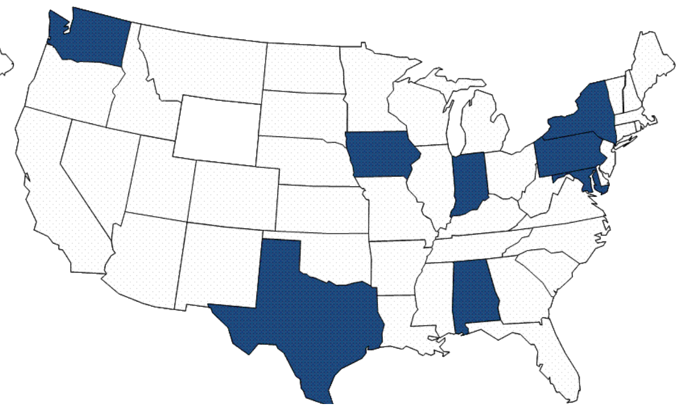


F Maps of some industry leaders

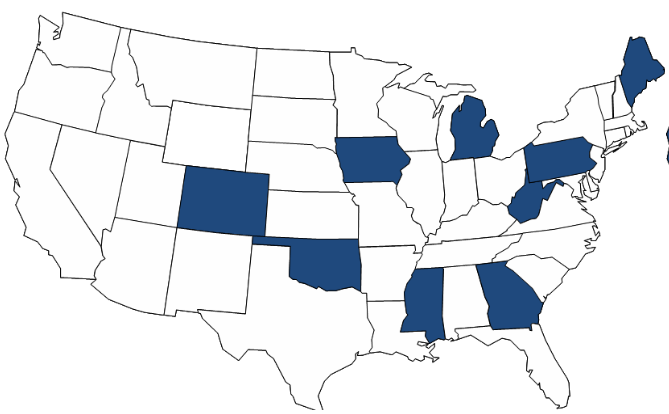
LEHIGH PORTLAND(1967)



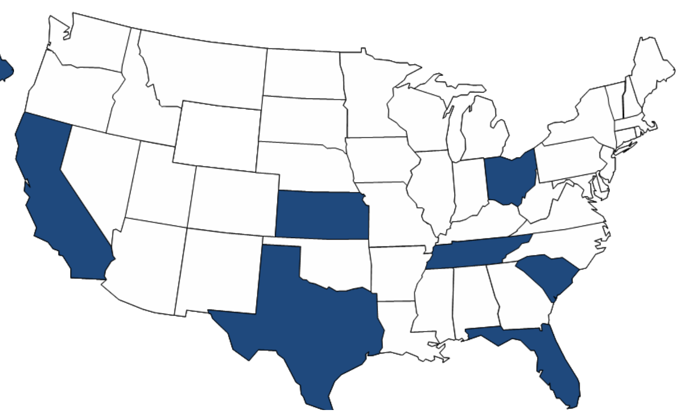
HEIDELBERG ZEMENT (1987)



MARTIN MARIETTA (1972)



GENERAL PORTLAND(1972)



G Estimation results

Table 8: Estimates of the model (I)

	SMM (true model)	SMM (wrong model)	OLS
Demand parameters:			
Quantity	-19.18	-12.21	-9.84
	(2.42)	(7.42)	(1.33)
Quantity of competitors	-1.13	-1.21	-0.85
	(0.31)	(0.87)	(0.405)
Construction activity	0.102	0.102	0.073
	(0.079)	(0.036)	(0.131)
New plant	-1.74	-1.91	-1.19
	(0.47)	(0.308)	(1.33)
Standard deviation of price	7.84	9.67	12.19
	(2.33)	(1.10)	
Optimum investment parameters:			
Log of size	0.359	0.323	0.564
	(0.082)	(0.044)	(0.097)
TFP	-1.425	-1.509	-1.297
	(0.14)	(0.20)	(0.330)
Log of number of plants in market	-1.47	-1.336	-0.109
	(0.252)	(0.71)	(0.357)
Standard deviation of error term	0.916	0.68	2.229
	(0.011)	(0.049)	
New capital cost parameters:			
Capital variable term	0.227	0.304	
	(0.015)	(0.095)	
Sunk cost 1963-2002 (in m. dollars)	27.78	30.53	
	(8.00)	(14.01)	
Additional sunk cost 1992-1997 (in m. dollars)	10.58	24.85	
	(1.210)	(4.839)	
Equilibrium selection rule:			
Profit maximizing equilibrium	2.233	1.85	
	(0.91)	(0.409)	

Notes: Standard errors in parenthesis. Prices expressed in deflated dollars per million short ton of cement. Construction activity measured in deflated billion dollars (measured as personal income), averaged over 10 years after the year of entry. Capital cost in million deflated dollars.

Table 9: Estimates of the model (II)

	SMM (true model)	SMM (wrong model)	OLS
Marginal cost parameters:			
Size	-0.012	-0.010	-0.022
	(0.0021)	(0.0036)	(0.014)
TFP	-0.10	-0.113	-0.310
	(0.006)	(0.044)	(0.058)
Year trend	-0.064	-0.064	-0.0504
	(0.030)	(0.013)	(0.011)
Capital	-0.091	-0.091	-0.062
	(0.033)	(0.006)	(0.011)
Wages	0.076	0.077	0.362
	(0.005)	(0.017)	(0.144)
Fuel price	0.279	0.247	0.524
	(0.053)	(0.073)	(0.115)
Electricity price	0.085	0.082	0.119
	(0.016)	(0.049)	(0.076)
New plant	-0.033	-0.037	0.128
	(0.015)	(0.024)	(0.091)
Insider firm	-0.139	-0.121	-0.106
	(0.037)	(0.017)	(0.062)
Age of plant	0.071	0.064	0.0074
	(0.01)	(0.013)	(0.008)
Constant (marginal cost)	5.06	5.15	4.96
	(2.56)	(1.21)	(0.50)
Standard deviation of error term	0.147	0.153	0.349
	(0.023)	(0.055)	
Fixed merge cost (in m. dollars):			
Fixed merge cost (1963-2002)	20.54		
	(6.866)		
Additional fixed merge cost (1982-1992)	-18.25		
	(4.33)		

Notes: Standard errors in parenthesis. Marginal costs expressed in deflated dollars per million short ton of cement. Capital expressed in deflated dollars.

Table 10: Biases from the true model (in percentage deviation from the estimations of the true model)

	SMM (wrong model)	OLS
Demand parameters:		
Quantity	-36.34%	-48.69%
Quantity of competitors	7.08%	-24.77%
Construction activity	0%	-28.43%
New plant	9.77%	-31.61%
Standard deviation of price	23.34%	55.48%
Optimum investment parameters:		
Log of size	-10.03%	57.10%
TFP	5.89%	-8.98%
Log of number of plants in market	-9.11%	-92.58%
Standard deviation of error term	-25.76%	143.34%
Marginal cost parameters:		
Size	-16.66%	83.33%
TFP	13.00%	210.00%
Year trend	0%	-21.25%
Capital	0%	-31.86%
Wages	1.31%	376.31%
Fuel price	-11.47%	87.81%
Electricity price	-3.52%	40.00%
New plant	12.12%	-487.87%
Insider firm	-12.95%	-23.74%
Age of plant	-9.85%	-89.57%
Constant (marginal cost)	1.77%	-1.97%
Standard deviation of error term	4.08%	137.41%
New capital cost parameters:		
Capital variable term	33.92%	
Sunk entry cost	9.89%	
Sunk entry cost (1992-1997)	134.87%	
Equilibrium selection rule:		
Profit maximizing equilibrium	-17.15%	

H Counterfactual experiments

Table 11: Counterfactual policy experiments: Period 1963-2002 ("true" model)

	Simulated values (true parameters)	Counterfactual (I): Higher merger costs	Counterfactual (II): Higher greenfield barriers
Average Price (in dollars)	50	49	50
Total production (m. short tons)	833	803	747
Total net consumer surplus (b. dollars)	13.2	12.7	11.8
Total variable cost (b. dollars)	24.7	23.7	22.7
Total revenues (b. dollars)	41.4	39.5	37.0
Average marginal cost	30.3	30.4	30.6
Average maximum TFP	4.24	4.19	4.22
Total new capital (b. dollars)	1.7	1.8	0.6
Total number of greenfield entrants	110	115	38
Total number of acquisitions	177	83	180

Notes: Values in this table are obtained by solving for all equilibria in every market 150 times and using the estimated equilibrium selection rule to determine the average outcome in every market. Model used is the entry model where firms can enter by acquisition or by building new plants. Simulated values (true parameters)are obtained using the estimated parameters. Counterfactual experiment (I) is obtained by increasing greenfield sunk entry costs for all years by 25 percent. Counterfactual experiment (II) is obtained by increasing greenfield sunk entry costs for all years by 25 percent. Average price is obtained by dividing total revenues by total quantities in U.S.. Numbers are rounded for disclosure reasons

Table 12: Counterfactual policy experiments: Period 1982-1992 ("true" model)

	Simulated values (true parameters)	Counterfactual (I): Merger benefits eliminated	Counterfactual (II): Higher greenfield costs
Average Price (in dollars)	49	47	48
Total production (m. short tons)	338	286	308
Total net consumer surplus (b. dollars)	7.0	6.1	6.4
Total variable cost (b. dollars)	10.1	8.4	9.3
Total revenues (b. dollars)	16.7	13.4	14.9
Average marginal cost	33.0	34.6	36.7
Average maximum TFP	3.66	3.61	3.64
Total new capital (b. dollars)	0.4	0.5	0.02
Total number of greenfield entrants	33	40	2
Total number of acquisitions	154	14	156

Notes: Values in this table are obtained by solving for all equilibria in every market 150 times and using the estimated equilibrium selection rule to determine the average outcome in every market. Model used is the entry model where firms can enter by acquisition or by building new plants. Simulated values (true parameters)are obtained using the estimated parameters. Counterfactual experiment (I) is obtained by eliminating the merger benefits estimated for 1982-1992. Counterfactual experiment (II) is obtained by increasing the greenfield entry costs by the same amount as in experiment (I).Average price is obtained by dividing total revenues by total quantities in U.S.. Numbers are rounded for disclosure reasons

Table 13: Counterfactual policy experiments: Period 1992-1997 ("true" model)

	Simulated values (true parameters)	Counterfactual (I): Greenfield costs eliminated	Counterfactual (II): Merge costs eliminated
Average Price (in dollars)	51	50	52
Total production (m. short tons)	198	252	207
Total net consumer surplus (b. dollars)	2.3	3.1	2.5
Total variable cost (b. dollars)	5.9	7.1	6.2
Total revenues (b. dollars)	10.1	12.7	10.7
Average marginal cost	25.7	26.4	25.0
Average maximum TFP	3.37	3.41	3.38
Total new capital (b. dollars)	0.2	0.7	0.1
Total number of greenfield entrants	10	53	9
Total number of acquisitions	59	57	89

Notes: Values in this table are obtained by solving for all equilibria in every market 150 times and using the estimated equilibrium selection rule to determine the average outcome in every market. Model used is the entry model where firms can enter by acquisition or by building new plants. Simulated values (true parameters)are obtained using the estimated parameters. Counterfactual experiment (I) is obtained by eliminating the extra greenfield entry costs estimated for 1992-1997. Counterfactual experiment (II) is obtained by decreasing the merger entry barriers by the same amount as in experiment (I). Average price is obtained by dividing total revenues by total quantities in U.S.. Numbers are rounded for disclosure reasons

Table 14: Counterfactual policy experiments: Period 1963-2002 ("wrong" model)

	Simulated values (true parameters)	Counterfactual experiment: Higher greenfield barriers
Average Price (in dollars)	50	51
Total production (m. short tons)	1093	1002
Total net consumer surplus (b. dollars)	16.5	15.0
Total variable cost (b. dollars)	35.1	33.2
Total revenues (b. dollars)	57.2	53.3
Average marginal cost	31.1	31.7
Average maximum TFP	4.28	4.24
Total new capital (b. dollars)	5.9	3.3
Total number of greenfield entrants	118	68

Notes: Values in this table are obtained by solving for all equilibria in every market 150 times and using the estimated equilibrium selection rule to determine the average outcome in every market. Model used is the entry model where firms can only enter by building new plants. Simulated values (true parameters)are obtained using the estimated parameters. Counterfactual experiment is obtained by increasing greenfield sunk entry costs by 25 percent. Average price is obtained by dividing total revenues by total quantities in U.S.. Numbers are rounded for disclosure reasons

Table 15: Counterfactual policy experiments: Period 1992-1997 ("wrong" model)

	Simulated values (true parameters)	Counterfactual experiment: Eliminate greenfield barriers
Average Price (in dollars)	51	49
Total production (m. short tons)	267	356
Total net consumer surplus (b. dollars)	3.1	4.6
Total variable cost (b. dollars)	8.2	9.9
Total revenues (b. dollars)	13.5	17.5
Average marginal cost	27.7	25.6
Average maximum TFP	3.35	3.48
Total new capital (b. dollars)	0.4	2.8
Total number of greenfield entrants	9	58

Notes: Values in this table are obtained by solving for all equilibria in every market 150 times and using the estimated equilibrium selection rule to determine the average outcome in every market. Model used is the entry model where firms can only enter by building new plants. Simulated values (true parameters)are obtained using the estimated parameters. Counterfactual experiment is obtained by eliminating the extra greenfield entry costs for 1992-1997. Average price is obtained by dividing total revenues by total quantities in U.S.. Numbers are rounded for disclosure reasons