Cementing Relationships: Vertical Integration, Foreclosure, Productivity, and Prices[*]

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August 2005

Abstract

This paper looks at the reasons for and results of vertical integration, with specific regard to its possible effects on market power as proposed in the theoretical literature on foreclosure. It uses a rich data set on producers in the cement and ready-mixed concrete industries over a 34-year period to perform a detailed case study. There is little evidence that foreclosure effects are quantitatively important in these industries. Instead, prices fall, quantities rise, and entry rates remain unchanged when markets become more integrated. We suggest an alternative mechanism that is consistent with these patterns and provide additional evidence in support of it: namely, that higher productivity producers are more likely to vertically integrate, and as has been documented elsewhere, are also larger, more likely to grow and survive, and charge lower prices. We explore possible sources of vertically integrated producers' productivity advantage and find that the advantage is tied to firm size, possibly in part through improved logistics coordination, but not to several other possible explanations.

I. Introduction

Is vertical integration a device for firms to create and harness market power, or does it enhance efficiency and improve social welfare? This paper looks at this issue in two vertically linked industries, using a rich data set on their producers, by investigating patterns of prices, entry, exit, productivity, and scale across integrated and unintegrated firms.

The reasons for, and results of, vertical integration (VI) have been a topic of considerable attention since Coase's (1937) landmark paper. Economic theories of vertical mergers have evolved both in response to and as drivers of antitrust policy. Recent years have seen a surge in new theoretical work on the topic, particularly with regard to formalizing and extending the theoretical arguments for the possible harm that can arise through vertical integration's foreclosure, or market power, effect.[1]

This study utilizes integration episodes in the cement (SIC 3241) and ready-mixed concrete (SIC 3273) industries between 1963 and 1997 as an empirical laboratory to investigate the causes and consequences of vertical mergers, particularly regarding evidence on the predictions of modern foreclosure theory.[2] We do not find that foreclosure is quantitatively important in these industries. Instead, prices fall, quantities rise, and entry rates remain unchanged when markets become more integrated. We go on to suggest an alternative mechanism that is consistent with the observed patterns. Specifically, the data may reflect the growth of more productive firms as they compete with and sometimes force the exit of less efficient producers. If these high-productivity firms are more apt to integrate, and we show evidence below that this is the case, then all of the empirical patterns we document can be explained.

Several features of the cement and ready-mixed concrete industries make them favorable for a case study. Their downstream markets are highly geographically segmented (especially for ready-mixed, where the vast majority of output is shipped less than 100 miles). These nationwide industries are therefore actually collections of many quasi-independent geographic

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[1] Recent examples from this literature include Salinger (1988), Ordover, Saloner, and Salop (1990), Hart and Tirole (1990), Bolton and Whinston (1993), Riordan (1998), and Nocke and White (2005). Snyder (1995), Rey and Tirole (forthcoming), and Bernheim and Whinston (2004) offer comprehensive surveys.

[2] While often interchanged colloquially, cement is *not* concrete. Cement—made by baking limestone and clay or shale together in a kiln and grinding the result into a powder—is a single but important ingredient in concrete production. Ready-mixed concrete is produced by mixing cement with sand, gravel, water, and chemical admixtures, and is what is contained in the familiar trucks with the spinning barrels on their backs. Thus cement is the upstream industry and ready-mixed the downstream industry.

markets, providing us with considerable variation to empirically identify effects of interest.

Second, cement and ready-mixed are relatively homogeneous in physical attributes and have little brand differentiation. Therefore the competitive effects we might find—on prices, for instance—more likely arise from market structure changes than from product mix alterations.

Third, we have access to detailed plant-level production information for these industries. This affords more variation in vertical market structures (thousands of producers operating in hundreds of local markets over a 34-year time span) than was typically available to previous researchers, and it allows us to study interacting effects that previous studies by necessity examined in isolation. But perhaps more importantly, it means we can explore for the first time elements of theoretical models that have not yet (to our knowledge) been studied empirically. These include vertical integration's long-run competitive impacts, specifically with regard to entry and exit. They also include the links between productivity and integration which, as we detail below, provide an alternative explanation to foreclosure for the empirical results.

Finally, vertical integration among producers in these two industries was the focus of substantial policy attention. U.S. antitrust authorities challenged the legality of several mergers in the late 1960s and early 1970s (no other industry saw as many vertical merger cases brought), and more recent cases have been brought by competition authorities in Europe and New Zealand. Thus our findings may be interesting from a policy evaluation perspective.[3]

This paper builds on an empirical literature that, compared to the resurgent theoretical literature surrounding the vertical foreclosure debate, has been relatively thin. Grimm, Winston and Evans (1992) study railroad destination pairs served by a single firm and find that increased interline competition—competing railroads that connect intermediate points on the otherwise monopolized route—reduces welfare distortion. Waterman and Weiss (1996) and Chipty (2001) show that U.S. cable television systems integrated with content providers are more likely to include their own suppliers' paid content. Chipty (2001), however, argues that higher quality programming is offered in integrated markets, resulting in higher consumer surplus. Hastings and Gilbert (2002) utilize both within- and across-market variation in integration status among producers of wholesale gasoline. They examine the effect of vertical mergers on the wholesale price paid by competing independent gasoline retailers, and find that the closer the competitor,

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[3] It should be made clear that we are not trying to evaluate the appropriateness of the antitrust authorities' actions in any particular case. We are investigating *all* mergers between U.S. producers in the two industries, not just those that were the subject of legal action.

the higher the wholesale price it has to pay.[4] Asker (2004) tests for foreclosure due to exclusive

dealing relationships in beer distribution and finds no significant evidence that exclusive dealing

increases market power. Rosengren and Meehan (1994) also find no support for foreclosure

theory in event studies of the effects of vertical merger announcements and antitrust challenges

on the stock prices of merging and rival firms. Snyder (1995), however, uses similar methods on

a different set of industries and finds support for foreclosure.[5]

The next section documents cement and ready-mixed concrete's patterns of integration

over the sample period. It also discusses the evolution of economic theories of vertical

integration over the same time frame, because this academic debate was mirrored by adjustments

in policies aimed at vertical integration in the two industries and social welfare. The third

section describes the data used in the analysis. In the fourth section we test the implications of

foreclosure in the industry. We follow with a section examining the evidence for an alternative

explanation for the observed empirical pattern. A short discussion section concludes.

II. Vertical Integration in Cement and Ready-Mixed Concrete: History, Policy, and Theory

Our data spans a 34-year observation period, from 1963 to 1997. Over this time the

cement and ready-mixed industries experienced two distinct periods of integration, separated by

an over decade-long period of initial disintegration and then stability. Table 1, which reports the

fraction of cement and concrete industry plants and sales accounted for by integrated producers

(i.e., plants in firms owning both cement and ready-mixed establishments), shows this evolution.

The first merger wave occurred in the early and mid 1960s and was driven by forward

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[4] Hastings (2004) analyzes the impact of a multi-market vertical merger on *retail* gasoline prices in California. She finds that reducing the market share of unintegrated retailers led to higher retail prices. However, she does not draw any connection with her work with the foreclosure literature, instead ascribing the finding to product differentiation between branded and unbranded gasoline.

[5] The aforementioned policy actions against cement and concrete producers in the 1960s and 1970s also spurred at the time a small literature on the impact of forward integration by cement producers. These papers, however, preceded the recent theoretical literature on foreclosure, and as such do not directly test for such effects. They did, however, center on the issue of whether and how integration might enhance market power. Allen (1971) reviews evidence brought forth in the Federal Trade Commission's 1966 report on these industries (U.S. FTC 1966). While institutionally instructive, this study does not conduct formal statistical tests of economic hypotheses. McBride (1983) attempts to do so, finding a negative correlation between average cement prices in 17 markets and the cumulative number of market ready-mixed plants acquired by cement firms. He explains these results as resulting from the fact that forward integration into concrete makes it easier for cement plants to "adjust" their prices to accommodate demand swings, presumably due to (undocumented) collusive agreements in cement pricing that are be easier to monitor than concrete prices. However, Johnson and Parkman (1987) argue accounting for pre-existing price trends makes this result statistically insignificant.

integration by cement producers. Between 1963 and 1967, the fraction of cement plants owned by vertically integrated firms rose from 21.9 to 47.4 percent. A similar rise (though at a much lower level) occurred in ready-mixed concrete, from 1.8 to 3.2 percent of plants. Fractions of sales due to integrated firms for the respective industries show analogous changes at higher levels, indicating that integrated producers are larger on average.

This initial merger wave received substantial attention from antitrust authorities. The Federal Trade Commission (FTC) brought 15 antitrust cases during the 1960s against cement companies that had purchased concrete firms. Each case ended in the divestiture of ready-mixed plants. The antitrust stance against vertical mergers in the cement and concrete industries is summarized in a report prepared by the FTC (1966). It dismisses efficiency explanations for vertical mergers between the industries and cites several likely anticompetitive effects. The foremost concern is limitation of unintegrated cement firms' market access; the report argues that diminished access to concrete outlets because of integration would in turn lead to higher entry costs for unintegrated cement suppliers, decreasing competition. Moreover, it claims that vertical acquisitions could also increase the entry costs of unintegrated concrete firms. Finally, the report contends that integration of large downstream customers would decrease the remaining ready-mixed producers' bargaining power relative to that of cement producers.

The vigorous enforcement action might explain the chilling of merger activity in this sector throughout the 1970s. At the same time, however, the economic foundations of the so-called "naïve foreclosure theory" exemplified by the FTC report were under attack by "Chicago School" critiques. Allen (1971), Posner (1976), and Bork (1978) pointed out that in cases of fixed-proportions technology (as cement is for ready-mixed concrete), a monopolist upstream producer cannot raise its profits by monopolizing its downstream market.[6] Thus, vertical mergers would only occur if there are efficiency gains.

These and similar arguments influenced antitrust authorities in the Reagan and first Bush administrations and softened official views toward vertical mergers considerably. Indeed, between 1980 and 1992, only two vertical antitrust cases were initiated in any industry. And in 1985, the FTC explicitly eased its enforcement policy regarding cement and ready-mixed vertical

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[6] Vernon and Graham (1971) pointed out that in the case where the downstream firm can substitute away from the monopolist supplier's input, a vertical acquisition may increase the monopolist's profits, though with ambiguous welfare effects.

mergers.[7] Industry firms responded by reintegrating. Between 1982 and 1992, the fraction of cement plants in vertically integrated firms rose from 32.5 to 49.5 percent (the fraction of sales grew from 49.5 to 75.1 percent).[8] For ready-mixed the corresponding growth was from 3.0 to 11.1 percent for plants and an 8.5 to 14.4 percent rise in the share of industry sales.

The theoretical debate pendulum swung back in the other direction in the late 1980s, as several authors formulated game-theoretic models to formalize certain conditions, robust to Chicago School criticisms, under which vertical mergers would have anticompetitive effects. An example of these newer foreclosure models, and one that we believe fits the institutional details of the cement and concrete industries well, is the "ex-post monopolization" model of Hart and Tirole (1990).[9] It is the predictions of this class of models—which form the vanguard of current thinking on the subject—that we seek to test here.

The Hart and Tirole (1990) framework has upstream homogeneous-good producers with asymmetric marginal costs competing in prices. In the cement-concrete context, one can think of these cost differences arising because a local cement producer has a transport cost advantage over more distant producers. In other words, we can without loss of generality think of a local monopolist U providing the essential input.

Suppose that this monopolist supplies two downstream producers, D_1 and D_2. The structure of the game is as follows: U offers each D_i a (possibly nonlinear) tariff $T_i(\cdot)$. D_i then orders a quantity q_i and pays $T_i(q_i)$. The D_i then produce q_i, observe each others' outputs, and set prices. Downstream competition is modeled as Bertrand with capacity constraints, which yields the Cournot outcome under conditions described in Kreps and Scheinkman (1983).[10]

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[7] 50 Federal Register 21507 (1985). The announcement cites "developments in economic thinking" as being in part behind the decision. It also states that mergers in the cement industry after 1977 were no longer subject to special consideration.

[8] The decline in integration seen from 1992 to 1997 was most likely due to a demand-driven bout of unprecedented entry in the cement industry. There was a net gain of 61 plants over the five year period over 1992's 218 plants, which was near the industry's long-run average. These new plants were primarily small, unintegrated plants that specialized in grinding clinker (an intermediate material in the cement-making process) that had been kilned elsewhere, sometimes overseas.

[9] We thank Michael Whinston for an insightful discussion that led us to this model. Incidentally, in a section on applications, Hart and Tirole explicitly cite cement and ready-mixed mergers as involving the anticompetitive effects they highlight. The model is also described in detail in Snyder (1995) Rey and Tirole (2003), and Bernheim and Whinston (2004), and is used in the experimental study of Martin, Normann, and Snyder (2001).

[10] Note that foreclosure is not dependent on the general nature of the reaction functions in the downstream game. While the downstream firms play Cournot here (involving strategic substitutes), other models—e.g., Ordover,

Let (Q^m, p^m) be the monopoly price and quantity if U also had monopoly power in the downstream market. U would like to offer the quantity and tariff schedule $(q_i, T_i) = (Q^m/2,$ $p^m Q^m/2)$ to the downstream producers in order to achieve monopoly profits. However, Hart and Tirole (1990) point out that offering this contract may not be credible if contracts are secret or can be secretly renegotiated ex-post. If one downstream firm did agree on the above contract terms, it can be shown that the monopolist has an incentive to sell more than $Q^m/2$ to the other downstream firm.[11] But this action would lower the profits of the first downstream firm, thereby making it reluctant to sign such a contract in the first place. Hart and Tirole show that the equilibrium of the game with secretly renegotiable contracts has U selling Cournot quantities to the downstream firms, yielding less than the monopoly profit to U.

However, by vertically integrating U can commit to reducing total supply to the monopoly quantity, as an integrated U could sell Q^m through its subsidiary and sell nothing to the other downstream firm. Of course, this polar case is unlikely to happen in reality because the outside downstream firm could try to buy input from a more distant supplier. A more realistic solution to the model is for the integrated firm to instead sell the input to the outside downstream firm at a price that just undercuts the more distant upstream supplier. This leads to an asymmetric Cournot outcome in the downstream market, with the unintegrated downstream firm at a cost disadvantage. The end results of integration, therefore, are higher average prices and lower quantities in the downstream output market. Moreover, if the downstream technology has a fixed operating cost (or in the extreme case where no other upstream supplier is available), exit of unintegrated downstream firms is more likely. While the above version of the model is silent about what happens to (potential) competitors in the upstream market, Hart and Tirole (1990) also provides a variant—the "scarce needs" version, in which two upstream competitors with the same marginal costs but different fixed entry costs—where vertical integration leads to the non-entry of one of the upstream firms.

Therefore we should expect, if foreclosure effects are important, that vertical integration will be associated with higher prices and lower quantities of the final good, higher exit rates among unintegrated producers, and lower entry rates in the upstream and downstream industries.

Saloner, and Salop (1990)—model downstream competition as a differentiated product Bertrand game, where optimal prices are strategic complements.

[11] The monopolist takes $Q^m/2$ as given for the contracted firm, and reoptimizes quantity for the other firm using the "right-shifted" version of the residual demand curve. This yields an optimum quantity that is greater than $Q^m/2$.

We test these implications below.

III. Data

A. *Plant-Level Ownership, Productivity, and Prices*

The core of our analysis uses plant-level microdata from the 1963, 1967, 1972, 1977, 1982, 1987, 1992, and 1997 Census of Manufactures (CM). The CM is comprehensive; we observe every U.S. cement and ready-mixed concrete plant operating in the respective census years. A typical CM has 220 cement and 5200 ready-mixed plants. With the exception of the 1992-1997 period in the cement industry, these plant counts have been roughly constant for the past 30 years, though the stable levels hide substantial plant turnover rates in both industries. The CM microdata contain a wealth of information on plants' production activities that we describe and exploit below. Crucially here, they also contain firm identification numbers for each plant. (Plants, or "establishments" in Census Bureau terminology, are unique physical locations at which products are manufactured. A firm can own one or more plants.) Thus we are able to observe when a single firm owns plants in both industries, in which case we consider the firm and its component plants vertically integrated.

The comprehensiveness of the CM is extremely useful. It allows us to observe each plant's integration status in each census year, and because the CM contains permanent plant identifiers that are invariant to ownership changes, we can track changes in this status over time. Entry and exit of plants between census years are completely observable as well, allowing us to look at vertical integration's long-run impact on markets.

Besides this ownership information, the CM contains data on plant revenues, several employment measures (total number of employees, number of production workers, production worker hours), the book values of and investment in equipment and building capital stocks, inventories, expenditures on inputs (the total wage bill, supplements to wages, production worker wages, energy expenditures, and intermediate materials purchases), and state and county codes. We use the production data both directly and to calculate other technological measures of interest. These include labor productivity (output per hour) and total factor productivity (TFP). Both will play a prominent role in our empirical investigation. Details of these constructions can be found in the data appendix.

For some of our ready-mixed concrete plants, we augment this base data with the CM

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product supplements. These auxiliary files contain, by plant, highly detailed product-level information on outputs (defined at the seven-digit SIC level). This includes the total value and the physical quantity of product shipments. Conveniently for us, most plants in the ready-mixed concrete industry are highly specialized; virtually all of their production—roughly 95 percent of revenue on average—comes from sales of ready-mixed, which is itself a seven-digit product.[12] Therefore for those ready-mixed plants with available product supplement data, we can measure output in either dollars or physical units (cubic yards, in this case). We also use the product-level data to calculate plants' average unit prices (measured on a free-on-board basis), offering a rich set of producer price observations collected across various firm organizational structures and different local markets.[13]

While the CM contains enormous amounts of production information, it does not offer full coverage for every variable discussed above. Very small plants (typically with fewer than five employees)—called Administrative Record (AR) establishments—have imputed data for most production variables. AR plants amount to roughly one-sixth of cement establishments and one-third of ready-mixed plants, but because of their small size they comprise much smaller share of employment (0.6 percent in cement—these are almost surely grinding-only plants without kilns—and 5.1 percent in ready-mixed) and output (0.8 and 4.3 percent in cement and ready-mixed, respectively). Due to the imputations, we exclude AR plants from analyses that compare production variables like productivity, output, or prices. However, we are of course able to use these plants when computing entry and exit rates or integration status. Additionally, not every variable was collected in each census. For example, equipment capital stocks were not collected in 1963 and 1997, making it impossible to compute TFP values and capital-to-labor ratios during these years. Finally, the CM product supplements are not comprehensive; they not only exclude all AR plants, but also have imputed values for some non-AR respondents. We have removed likely imputes (they are not explicitly flagged) from our sample using methods described in Roberts and Supina (1996) and Syverson (2005).

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[12] Other concrete products such as block, pre-fabricated structural members, and pipe are typically made by producers in concrete industries other than SIC 3273. Likewise, the share of these other industries' revenues accounted for by ready-mixed is minuscule.

[13] Unlike the specialized ready-mixed industry, cement plants produce a number of seven-digit products (different cement types based on their chemical composition). This makes cement plants' average unit output prices more difficult to construct and somewhat less meaningful.

B. Local Markets in the Cement and Ready-Mixed Concrete Industries

One of the more useful attributes of these industries as a forum for testing foreclosure theory is the fact that they are comprised of many local markets. This naturally raises the empirical issue of how to define markets for the industries. We choose to use different but closely related market definitions for cement and concrete. For cement, we define a market as a Bureau of Economic Analysis Economic Area (EA). EAs are collections of counties usually, but not always, centered on Metropolitan Statistical Areas (MSAs). Counties are selected for inclusion in a given EA based upon their MSA status, commuting patterns, and newspaper circulation configurations, subject to the condition that EAs contain only contiguous counties. There is no requirement that EA boundaries coincide with state boundaries. The selection criteria ensure that counties in a given EA are economically intertwined. This classification process groups the roughly 3200 U.S. counties into 172 markets that are mutually exclusive and exhaustive of the land mass of the United States.[14]

We choose a smaller market definition for ready-mixed concrete. This is suggested by the fact that average concrete shipment distances are lower than in the cement industry, and by the related facts that there are a much larger number of ready-mixed plants and they are geographically ubiquitous. Conveniently, the Bureau of Economic Analysis disaggregates EAs into Component Economic Areas (CEAs). These subdivisions are again based on commuting and newspaper circulation patterns within EAs to make the divisions as economically natural as possible. There are 348 CEAs, an average of two per Economic Area, but larger and denser EAs typically have more CEAs than do those in less populated areas.[15]

These market definitions are obviously imperfect compromises between conflicting requirements. We especially wish to limit across-market interactions between ready-mixed producers, and CEAs are large enough to do so. While there are bound to be some across-market concrete sales in reality, the high transport costs of the industry—industry managers state maximum ideal delivery distances of 30- to 45-minute drives from the plant—are likely to curtail long-distance shipments. (An additional factor minimizing cross-market shipments is that most CEA boundaries are in outlying parts of urban areas and are thus less likely to be near areas

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[14] See U.S. Bureau of Economic Analysis (1995) for more detailed information about EA creation.

[15] For example, the Kansas City EA is comprised of the Kansas City (Kansas-Missouri), Lawrence (Kansas), and St. Joseph (Missouri) CEAs, while the Bangor (Maine) Component Economic Area is the only CEA in the Bangor EA.

heavily populated with concrete plants.) Balanced against this consideration is to not make markets so large as to result in very little competitive interaction between many of the included establishments. Plants placed in too large a market may not all respond to the same market forces—either external or the actions of industry competitors.

The average number of ready-mixed plants in a CEA market in our sample is 14.8 and the median is 10. The largest market has 124 plants. For the EA cement markets, the mean cement plant count is 1.3 and the median one. The largest market contains 20 cement plants.

C. Market Size and Density

In some of our empirical tests below, we include as covariates measures of the size and density of the local construction sector, the downstream user of the cement and concrete industries' outputs. These are created from County Business Patterns construction sector (SICs 15-17) employment data, aggregated to the CEA and EA levels.[16] Market size is measured simply as logged total construction employment. Density is calculated as the (log of the) number of construction-sector workers per square mile in the market. As discussed in Syverson (2004, 2005), construction activity is likely exogenous to the specifics of local concrete competition because while the construction sector accounts for virtually all ready-mixed sales, concrete's cost share among the sector's intermediate inputs is small. We expect by extension that similar effects operate on a broader geographic scale in cement.

IV. The Extent of Integration and Market Power

We begin our analysis by looking at the primary implications of foreclosure theory: that the increases in market power made possible through vertical integration lead to higher prices and lower quantities downstream in the final goods market, exit of unintegrated producers, and lower entry rates.[17]

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[16] County Business Patterns data occasionally have missing observations due to data disclosure regulations. The construction sector's ubiquity and abundance of small firms allows full disclosure of total employment in nearly all counties, however (employment data is withheld in roughly 1.5 percent of the county-year observations). We impute employment when missing by multiplying the number of establishments in each of nine employment ranges (which are always reported) by the midpoint of their respective employment ranges, and summing the result. The impact of using imputes is likely to be even less than their proportion indicates, as the typically small nondisclosure counties are less likely to contain ready-mixed plants.

[17] A related implication of foreclosure models is that unintegrated downstream producers face higher input costs. Testing this additional implication could in principle be done with our data, because CMs also have a materials

A. Does Vertical Integration Raise Prices?

Foreclosure effects imply a positive relationship between average prices and the extent of vertical integration in a market. We test this in our data by regressing the quantity-weighted average (logged) ready-mixed concrete price in a market—this mean is calculated from our plant-level price data—on two measures of the extent of integration: the total market share and count of vertically integrated firms operating in the market. We also control for market demand density (described above) because Syverson (2005) shows how it impacts average prices through competition-driven selection and markups. Year fixed effects are included in all regressions to account for aggregate movements in industry prices (all prices have been deflated to 1987 dollars using the industry-level price index from the NBER Productivity Database). We cluster standard errors by market to account for temporal correlation in market unobservables.

The results are shown in Panel A of Table 2. Columns 1 and 2 show the benchmark estimates. More integrated markets have *lower* average prices, even controlling for demand density.[18] The estimates imply that going from a market with no integrated producers to one where integrated firms hold a market share of 0.316 (the average share conditional upon at least one VI producer being in a market) corresponds to a four percent decline in the average ready-mixed price, just under one-fourth of the standard deviation across markets. Likewise, the coefficients indicate an additional integrated firm in a market corresponds to a three percent drop in average prices.

These results are not on their face consistent with the positive relationship between prices and integration implied by foreclosure. Of course, the decision to vertically integrate is a choice made by firms, and the extent of integration is not random across our sample markets. This would suggest caution in interpreting the results as reflecting integration's causal impacts. Perhaps integration does facilitate foreclosure but there are market-specific unobservables

supplement that contains plants' total expenditures and purchased quantities of intermediate-input products. This information allows us to compute unit cement prices paid by concrete producers. We found that, rather than unintegrated concrete producers reporting higher cement input prices, there were no significant differences in integrated and unintegrated plants' cement prices. However, it is far from clear what the reported cement prices from integrated concrete makers reflect. The Census Bureau instructs establishments to report the value of internal materials transfers, "at their full economic value (the value assigned by the shipping plant, plus the cost of freight and other handling charges)." It is possible that these results simply reflect integrated plants' "marking to the market" their internal transfer prices.

[18] The density coefficients, not reported here, are negative and significant. Thus the relationship in Syverson (2005) holds when controlling for integration intensity.

correlated with both higher integration intensity and lower prices. However, we make a few observations on this point. First, any such unobservables would have to have particularly strong correlations with higher integration intensity and lower prices to swamp the positive price effects of foreclosure, as the net observed integration-price correlations are substantially negative. Second, it is unclear what the candidates for such unobservables might be. They would have to induce large, expanding firms (which, as we will discuss later, aptly describes integrated firms in these industries) to prefer integrating into markets with idiosyncratically low prices. If anything, one would expect them to expand into markets with positive demand shocks and therefore idiosyncratically high prices. That said, one should minimize any possible endogeneity concerns to the greatest extent possible given the data. We take four distinct approaches toward this end.

The most straightforward approach is to include market (CEA) fixed effects in the regression. This controls for any market-specific unobservables that are constant over time. The results are shown in columns 3 and 4 of Panel A. The negative correlations between average prices and the extent of integration remain, though the coefficients have smaller magnitudes and one loses its statistical significance. The smaller coefficients could result either because there are market unobservables correlated positively with vertical integration and negatively with prices, or because attenuation bias from measurement error (perhaps due to our market definitions imperfectly capturing the true geographic markets) is exacerbated when we identify vertical integration effects only from within-market changes. Regardless, the estimates indicate on balance that not only do more integrated markets have lower prices, but prices also fall within markets as they become more integrated.

The second approach uses the variation in antitrust authorities' enforcement regimes discussed above as an instrument for the extent of integration in a market. The logic is as follows. In January 1967, in response to industry complaints that it was impossible to predict which vertical mergers would be challenged, the FTC announced a set of guidelines that promised challenges to any acquisitions by cement producers of any "substantial" ready-mixed concrete company. "Substantial" was defined as a ready-mixed firm that was one of the four largest in its market or one that used over 50,000 barrels of cement per year (Wall Street Journal, 1967). This rule was dropped by 1977, and as mentioned above, virtually all vertical merger challenges stopped after 1980. The usefulness of this policy to construct an instrument for vertical integration arises because the combined market share of substantial firms plausibly

varies across markets for reasons unrelated to equilibrium prices or quantities (at the very least once exogenous demand is conditioned upon). Therefore some markets are likely to receive more FTC scrutiny than others simply due to the specifics of the rule. Moreover, the fact that the rule was only in effect during the 1967 and 1972 CMs also creates intertemporal variation in enforcement likelihoods. We can use this cross-sectional and time-series variation in likely FTC scrutiny as an exogenous shifter for the extent of integration. One would expect less vertical integration in markets where substantial firms have higher combined market shares during the 1967 and 1972 CMs than in other years or markets where such firms are less prominent.

We therefore construct for each market-year in our sample the total market share of "substantial" concrete firms.[19] We interact this value with an indicator variable denoting the 1967 and 1972 CMs. One should expect that this interaction is negatively correlated with the extent of vertical integration in a particular market-year. First-stage regression results bear this out: while the coefficients on substantial firms' market share are positive for both measures of the market's vertical integration intensity, the interaction effect is negative. That is, markets where firms subject to FTC scrutiny are more prominent are less likely to be vertically integrated during the years the enforcement regime was in effect.[20]

The results of the instrumented specification are shown in columns 5 and 6. The implied impact of vertical integration on prices is insignificant on both cases, reflecting in part the loss of precision from using instruments. The coefficient is positive for the market-share measure of integration intensity and negative for the number of integrated firms. The results in this case are thus inconclusive.

Our third approach estimates price effects using the subsample of CEA-years that were involved in multi-market mergers. The idea, as with Hastings and Gilbert (2002), is to identify integration's impacts using arguably random variation in the extent of integration across the

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[19] Recall that the CM materials supplement allows us to observe the physical quantity of cement purchases for a number of producers. We regressed cement purchases on plant revenues for this set of plants (which tended to be the largest in the industry) to obtain a total firm revenue value such that firms with greater real sales than this would be expected to buy more than 50,000 barrels of cement. This allowed us to determine which firms met the FTC's second definition of "substantial" even if we did not observe physical cement purchases for the entire firm. The first, market-share-based definition requires only revenue data, of course.

[20] The first-stage coefficients are as follows. For predicting the market share of vertically integrated firms, the main effect of the "substantial" firm share is 0.132 (s.e. = 0.025), while the interaction of the substantial share with the 1967/1972 indicator is -0.075 (0.028), which is significant at the one-percent level. The F-statistic for joint relevance of these two instruments is 15.7. For predicting the number of vertically integrated firms, the main effect is 0.408 (0.084), the interaction -0.167 (0.096), and the F-statistic 14.2. All regressions include year effects.

several markets experiencing a single-firm merger. For example, consider the simple case of a cement firm integrating by purchasing a concrete firm that owns two plants, each operating in a different market. One plant has a market share of 20 percent in its local market, and the other a 30 percent share. If the cement firm's decision to integrate with this particular downstream firm was made based on considerations of the target firm as a whole rather than in its specific markets, the change in the extent of integration due to the merger—the market share of integrated firms will grow 10 percentage points more in the second market than in the first—will be exogenous to market-specific outcomes. Hastings and Gilbert use this type of variation from a particular merger in the wholesale gasoline industry that impacted 14 markets. While most of the multi-market mergers in our sample involve a smaller number of markets, we observe not one but many such mergers over our sample.

We define a multiple-market merger to have occurred if the same firm newly integrates plants in at least two different markets between CMs. Such events occurred 29 times in our sample, each involving an average of just under five different markets, giving us a sample of 148 market-years with which to estimate vertical integration's effects. We run the price regressions as before on this subsample but now include merger fixed effects in the regressions. Therefore all the variation in integration intensity used to identify VI's impact comes from across-market variation within particular merger episodes. That is, referring back to the example above, the specification uses the fact that the market-share vertical integration measure was 10 percentage points higher in the second market than in the first and compares this difference to the average price variation between the two markets.

The results using the sample of multi-market merger episodes are shown in columns 7 and 8 of Panel A. Increases in either the market share or number of vertically integrated firms lead to lower prices (although the market-share coefficient is not statistically significant). The magnitude of the significant firm-number VI measure coefficient is roughly comparable with that in the benchmark specification.[21]

The fourth approach repeats the analysis using market-level fixed effects, but this time also controls for the change in the quantity-weighted average TFP among ready-mixed producers

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[21] Recall that the exogeneity argument in this case is that firms make merger decisions on a whole-firm basis, not on the expected market structure change in any particular market they are merging into. Obviously we cannot test this proposition directly. However, arguments that particular market outcomes are instead the primary concern would have to explain, as is implied by the results, why the merging firms choose to most intensively enter markets with idiosyncratically low prices.

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in the market. This should parsimoniously control for efficiency impacts of changes in the extent of integration in the market. Thus any foreclosure-driven price increases that were being hidden by efficiency gains are more likely to be seen in the coefficients on our integration measures.

The results of this exercise are shown in columns 9 and 10 of Panel A (the smaller sample size is due to the fact that we observe prices but not plant TFP levels in 1967). Note first that the average TFP coefficients are negative: growth in the average productivity of a market's producers is associated with declining average prices. Our TFP control does therefore seem to capture efficiency effects on market outcomes. With these controls added, the coefficients on both measures of the extent of integration remain negative, but shrink in size and become insignificant. Hence if changes in average TFP sufficiently capture the efficiency gains that accompany vertical integration, the results suggest the remaining price effects of integration are essentially zero. These coefficients would expectedly be positive if foreclosure were important but hidden by efficiency effects or by unobservables correlated with productivity changes.

On whole, the results do not point to foreclosure-driven price increases. Instead, more vertically integrated markets have lower average prices, and prices fall when integrated producers in a given market becomes either larger or more numerous. Differences in vertical integration intensity across markets that are plausibly exogenous to market-level outcomes also offer no indication that prices rise, and if anything reflect a negative impact of integration on prices. Finally, when we control for efficiency effects by looking at the influence of integration intensity changes that are orthogonal to average TFP gains, we do not find positive residual effects of integration on prices.

We supplement this market-level analysis by looking at vertical integration and plant-level patterns in concrete prices. We regress plants' logged prices (or price growth) on an indicator for a plant's vertical integration status (or change in integration status) and a full set of market-year fixed effects. The coefficient on the vertical integration dummy captures the mean difference in integrated and unintegrated producers' prices (price growth). Note that by including fixed effects, we identify these mean differences by comparing plants within the same market-year, thereby removing the influence of broader spatial or time-specific unobservables.

Panel B of Table 2 shows the results. The first column shows the coefficient on the vertical integration indicator in the logged price regression. On average, integrated producers' charge 2.1 percent lower prices than their unintegrated competitors in the same market. This

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within-market producer-level difference echoes the across-market average price differences. The second column compares price growth patterns among continuing plants (i.e., those that operated in both the previous and current CMs), and we restrict our attention to plants unintegrated in the previous CM. The vertical integration dummy in this case takes a value of one if a plant became integrated between the previous and current CMs. The estimated coefficient implies that these newly integrated plants have somewhat—1.4 percent—more positive price *changes* than their cohorts that remain unintegrated. The difference is not statically significant, however. The third and fourth columns contrast the prices of integrated entrants (plants that appear for the first time in the current CM) to unintegrated entrants and unintegrated incumbents, respectively. (We discuss below why we look in particular on entrants.) All comparisons are again within market-year. As with the broader comparison in the first column, integrated producers' have lower prices than the unintegrated comparison groups. Integrated firms' new plants price 3.5 percent below new plants of unintegrated firms and 2.0 percent below integrated incumbents, though this last difference is not statistically distinguishable from zero.[22]

B. Does Vertical Integration Reduce Quantities?

We use specifications similar to those above to investigate how vertical integration impacts market quantities. We replace the average price as the dependent variable with the total (logged) physical quantity of ready-mixed concrete sold in the market. Here we must be particularly careful with regard to measurement issues. Because the CM product supplement does not cover all plants, we cannot directly calculate total market quantity simply by aggregating reported quantities across all market plants. So we instead use plant revenue, which is available. Yet revenue data alone is problematic because it incorporates price variation across plants. Even though we deflate revenues across years to 1987 dollars using an industry-level price index, we are still faced with the problem that, because the deflator is not market specific, unadjusted revenue overstates (understates) output in markets with higher (lower) than average prices. Our solution is to measure market quantities sold as total market revenues divided by the market's quantity-weighted average price that we use above. Other than this new dependent variable, the only difference in these market quantity regressions from the price regressions

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[22] Note that the market-level price differences we find above reflect not only these within-market price differences between integrated and unintegrated producers, but also changes in the market's average price level across induced by the entry or expansion of integrated producers in a market.

above is that we replace density with our market demand measure, logged total construction sector employment. This is because of the conceptual necessity of controlling for overall market size when looking at quantity effects (not surprisingly, market demand enters positively and significantly in all the market-level quantity regressions discussed below). As with the price regressions, we estimate several specifications.

The results are presented in Panel A of Table 3. Greater vertical integration is associated with higher output levels. This is true in the cross section, as seen in the benchmark regressions in the first two columns, where the coefficients on both the market share and number of VI firms are positive and imply sizeable corresponding quantity gains with respect to the extent of integration. The estimates imply roughly 20 percent more output is sold in a market where integrated firms have a 0.316 market share than in another of the same size without any integrated producers. An additional vertically integrated firm in a market implies a quantity increase of similar size.[23]

Similar patterns are seen in response to changes in integration within markets. Columns 3 and 4 of the table show the results when market fixed effects are included. There are positive and significant increases in output when a market becomes more integrated.

The specifications using the "FTC scrutiny" instruments and the multi-market merger approaches described in the previous section are shown in columns 5 through 8. Positive point estimates remain in all specifications. The point estimates in the instrumental variables specification are comparable to those in the benchmark specification, but they are imprecisely estimated and not statistically significant. One of the multi-market merger coefficients is virtually zero, while the other is significant and about the same size as that in the benchmark.

When we add quantity-weighted average TFP controls to the specification including market fixed effects, we find that productivity gains do correspond to quantity increases as well.

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[23] We note that comparing these quantity increases with the implied price decreases from the previous section does not reflect the demand elasticity of concrete, because the two specifications condition on different market-level demand measures. The quantity regressions hold the level of construction employment constant, while the price specifications compare markets of equal construction employment densities. Additionally, the above argument that market-level construction activity is likely exogenous to concrete prices is not inconsistent with a nonzero price elasticity of concrete demand. To see why, note that the exogeneity argument implies that the derivative of construction output with respect to concrete prices is roughly zero. This derivative can be restated as the product of two derivatives: construction output with respect to concrete output, and concrete output with respect to concrete prices. Thus even when the latter is nonzero (that is, concrete quantities are responsive to concrete prices), the total derivative is roughly zero if the former derivative is small enough. This former derivative is determined by the construction sector's production function. The very small cost share of concrete in total construction costs (around two percent in the Benchmark Input-Output tables) suggests that this derivative is in fact quite small.

Once efficiency gains are accounted for in this way, changes in integration intensity have residual correlations with quantities that are weakly positive, and in one case significantly so. As with the price results, if average TFP changes adequately capture any efficiency gains of integration, then the remaining impact should reflect foreclosure. Yet the expected declines in quantity are not observed.

We again complement the market-level results with plant-level analysis. Panel B contrasts physical outputs of integrated producers with those of various comparison groups. The first column shows that integrated ready-mixed producers make considerably more output than do their unintegrated competitors in the same market. However, the output of ready-mixed plants that become integrated actually *shrinks* (some 18 percent) relative to unintegrated continuers. This is balanced in part, though, by the building of new plants by the integrated firm. As can be seen in the estimates in the two rightmost columns, new integrated plants are larger than both new and continuing plants of unintegrated producers.[24]

These quantity tests, as with the price tests above, give no indication that vertical integration in the cement and ready-mixed industries facilitates the exercise of market power. In all market-level specifications, additional integration is associated with neutral to positive changes in equilibrium market quantities. Producer microdata offer similar results: vertically integrated plants sell more and charge lower prices on average than their unintegrated competitors in the same markets, and the net impact of the entry of a vertically integrated firm into a market is positive because the decline in output from acquired plants is compensated by additional output from newly built plants.

C. How Do Integration's Effects Depend on Upstream Market Structure?

The tests above assume that vertical integration has common price and quantity implications for all markets in the sample. However, the model exposited earlier suggests that foreclosure potential may be linked to upstream market structure. Specifically, the ability of the upstream firm to leverage market power gains through integrating depends in part on the extent

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[24] The expected output change due to the entry of a new integrated firm into a market depends on the relative magnitudes of newly acquired plants' output reductions and the additional output from the integrated producer's newly built plants. We have looked at net revenue changes when a new vertically integrated firm comes into a market and found that they are on average positive, consistent with the market-level regressions above. We discuss further below why an integrated producer might, in the same market over the same period, purchase and shrink existing plants while also building new ones.

of its pre-integration market power. In this section, we see whether there are noticeable differences in price and quantity effects as the structure of the local cement market varies.[25]

We first investigate variations over three likely correlates with market power in the local cement market. The first takes the model's polar case quite literally by allowing differential price and quantity impacts when the ready-mixed market is served by a single cement firm that is vertically integrated. Market power gains are presumably largest in these cases since unintegrated ready-mixed producers are more vulnerable to being foreclosed. The second is a slightly looser version of the monopoly test, where we allow the integration coefficients to differ depending on whether the Herfindahl-Hirschman concentration index (HHI) in the local cement market is above or below its mean value in our sample. The third variation allows differential impacts in markets where cement imports are more likely to be a viable alternative for cement buyers. For a fixed structure of local domestic producers, easier substitution to imports by cement demanders could reduce any foreclosure abilities. We consider imports to be of possible consequence in cement markets that contain a port that was one of the 25 largest reception points for imported cement (using 1998 data from the U.S. Customs Service) *and* if the year was 1977 or later, since before that time cement imports were a trivial share of national consumption.[26]

Table 4 shows the results of this exercise, with three panels corresponding to the different sample splits by upstream market structure. Each set of estimates was obtained using the benchmark specification and sample of the previous two sections, except here the price and quantity effects are allowed to vary depending upon whether or not one of the conditions above (e.g., market with import availability) is met.

When integration's impacts are allowed to differ in markets with cement firms that are vertically integrated monopolists (Panel A), the implied price effects—shown in the first two numerical columns—are not significantly different across monopoly and non-monopoly markets.

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[25] We realize that these upstream market structure measures are themselves endogenous outcomes that could have been influenced by the vertical structure itself rather than simply capturing pre-existing conditions. However, we are in one sense already controlling for upstream market structure by including our construction-sector density or demand measure in the regressions. As discussed above, local construction activity is a likely exogenous influence on market structure in both the ready-mixed and cement industries.

[26] While imported cement may not always be consumed in the market where it is brought to port, the fraction moved to other markets is likely to be small. Land transport of cement is expensive relative to its value, and "ports" in the Customs data include interior cities on navigable waterways, such as St. Louis, Minneapolis, and Cleveland. One possible factor that would counteract the ability of cement consumers to substitute to imports is if most cement imports are comprised of clinker (cement in an intermediate, post-kiln, pellet-like stage) that is purchased and then ground into cement and sold by domestic cement firms. Unfortunately the data does not reveal importers' identities.

For both integration intensity measures, a negative relationship between price and integration remains in monopoly cement markets (the high standard error on the interaction term due to the relatively small number of such monopoly markets leads to an insignificant total effect, though the point estimates are similar). However, the quantity impact of integration does seem to be tempered in monopoly markets. While vertical integration is associated with quantity gains in non-monopoly markets, the coefficients on the interaction of integration intensity and the monopoly indicator are negative and of slightly smaller magnitude, implying positive but insignificant effects of vertical integration on market quantities in cement markets where there is an integrated monopolist.

When this comparison is broadened to all markets with above-average cement HHIs, negative price response to integration is actually larger in more concentrated markets. As with the integrated-monopolist market results above, the point estimates on the interaction terms imply muted quantity responses. The differences are not statistically significant in this case, however, and the implied overall relationship between integration and market quantities is still positive and significant for the concentrated markets.

The estimations allowing differential responses in markets with available cement imports indicate no significant differences in integration's price or quantity effects. All coefficients are small and statistically insignificant. The prevalence of cement imports is apparently uncorrelated with any relation between vertical integration and ready-mixed prices and quantities.

We have in this section focused on the final goods markets that theory specifically indicates are most susceptible to foreclosure. The results suggest that in such markets the negative correlation between integration and prices is, if anything, stronger. On the other hand, the positive relationship between ready-mixed quantities and integration is somewhat weakened. This latter result could indicate that foreclosure effects only exist in such markets, particularly in the polar case of an integrated cement monopoly. However, this explanation would leave as a puzzle why the negative price correlations remain.[27]

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[27] A possible way to reconcile these results is if imperfect market definitions cause our earlier quantity estimates to somewhat overstate the true connection between integration and market quantities. This would be the case if the price reductions accompanying additional integration increase demand from concrete consumers not just within the market itself but from neighboring markets as well. Then true positive integration-quantity relationship in the one market will be accompanied by quantity decreases in the neighboring markets even though they experience no changes in integration. By allowing the quantity effect to differ in concentrated markets (which all else equal are likely to be more geographically isolated and have less cross-market concrete shipments), the specifications here

D. Does Vertical Integration Force Exit of Unintegrated Downstream Producers?

Foreclosure models predict that firms can use leverage afforded by vertical integration to force unintegrated rivals out of business. We visit that implication in this section.

The first test directly compares exit probabilities across integrated and unintegrated producers. We regress an indicator for plant death by the next census (i.e., it does not show up in the following CM) on an indicator for integration status as well as a full set of market-year fixed effects, again ensuring that systematic market-level differences in demand or cost structures are not confounded in the measured correlation between survival and vertical integration.[28]

Panel A of Table 5 contains the results for both cement and ready-mixed concrete. Integrated plants in both industries are more likely to survive than their unintegrated competitors in the same market-year. The implied differences are nontrivial; the mean differences in exit rates (over the 5-year inter-census period) are -0.046 in ready-mixed (that is, integrated concrete plants have a 4.6 percentage-point lower probability of exit) and -0.069 for cement. As a point of comparison, the unconditional exit probabilities across all plants (again over 5 years) are 0.305 in ready-mixed concrete and 0.173 in cement.

We next look at how the level of vertical integration in a market affects the survival prospects of unintegrated producers. While the exercise above characterizes the differences in exit probabilities across producer types, this test asks how unintegrated producers' exit likelihoods vary with the extent of integration in their market. Restricting our sample to unintegrated plants, we regress an exit indicator on market-level integration measures. We also control for changes in market demand (i.e., logged construction employment) between the present and future CMs to control for short-run demand shifts' influence on survival.

The results are in Panel B of Table 5. Even after controlling for market demand growth (higher growth implies lower exit probabilities, as expected), unintegrated plants are more likely to exit in more integrated markets. The estimates suggest, for instance, that an additional integrated ready-mixed firm in a market is associated with about a two-percentage-point higher

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may reduce this misattribution. As discussed above, we have chosen our market definition to minimize across-market concrete shipments, but undoubtedly some still exist in the data.

[28] We do not count as exits plants that leave the cement or concrete industries but continue to operate in a different industry. The exits with which we concern ourselves—complete disappearances of plants from the CM universe—correspond to the cessation of economic activity at the former plant's location. In this sense, our exit rate measures are probably conservative. We have also run probit exit models and found similar results to those reported here.

exit probability for unintegrated ready-mixed producers. The results for the cement industry are statistically weaker, but the point estimates are commensurate with the ready-mixed results.[29]

These results point to relationships between survival and vertical integration at both the plant and market level. In contrast to the price and quantity results above, these survival patterns are consistent with the predictions of foreclosure theory. However, we show below that they are also consistent with an alternative mechanism where integration and efficiency are closely linked even in the absence of foreclosure effects.

E. Does Vertical Integration Reduce Entry?

Many foreclosure models, as well as the FTC report on cement-concrete integration, imply that vertical mergers can lead to higher entry barriers. From a dynamic perspective, this prediction has some of the strongest implications about welfare over the long run, as the ability of firms with market power to preserve it by restricting the entry of new competitors is socially harmful. We explore the link between entry and vertical integration here.

We compute two types of entry rates for each market. One is plant-based and is calculated by dividing the number of new plants in the market by the average number of plants over the current and previous census. Using the average number of establishments in the denominator rather than just the prior value bounds entry rates at two, rather than infinity, while still being a monotonic transformation of the standard measure. Doing so keeps from giving undue influence to observations of small markets that would otherwise have infinite or extremely high computed entry rates. We also weight by market demand in our regressions to further adjust for the small-market effect.

The second entry rate is firm-based. Here definition issues are more complex. Unlike plants, which are geographically unique, firms can operate in several markets. We must therefore take a stand on how to treat entry of existing firms into new geographic markets. For example, if a company that has operated in Texas for fifteen years builds a plant in Ohio, is that entry? We do consider it as such because of the highly geographically segmented nature of these industries' product markets. Note that not only could this entry occur by the firm building a new plant, but also by its purchase of an existing one. That is, a market could experience firm entry

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[29] A specification comparing exit probabilities to *changes* in integration, rather than initial levels, indicated no significant effect of these changes on exit probabilities of unintegrated producers.

but no plant entry. The implied entry rates for a market are the number of entry episodes divided by the average number of firms operating in the market across the current and past censuses.[30]

The empirical specification is straightforward. We regress entry rates in a market-year, which are of course based on entry episodes between the past and current CMs, on the market share of vertically integrated establishments in the previous CM (specifications using the number of integrated firms yield comparable results). As with the exit regressions, we control for market demand growth to capture short-run impacts of demand fluctuations on entry. We estimate specifications using both overall entry rates, which include entry by integrated and unintegrated producers, and entry rates of unintegrated producers alone.

The results are presented in Table 6. Panel A reports those corresponding to overall entry rates. As can be seen, there is no evidence that plant or firm entry rates are lower in more integrated markets in either the concrete or cement industry. Three of the four coefficients are positive and insignificant. Notice that this no-impact result is not driven simply due to lack of variation in the data; the point estimates are in fact "tight zeroes." They imply, for instance, that going from one extreme case to the other—from a completely unintegrated market to one that has *only* integrated firms—raises plant entry rates by 0.061 (6.1 percentage points), one-fifth of the mean entry rate of 0.299. The implied effects for the cement industry are smaller still: a similar polar change in integration intensity implies an entry rate change that is roughly one-tenth of the mean. Moreover, these point estimates are positive, not negative as foreclosure effects would imply.

When we restrict our attention to the entry rates of unintegrated producers alone, perhaps the most direct test of foreclosure on entry, we again find no discernable differences in entry rates across markets with different levels of integration. All coefficients are statistically indistinguishable from zero and are estimated precisely. Greater vertical integration does not

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[30] There is an additional data difficulty regarding computation of firm-level entry rates. While firm identifiers in the CM remain constant if the plant-owning entity does not change, there is an exception to this. Single-unit and multi-unit firms are numbered according to different systems, so when a plant in a single-unit firm becomes part of a multi-unit firm, its firm identifier changes from one format to the other. This presents no measurement problems when a formerly single-unit plant is bought by a previously multi-unit firm; the plant simply assumes the identifier of the purchasing firm. However, if the plant is purchased by a firm that was previously only a single-unit firm, or if the plant's owner itself becomes multi-unit by purchasing or opening another plant, the plant's firm identifier could change even though no new firm actually entered the market. We therefore count as firm entry episodes only those instances where a firm identifier changes *and* the plant either was part of a multi-unit firm in the previous census or was previously a single-unit firm and its new firm ID number existed in the previous CM.

seem lead to reduced entry into a market.[31]

F. Foreclosure Effects: Discussion

The bulk of the evidence suggests foreclosure effects are not quantitatively important when cement and ready-mixed producers vertically integrate. More extensive integration in a market is related to lower prices and higher quantities in both the cross section and within markets over time. There is some evidence that the positive quantity effects are muted somewhat in cement markets with an integrated monopolist, but this is not more generally true in concentrated non-monopoly markets, and the negative correlation between integration and prices remains across all markets. Entry rates are not lower when vertically integrated firms are prominent or numerous. The only finding above consistent with foreclosure being significant is that unintegrated producers' have worse survival prospects, both compared to integrated producers in the same market and when total integration in a market increases. Therefore, excepting some temporary reservation due to the survival result (which we will argue below is not due to foreclosure and offer some evidence in this vein), we conclude that if foreclosure is present at all, it is quantitatively small and dominated by opposing factors.

V. An Alternative Mechanism

Does an alternative explanation to foreclosure link vertical integration to the empirical patterns above? We believe so. The mechanism we propose is at work involves the impact of more efficient producers expanding within and across markets. If high productivity is associated with vertical integration (whether causally or simply by correlation), the patterns documented above will obtain.

How would this alternative mechanism drive the relationships observed in the data? With a link between productivity and integration, the results above can be reinterpreted as showing that markets where higher-productivity firms are larger or more numerous have lower prices and higher quantities sold. This is consistent with lower-cost (higher-productivity) producers passing on part of their cost advantages to their customers through lower prices, and this is exactly what is implied by many models of market equilibrium with heterogeneous

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[31] We have also estimated these entry specifications including market fixed effects. We did not find a significant negative impact of vertical integration, and the point estimates had comparable magnitudes.

producers. The negative correlation between price and productivity levels has also been documented in previous empirical work (e.g., Roberts and Supina (1996); Eslava, Haltiwanger, Kugler, and Kugler (2004); Syverson (2005); and Foster, Haltiwanger, and Syverson (2005)). Further, the results above most indicative of foreclosure—unintegrated plants' lower survival probabilities—can also be explained by a link between productivity and vertical integration, as we show below.

In this section we show evidence that integration and productivity are correlated and explore possible sources of the connection. We lay the groundwork for this argument by first exploring productivity and operating scale patterns across integrated and unintegrated producers.

A. How Are Integrated Producers Different?

We characterize how vertical integration is related to producer size and productivity by comparing a number of plant-level productivity and technology measures across integrated and unintegrated producers. We do so by regressing the plant-level measure of interest on an indicator for integration status, along with a full set of market-year fixed effects. Therefore for all comparisons, the estimated differences between integrated and unintegrated producers reflect within-market variation.

We present comparisons for plants in both industries in Table 7; differences among ready-mixed concrete plants are shown in Panel A and those for cement producers in Panel B.[32] Notice first the productivity differences. Integrated ready-mixed producers are indeed more productive; their labor productivity levels are 33 percent (29 log points) higher than those of their unintegrated counterparts in the same market. TFP levels are also higher, though the gaps are much smaller; the mean difference in revenue-based TFPR is 2.8 percent and physical-quantity-based TFPQ difference is 4.8 percent.[33] The smaller TFP differences reflect the fact

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[32] The sample size differences across dependent variables reflect variation in the availability of the underlying production data necessary to compute the measures. Most of this variability arises because not all production data was collected in every CM. See the discussion in the data section as well as the appendix.

[33] These TFP measures (whose construction is described in detail in the appendix) differ in their measure of output. TFPR uses plant revenue deflated to a common year using industry-level price deflators. This is the standard practice in the literature. However, any within-industry price dispersion will be built into the output measure; all else equal, lower-price plants look less productive because their revenue is lower. If within-industry price variations reflect differences in local demand conditions rather than quality differentiation—a distinct possibility in a localized homogeneous-product industry like ready-mixed concrete—revenue-based TFP confounds technological with demand factors. Therefore we also construct a TFP measure using physical output data from the CM product supplement. Differences in this measure, TFPQ, reflect variation in the number of cubic yards of concrete plants

that, as can also be seen in the table, integrated plants are more capital intensive. In the cement industry, integrated producers also have higher labor productivity levels, by just under 10 percent, than unintegrated cement plants in their market. However, there are no statistically significant TFP differences.

Besides being more productive, integrated ready-mixed plants do a larger volume of business than unintegrated plants in their markets; their real revenue is on average about 30 percent higher. Despite their higher output, integrated ready-mixed plants do not employ significantly more labor (workers or hours), as manifested in the higher labor productivity result. There are differences in labor *composition*, however: nonproduction workers comprise a smaller share of the labor force in integrated plants.[34] This suggests that integrated producers may be able to harness gains coming from the consolidation of administrative duties, a point to which we shall return below. Comparing cement plants, integrated producers are also considerably larger in terms of total sales, have a smaller share of nonproduction workers, and have higher capital labor ratios than their unintegrated counterparts. Unlike in concrete, they also hire more labor (employees and hours).

Integrated plants are indeed different. However, these patterns are less useful for determining whether the differences are caused by, or themselves cause, vertical integration. We look at three additional comparisons that are less likely to confound the causal impacts of vertical integration with selection on preexisting heterogeneity. The first is to contrast plants that become integrated with those in the same market that remain unintegrated. This first-differences specification controls for fixed plant unobservables that may be correlated with production outcomes and integration status. We next compare new plants: those entering as part of integrated firms versus those entering in unintegrated firms. The final comparison again looks at integrated entrants, but this time contrasts them with unintegrated incumbents. Using new integrated plants in these last two comparisons implies by definition that any observed

can produce with a fixed set of inputs, rather than differences in production revenue per unit input. We could similarly use two labor productivity measures, but for the sake of brevity split only TFP here. Only TFPR was computed for cement plants because of the difficulty constructing plant-level prices in the industry; see the discussion in Section III and the appendix.

[34] The U.S. Census Bureau defines production workers (all other employees are considered nonproduction workers) as: "Workers (up through the line-supervisor level) engaged in fabricating, processing, assembling, inspecting, receiving, packing, warehousing, shipping (but not delivering), maintenance, repair, janitorial, guard services, product development, auxiliary production for plant's own use (e.g., power plant), record keeping, and other closely associated services (including truck drivers delivering ready-mixed concrete). Exclude proprietors and partners."

differences are not resulting from preexisting differences among plants. We again control for market-year fixed effects in all of these comparisons.

The outcomes for ready-mixed producers are shown in Table 8. Panel A compares productivity and production scale growth among ready-mixed concrete plants that were unintegrated in the previous census. Those becoming integrated in the interim had higher productivity growth than their market counterparts that remained unintegrated. Labor productivity growth was 10 percent faster, and there are positive but not significant growth rate differences in TFPR and TFPQ. Somewhat surprisingly, these newly integrated ready-mixed plants shrink after the merger—at lease in relative terms (recall that the reported coefficients give relative growth rates): revenues go down by a third more, and total labor hours by 36 percent.[35]

As mentioned in the earlier discussion of quantity patterns, it appears the decline in production by acquired concrete plants is on average more than compensated by new entrants. Panels B and C of Table 8 compare integrated entrants to, respectively, unintegrated entrants and unintegrated incumbents. Integrated entrants have higher sales than unintegrated entrants (though they hire less labor). New ready-mixed plants that are in integrated firms are also more noticeably productive than both unintegrated entrants and unintegrated incumbents. As with the comparisons among all producers earlier, integrated entrants have lower nonproduction worker ratios and are more capital intensive than both comparison groups.

Similar comparisons for cement plants—not reported here—found no significant differences among either continuing plants or entrants. This suggests, interestingly, that the differences seen between integrated and unintegrated cement producers are driven by selection into integration based upon pre-existing differences, while some of the differences among ready-mixed concrete plants are more likely to be a result of becoming integrated. Moreover, the largest impact vertically integrated firms have on concrete markets in terms of productivity may be through their newly built plants. We will return to these points below.

The link between productivity and vertical integration shown here suggests that increases in vertical integration at the market level can be thought of as reflecting a greater presence of

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[35] While in the absence of randomized integration at the plant level we cannot be sure these estimates reflect exclusively causal effects, our productivity-based explanation for the results above requires only that vertical integration is correlated with productivity. We also find it difficult to form a reasonable explanation for the observed patterns that implies reverse causation; that is, why integrating firms would explicitly target plants that are expected to increase in productivity *and shrink* in the near future.

more productive firms. Their lower production costs allows these firms to charge lower prices and sell more output than the unintegrated producers they replace. This can lead to, as we have already seen in the data, integrated firms pushing out unintegrated producers. But while foreclosure attributes this to the exercise of market power facilitated by vertical integration, it is also consistent with a straightforward churning process of more efficient firms replacing less efficient competitors. We explore this further now.

B. Revisiting Unintegrated Plants' Survival Rates

The empirical evidence in the previous section that supported foreclosure being an important factor in these industries was the fact that integrated producers have a survival advantage. However, as was just shown integrated producers have higher productivity levels than unintegrated producers. This is important, because there is extensive evidence that more productive plants are less likely to exit.[36] The observed survival-rate differences may therefore be reflecting integrated producers' productivity advantages rather than their market power.

Furthermore, there may be other factors that enhance integrated producers' survival prospects that do not show up in plant-level TFP. Vertically integrated plants are larger than unintegrated producers and by definition belong to multi-plant firms. Therefore integrated firms are likely to be among the largest in their industry.[37] To the extent firm size itself conveys survival benefits to plants, say because their greater ability to gather financial capital from internal transfers would allow them to ride out temporary downturns that credit-constrained single-plant firms could not, then survival differences across integrated and unintegrated producers may also reflect this size benefit instead of some specific effect of vertical integration. The results in Dunne, Roberts, and Samuelson (1989) suggest there are such survival-enhancing elements inherent to belonging to a multi-unit firm. (Another possibility is that firm size reflects the long-run productivity values of its component plants, and firm size acts as a sort of "permanent TFP" proxy.)

To account for these factors, we add two covariates to the earlier survival regressions:

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[36] See, for example, Baily, Hulten, and Campbell (1992); Olley and Pakes (1996); Aw, Chen, and Roberts (2001); and several of the papers reviewed in Bartelsman and Doms (2000).

[37] The average real revenue (1987 dollars) of vertically integrated ready-mixed firms is about 20 times that of the average unintegrated firm, a fact partly reflecting the prevalence of single-establishment firms in the industry. The same ratio is 4 in the cement industry.

plant TFP and a dummy indicating if a plant belongs to a multi-unit firm. Vertically integrated firms are of course a subset of multi-plant firms. The results are shown columns 3 and 6 of Table 9. Columns 1 and 4 of the table reprint the original results from Table 5 for comparison, and columns 2 and 5 apply the earlier specification to the more limited sample necessary here because TFP is not available for every plant-year observation.

The coefficient on the vertical integration dummy shrinks considerably in magnitude and becomes insignificant when the two covariates are added. Vertically integrated plants are more likely to survive apparently not because of any particular facet of being integrated, but instead because they are in large firms and are relatively productive. Such conditional equivalence is inconsistent with foreclosure theory, which implies a *per se* survival benefit of being vertically integrated. The alternative productivity-based story of vertical merger effects, on the other hand, does not predict a differential impact of integration except through its correlation with productivity and size.

A similar reinterpretation is applicable to the results in Panel B of Table 5, which showed that unintegrated producers were more likely to exit in more integrated markets. A substantial literature (again see Bartelsman and Doms (2000) and the references therein) has shown that plant- and firm-level churning processes lead to higher-productivity producers gaining market share at the expense of less efficient ones. Given that the survival benefit of being vertically integrated disappears once we control for plant productivity and multi-unit status, it seems possible that the latter half of Table 5 also reflects the higher productivity of integrated plants as opposed to a differential in market power.

C. Why Do Integrated Producers Have Higher Productivity Levels?

Our proposed alternative explanation for the empirical evidence raises issues of its own. What are the efficiency gains harnessed through integration, or is the connection merely a correlation?

Eliminating Double Marginalization. A classic efficiency argument for vertical integration is eliminating double marginalization. Vertical integration by firms on the production chain is one way to internalize these markup externalities, resulting in a lower final good price, higher

quantity sold, and higher profits.[38]

A conceptually direct way to see if the elimination of double marginalization explains our results would be to compare markups across integrated and producers. A practical limitation to this approach is that given the high fixed-cost component of cement manufacturing, marginal costs are extremely hard to accurately measure with the data at hand (we do not observe, for example, the shadow costs associated with fixed factors in cement production).

However, we do see the prices cement plants pay per kilowatt-hour for electricity, which is an important input in the industry (the industry spent $480 million on electric power in 1997, accounting for 20 percent of its total purchases of raw materials and roughly equal to the amount the industry spent buying fuel to heat the kilns). We use this input price to construct a proxy for vertical chains' total markup of the final good price over marginal cost. We compare the difference between the ready-mixed prices and electricity prices within integrated firms to the same price difference among unintegrated producers. Construction of this proxy is straightforward for integrated firms: we compute a size-weighted average electricity price among the firm's cement plants and subtract this from the prices charged by the firm's concrete plants. For unintegrated firms, since the data does not allow us to identify the destination of cement plants' shipments or the origin of concrete plants' input purchases, we subtract from unintegrated concrete plants' prices the size-weighted average electricity price across all unintegrated cement firms in the same EA. This effectively assumes that the ready-mixed plants receive a substantial share of their cement inputs from local unintegrated producers, as opposed to a local integrated producers or unintegrated producers out of market.

When we compare these estimated markups across integrated and unintegrated ready-mixed plants in the same market, we do not find notable differences. Regressing plants markups on a vertical integration indicator and a set of market-year dummies yields an estimated coefficient on the integration indicator of -0.005 (s.e. 0.011), which is statistically and economically zero. Hence our test offers no indication of obvious reductions in double marginalization from integration. These results may indicate that contractual arrangements allow unintegrated ready-mixed plants and their suppliers to circumvent the problems of double

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[38] As is well known, actual integration is not necessary to eliminate double marginalization. Contractual agreements can be written between firms (such as where an upstream supplier sells the input to the downstream producer at its marginal cost, but then recovers its rents through a lump-sum payment) to accomplish the same. Of course, such contracts might be impractical in the face of particular institutional details.

marginalization, though we cannot rule out that having to use a noisy proxy for actual markups simply lowers the power of the test.

Production Smoothing and Inventory Management. Cement manufacturing involves high fixed costs: clinker-producing plants are comprised of a few (typically one or two) very large kilns that, once operational, run continuously unless shut down for occasional maintenance spells. The ramp-up and shut-down costs make production interruptions expensive, creating a large incentive for production smoothing at the kiln level. Better information about future demand conditions is therefore likely to have substantial value to cement firms. Since the ready-mixed concrete industry is one step closer to the final demand sector for the industry, owning a concrete firm may provide a valuable "ear to the ground" to cement producers, allowing them to better forecast future demand and more efficiently schedule production. Moreover, this may make operations at integrated ready-mixed plants more efficient by avoiding both cement stockouts and excess inventory costs.

We are able to test a facet of this story. The CM contains data on plants' inventory holdings. Specifically, we observe, at the beginning and end of each year, the total dollar value of three types of plant inventories: raw materials, work-in-process, and finished products. We compare inventory-to-revenue ratios across integrated and unintegrated producers in both industries (we look at only raw materials inventory ratios for concrete plants because the latter two are not empirically relevant for the batch-and-deliver nature of ready-mixed production). Again we control for market-year fixed effects in all comparisons.

The results are in Table 10. Excepting final goods inventories in cement plants, integrated producers have higher inventory ratios—roughly 12 to 20 percent more than mean levels. While cement production smoothing has ambiguous predictions about the levels of cement inventories held by ready-mixed producers (an unambiguous implication is that concrete plants' inventory holdings should be less variable; unfortunately we cannot test this, since we only observe inventory levels every five years), one would expect that cement plants' materials and work-in-process inventory levels would be lower with improved production smoothing, as more constant throughput reduces the necessary buffers of inventory. Apparently integrated producers' productivity advantage does not arise from better production smoothing, or does so in a way that does not show up in the inventory-holding behaviors we can measure.

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Coordinated Logistics. We see above that integrated plants and firms are larger on average than their industry counterparts. Improved logistical coordination is one possible economy of size that could have a large impact particularly in the ready-mixed concrete business, where time-sensitive buyers in multiple locations desire delivery of a perishable product. Coordinating a firm's deliveries in a local area through a central office could offer the benefits of consolidating overhead (one dispatcher might handle the deliveries from several plants that would each have separate dispatchers in a single-unit firm) and allowing more efficient use of available resources through cross-plant substitution.

Gains from reducing overhead are suggested by integrated producers' lower nonproduction worker ratios as documented above. Efficiencies gained through coordination are consistent with integrated producers reshuffling the location of production in markets by reducing output at purchased plants and replacing it with production from their newly built plants, perhaps built closer to spatially shifting demand within the market. Such efficiencies are also used to motivate some stated practices of integrated producers. For instance, the large integrated producer Lafarge (a firm that was just starting to develop a sizeable presence in the U.S. at the end of our sample period), describes its preferred placement of ready-mixed operations in its 2004 20-F filing:

> "…[W]e aim to place our ready mix concrete plants in clusters in each micro market in which we operate in order to optimize our delivery flexibility, capacity and backup capability. … We evaluate each micro market in which we operate periodically and dismantle and move plants to locations where they can be used more profitably…"
> (Lafarge 2005, p. 39)

Plant clustering allows firms to better take advantage of any coordination efficiencies.[39]

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[39] We note that nothing about these gains requires spatial proximity between an integrated firm's cement and concrete operations, or even that the upstream division supply the downstream division at all. And indeed, Lafarge owns about two dozen ready-mixed plants in Colorado and Wyoming, even though its nearest cement distribution terminal is 490 miles away in Oklahoma City. We contacted some of these plants, and they confirmed that they receive all of their cement inputs from sources outside of Lafarge. A similar situation exists for Florida Rock Industries Inc., an integrated producer that owns ready-mixed plants in Florida, Southern Georgia, Virginia, and Maryland. The firm's cement facilities, however, are all located in Florida, and the company's financial filings state that the company's concrete operations purchased cement from 10 outside suppliers (Florida Rock Industries, Inc. 2005). Phone calls to management verified complete external cement sourcing among the company's 30 or so ready-mixed plants in Virginia and Maryland. We also note that these practices are hard to reconcile with

This begs the question, however, of why *cement* firms need to be the coordinating body. A possible answer is that they need not be. The ready-mixed industry has seen considerable consolidation over our sample—in 1963, 3999 firms owned 4621 ready-mixed plants, but by 1997, only 2898 firms owned 5252 plants—and much of this consolidation came through horizontal rather than vertical mergers. The fraction of ready-mixed plants in multiple-unit firms more than doubled between 1963 and 1997, from 24.8 to 55.6 percent. The corresponding change in the fraction of vertically integrated plants (from Table 1) was 1.8 to 10.6 percent. Clearly, then, the majority of merged ready-mixed concrete plants were folded into firms without cement divisions. Coordination and its possible efficiency gains, if they are tied primarily to firm size, have therefore not been exclusive to vertically integrated firms.[40]

We explore this notion further by repeating our earlier comparisons across integrated and unintegrated plants (controlling for market-year fixed effects), but this time controlling for the multi-unit status of the firm that owns the plant. This will allow us to see if vertical integration has impacts on productivity, scale, and such that cannot be explained simply by the fact that integrated ready-mixed plants are in multi-unit firms. We perform this comparison for those plant-level production values for which there were significant differences across integrated and unintegrated producers.

The results of this exercise, shown in Table 11, are instructive, especially in comparison to Panel A of Table 7. When we control for multi-unit status, the coefficients on the vertical integration dummy in the productivity regressions diminish in size and become insignificant for both TFP measures. That is, while plants in vertically integrated firms are more productive on average than unintegrated plants, they do not have significantly higher TFP levels than plants in unintegrated multi-unit firms. A substantial portion of the productivity advantage of integrated producers, therefore, is tied to firm size rather than integration specifically. Integrated plants do appear to be larger in revenue terms than plants in unintegrated multi-unit firms. Their nonproduction worker ratio also remains significantly smaller, which may help explain the remaining labor productivity advantage of integrated plants.

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foreclosure motives. Foreclosure necessarily implies that integrated downstream producers are at the very least being partially supplied by upstream producers in their firm.

[40] That is not to say that a large firm in *any* industry could harness coordinating economies, of course. But cement shares a final demand sector with ready-mixed and the two industries do have other key elements in common, such as the prominence of logistical concerns.

D. An Alternative Mechanism: Discussion

We contend that, at least for the cement and ready-mixed industries, viewing the expansion of the extent of integration in a market as reflecting an expansion of more efficient producers is consistent with empirical patterns. This is true at the plant level, where integrated producers are more efficient and larger than unintegrated producers. It also explains the market-level patterns described earlier: higher exit rates among unintegrated producers (which is predicted by foreclosure models as well) and greater integration being associated with lower prices, higher quantities, and unchanged entry rates (which are not).

When we ask why integrated producers are more productive, our data appears to suggest that *vertical* integration per se might not be the primary source of integrated producers' productivity advantage. We do not find obvious evidence for classic explanations like elimination of double marginalization or gains from better inventory management. Our data does suggest a scale economy of a different type, however: coordination advantages from having geographically clustered plants whose logistics are centrally managed. However, as we note, there is nothing inherent in vertical integration necessary to obtain such efficiencies; instead, they are likely to be tied to firm size more generally.

VI. Concluding Remarks

We have used unusually detailed data to investigate whether foreclosure effects are important in the cement and ready-mixed concrete industries. We find little evidence that foreclosure takes place when firms integrate in these industries, or at the very least any consequences of foreclosure are swamped by countervailing factors. Specifically, prices fall, quantities rise, and entry rates do not change when markets become more integrated (measured either by the market share or number of vertically integrated firms in the market).

In place of foreclosure effects, we explain these findings as resulting from more efficient vertically integrated firms taking market share from higher-priced and less efficient producers. A possible partial explanation for integrated producers' productivity advantage at the plant level is logistical coordination efficiencies tied to firm scale. Still, some distinctions remain between vertically integrated producers and unintegrated producers in large multi-unit firms. We think exploring these differences in much more detail is an interesting area for future work.

Our results, if correct, point to an interesting tradeoff for the social welfare implications of vertical integration. It may be that in the cement and ready-mixed industries, vertical integration is just one way for large, efficient firms to enter a market. In fact there has been extensive consolidation in the ready-mixed industry over the past four decades, and vertical integration has not even been the most common way in which industry plants have been folded into larger firms. As we show above, the churning process underlying such consolidations may have had significant impacts on productivity in the industry. This presents again the familiar difficulty of balancing efficiency and market power considerations in merger analysis.

We conclude by emphasizing that one should be careful when trying to generalize the results in this paper to other industries or markets. Vertical integration decisions of firms are driven by many different considerations, of which vertical foreclosure may or may not be important in any particular case. Our study is an attempt to study the short- and long-term effects of the decision to integrate in these particular industries. The fact that we do not find evidence of foreclosure here does not mean that market power gains made possible through vertical integration are not quantitatively important elsewhere.

Data Appendix

We describe here details on the construction of our production variables.

Labor Hours. Production worker hours are reported directly in the CM microdata. This value is then scaled up to total hours by multiplying by the ratio of total employees to production workers. This assumes, in essence, that average non-production worker hours equal average production worker hours within plants.

Capital Stocks. Equipment and building capital stocks are plants' reported book values of each capital type deflated by the book-to-real value ratio for the corresponding three-digit industry. (These industry-level equipment and structures stocks are from published Bureau of Economic Analysis data.) Any reported machinery or building rentals by the plant are inflated to stocks by dividing by a type-specific rental rate.[41] The total productive capital stock k_{it} is the sum of the equipment and structures stocks.

Real Materials and Energy Use. Materials and energy inputs are simply plants' reported expenditures on each divided by their respective industry-level deflators from the National Bureau of Economic Research Productivity Database.

Labor Productivity. We measure labor productivity as plant output per worker-hour, where output is the real value of shipments and hours are constructed as above.

Total Factor Productivity (Revenue- and Physical-Quantity-Based). We measure productivity using a standard total factor productivity index. Plant TFP is computed as its logged output minus a weighted sum of its logged labor, capital, materials, and energy inputs. That is,

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

where the weights α_j are the input elasticities of input $j \in \{l, k, m, e\}$. While inputs are plant-specific, we use industry-level input cost shares to measure the input elastiticies.[42] These cost shares are computed using reported industry-level labor, materials, and energy expenditures from the NBER Productivity Database (which is itself constructed from the CM). Capital expenditures are constructed as the reported industry equipment and building stocks multiplied by their respective capital rental rates in cement and ready-mixed concrete's corresponding two-digit industry.

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[41] Capital rental rates are from unpublished data constructed by the Bureau of Labor Statistics for use in computing their Multifactor Productivity series. Formulas, related methodology, and data sources are described in U.S. Bureau of Labor Statistics (1983) and Harper, Berndt, and Wood (1989).

[42] An implicit assumption in this index is constant returns to scale. If the scale elasticity were instead different from one, each of the input elasticities α_j should be multiplied by the scale elasticity. In earlier work, Syverson (2004) finds that returns to scale in ready-mixed concrete are essentially constant.

For both industries, we construct TFP measures using plants' reported revenues (deflated to 1987 dollars using price indexes from the NBER Productivity Database) as an output measure. This is the standard measure used in the literature. However, for ready-mixed plants when data is available, we also construct a TFP measure based on the plant's physical output (taken from the CM Product Supplement). This removes the influence of within-industry price variation on the output measure. We denote our revenue-based productivity measures TFPR and physical-output- (quantity-) based total factor productivity is called TFPQ.

We must make one adjustment to the output data when computing TFPQ. Since ready-mixed plants can produce multiple products (though most do not, as discussed above), but inputs are reported on an establishment-wide rather than product-specific basis, we must impute the share of inputs allocated to ready-mixed production in multi-product plants. We do so by dividing reported ready-mixed output by its share of total establishment sales. This adjustment method in effect assumes inputs are used proportionately to each product's revenue share. (For example, a plant producing 1000 cubic yards of ready-mixed concrete accounting for 80 percent of its revenues will have the same TFP as a completely specialized plant producing 1250 cubic yards with same measured inputs.)

Output and Factor Prices. We use product-level revenue and physical production and consumption data from the CM Product and Materials Supplements to compute ready-mixed plants' unit concrete output prices and cement factor input prices. We then adjust these to a common 1987 basis using the corresponding four-digit-industry-level shipments deflators from the NBER Productivity Database.

There are two important notes regarding these calculated unit prices. First, the value of shipments (sales revenue) data is collected on a free-on-board basis, i.e., exclusive of any shipping costs. Prices should reflect not the delivered cost of the ready-mixed but rather what one could buy it for at the plant gate. Second, the unit prices are annual averages. This can be shown to be equivalent to a quantity-weighted average of all transaction prices charged by the plant during the year. We do not observe product-specific data for administrative record (AR) plants, so they are dropped from the analysis as in the core sample. We also remove a small number of gross outliers having prices greater than five times or less than one-fifth the median in a given year, and limit the sample to those plants with ready-mixed sales accounting for over one-half of yearly revenues. (This sample criterion is not very restrictive in practice; most ready-mixed producers are specialists.) Finally, we attempt to exclude any non-AR plants who have (mostly because of incomplete reporting) physical quantities imputed by the Census Bureau. Unfortunately, these imputes are not flagged. To distinguish and remove imputed product-level data from the sample, we use the techniques described in detail in Roberts and Supina (1996) and Foster, Haltiwanger, and Syverson (2005).

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Table 1. Evolution of Vertical Integration in the Cement and Ready-Mixed Concrete Industries

Year	1963	1967	1972	1977	1982	1987	1992	1997
Percentage of cement plants that are vertically integrated	21.9	47.4	41.9	34.8	32.5	35.2	49.5	30.5
Percentage of cement sales from vertically integrated producers	25.2	51.2	48.4	41.0	49.5	51.3	75.1	55.4
Percentage of ready-mixed plants that are vertically integrated	1.8	3.2	3.8	3.1	3.0	5.5	11.1	10.6
Percentage of ready-mixed sales from vertically integrated producers	6.1	8.9	10.0	8.7	8.5	11.3	14.4	14.2

Table 2. Vertical Integration and Ready-Mixed Concrete Prices

A. Market-level price regressions—dependent variable is quantity-weighted average ready-mixed price in market

Specification:	Benchmark	Benchmark	Market fixed effects	Market fixed effects	"FTC scrutiny" instrument	"FTC scrutiny" instrument	Multiple-market mergers	Multiple-market mergers	Control for average TFP	Control for average TFP
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
N	1865	1865	1865	1865	1865	1865	148	148	1548	1548
R^2	0.079	0.080	0.425	0.425	n/a	n/a	0.395	0.423	0.571	0.571
Mkt share of VI firms	-0.128* (0.027)		-0.090* (0.040)		0.077 (0.211)		-0.059 (0.056)		-0.041 (0.038)	
Number of VI firms		-0.030* (0.007)		-0.015 (0.011)		-0.025 (0.030)		-0.030* (0.009)		-0.009 (0.009)
Q-wt. average TFP									-0.290* (0.054)	-0.291* (0.054)

Notes: All regressions control for the density of final demand in the market (measured as total construction sector employment per square mile) and year effects. Standard errors clustered by market. An asterisk denotes significance at the five percent level.

B. Plant-level price effects

	Within-market difference	Change for continuers	Integrated vs. unintegrated entrants	Integrated entrants vs. unintegrated incumbents
N	12,657	3984	2802	7531
R^2	0.391	0.457	0.607	0.430
VI Indicator	-0.021* (0.006)	0.013 (0.035)	-0.035* (0.018)	-0.020 (0.012)

Notes: All regressions include market-year fixed effects. An asterisk denotes significance at the five percent level.

Table 3. Vertical Integration and Ready-Mixed Concrete Quantities

A. Market-level quantity regressions—dependent variable is total physical units of concrete sold in market

Specification:	Benchmark	Benchmark	Market fixed effects	Market fixed effects	"FTC scrutiny" instrument	"FTC scrutiny" instrument	Multiple-market mergers	Multiple-market mergers	Control for average TFP	Control for average TFP
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
N	1865	1865	1865	1865	1865	1865	148	148	1548	1548
R^2	0.767	0.773	0.902	0.903	n/a	n/a	0.803	0.819	0.918	0.919
Mkt share of VI firms	0.596* (0.120)		0.342* (0.146)		0.680 (0.623)		0.031 (0.276)		0.090 (0.160)	
Number of VI firms		0.192* (0.026)		0.138* (0.032)		0.216 (0.194)		0.162* (0.066)		0.087* (0.033)
Q-wt. average TFP									0.393* (0.088)	0.396* (0.087)

Notes: All regressions control for final demand in the market (measured as logged total construction sector employment) and year effects. Standard errors clustered by market. An asterisk denotes significance at the five percent level.

B. Plant-level quantity effects

	Within-market difference	Change for continuers	Integrated vs. unintegrated entrants	Integrated entrants vs. unintegrated incumbents
N	12,657	3984	2802	7531
R^2	0.361	0.460	0.541	0.369
VI Indicator	0.480* (0.046)	-0.175 (0.097)	0.329* (0.117)	0.033 (0.085)

Notes: All regressions include market-year fixed effects. An asterisk denotes significance at the five percent level.

Table 4. Upstream Market Structure, Vertical Integration, and Concrete Prices and Quantities

A. Interaction with Vertically Integrated Cement Monopolist

Market-level outcome:	Average price	Average price	Total quantity	Total quantity
VI intensity measure:	VI mkt. share	No. VI firms	VI mkt. share	No. VI firms
R^2	0.079	0.081	0.769	0.773
VI intensity	-0.129*	-0.029*	0.699*	0.198*
	(0.027)	(0.006)	(0.125)	(0.027)
(VI intensity) X	0.007	-0.060	-0.663*	-0.377
(VI monopolist)	(0.082)	(0.076)	(0.299)	(0.277)
Implied effect in VI	-0.122	-0.090*	0.036	0.179
monopolist markets	(0.081)	0.075	(0.272)	(0.272)

B. Interaction with Cement HHI above Mean

Market-level outcome:	Average price	Average price	Total quantity	Total quantity
VI intensity measure:	VI mkt. share	No. VI firms	VI mkt. share	No. VI firms
R^2	0.082	0.085	0.768	0.773
VI intensity	-0.091*	-0.022*	0.744*	0.193*
	(0.037)	(0.008)	(0.191)	(0.031)
(VI intensity) X	-0.061	-0.025*	-0.249	-0.004
(Above-mean HHI)	(0.045)	(0.009)	(0.218)	(0.036)
Implied effect in above-mean	-0.152*	-0.047*	0.495*	0.190*
HHI markets	(0.032)	(0.008)	(0.126)	(0.031)

C. Interaction with Top-25 Cement Import Markets

Market-level outcome:	Average price	Average price	Total quantity	Total quantity
VI intensity measure:	VI mkt. share	No. VI firms	VI mkt. share	No. VI firms
R^2	0.088	0.089	0.769	0.775
VI intensity	-0.136*	-0.030*	0.623*	0.193*
	(0.029)	(0.007)	(0.140)	(0.027)
(VI intensity) X	0.025	-0.024	-0.051	0.040
(Top-25 import mkt)	(0.058)	(0.060)	(0.209)	(0.206)
Implied effect in top-25 import	-0.111*	-0.054	0.573*	0.233
markets	(0.052)	(0.059)	(0.184)	(0.200)

Notes: N = 1865 market-years. All regressions control for final demand in the market (measured as logged total construction sector employment) and year effects. Standard errors clustered by market. An asterisk denotes significance at the five percent level.

Table 5. Integration and Exit Probabilities

A. Likelihood of Exit Across Integrated and Unintegrated Plants

	Concrete	Cement
N	35,904	1414
R^2	0.086	0.445
VI indicator	-0.046*	-0.069*
	(0.013)	(0.031)

Notes: The dependent variable is a dummy indicating plant exit by next CM. Market-year fixed effects are included in all regressions. An asterisk denotes significance at five percent.

B. Unintegrated Producers' Exit Probabilities and the Extent of Integration in the Market

	Concrete		Cement	
	[1]	[2]	[3]	[4]
N	18,522	18,522	482	482
R^2	0.001	0.003	0.040	0.034
Mkt share Of VI firms	0.106*		0.122	
	(0.041)		(0.066)	
Number VI firms		0.019*		0.037
		(0.005)		(0.026)
Future Demand Growth	-0.027*	-0.026	-0.079	-0.094
	(0.013)	(0.014)	(0.077)	(0.086)

Notes: The dependent variable is a dummy indicating plant exit by the next CM. The sample is restricted to non-VI plants. Standard errors clustered by market. An asterisk denotes significance at five percent.

Table 6. Integration and Entry Rates

A. Overall entry rate (number of entrants ÷ average plants/firms in market over last two CMs)

| | Concrete | | | Cement | |
	Plant-level entry rate	Firm-level entry rate		Plant-level entry rate	Firm-level entry rate
N	1723	1723		429	429
R^2	0.068	0.051		0.021	0.030
Mkt. share of integrated firms in base year	0.061 (0.042)	0.112* (0.045)		0.021 (0.033)	0.035 (0.039)
Demand growth	0.048* (0.018)	0.066* (0.017)		-0.026 (0.036)	0.052 (0.047)

B. Unintegrated producer entry rate (number of unintegrated entrants ÷ average plants/firms in market over last two CMs)

| | Concrete | | | Cement | |
	Plant-level entry rate	Firm-level entry rate		Plant-level entry rate	Firm-level entry rate
N	1723	1723		429	429
R^2	0.082	0.068		0.020	0.017
Mkt. share of integrated firms in base year	-0.015 (0.038)	0.031 (0.037)		0.026 (0.030)	-0.019 (0.041)
Demand growth	0.055* (0.018)	0.062* (0.017)		-0.029 (0.032)	0.025 (0.046)

Notes: This table shows the impact of integration on entry rates. Panel A shows the results of regressing overall plant- and firm-level entry rates in a market (see text for definitions) on the market share of integrated firms in the base year. Panel B shows similar results for entry rates of unintegrated producers alone. Observations are weighted by market demand. (Similar patterns were observed using lagged number of VI firms as the explanatory variable, not reported here.) Standard errors are clustered by market. An asterisk denotes significance at five percent.

Table 7. Differences Between Integrated and Unintegrated Producers

A. Ready-Mixed Concrete

	Labor Prod.	TFPR	TFPQ	Real Revenue	Total Emp.	Total Hours	Nonprod. Worker Ratio	Capital-Labor Ratio
N	31,227	18,129	8555	31,990	31,705	31,291	31,700	18,838
R^2	0.216	0.174	0.307	0.212	0.166	0.164	0.179	0.329
VI indicator	0.294* (0.019)	0.026* (0.009)	0.043* (0.014)	0.270* (0.034)	0.006 (0.033)	0.036 (0.034)	-0.019* (0.007)	0.105* (0.030)

B. Cement

	Labor Prod.	TFPR	Real Revenue	Total Emp.	Total Hours	Nonprod. Worker Ratio	Capital-Labor Ratio
N	1449	875	1456	1452	1449	1452	885
R^2	0.565	0.495	0.560	0.582	0.572	0.502	0.550
VI indicator	0.093* (0.044)	-0.002 (0.046)	0.788* (0.108)	0.643* (0.099)	0.645* (0.099)	-0.028* (0.011)	0.261* (0.095)

Notes: This table report differences in key dependent variables (listed at the head of each column) across integrated and unintegrated producers in the ready-mixed concrete and cement industries. The reported coefficients are those for an indicator variable denoting that a plant is in a vertically integrated firm. Market-year fixed effects are included in all specifications. An asterisk denotes significance at five percent.

Table 8. Becoming Integrated: Ready-Mixed Concrete Continuers and Entrants

A. Changes among Continuers (conditioning on being unintegrated in previous CM)

Growth of:	Labor Prod.	TFPR	TFPQ	Real Revenue	Total Emp.	Total Hours	Nonprod. Worker Ratio	Capital-Labor Ratio
N	16,097	8735	2417	16,544	16,460	16,113	16,457	9306
R^2	0.194	0.218	0.415	0.274	0.204	0.216	0.179	0.188
Newly VI indicator	0.118*	0.031	0.101	-0.389*	-0.400*	-0.438*	-0.029	0.032
	(0.049)	(0.026)	(0.055)	(0.059)	(0.061)	(0.062)	(0.022)	(0.075)

B. Integrated Entrants Compared to Unintegrated Entrants

	Labor Prod.	TFPR	TFPQ	Real Revenue	Total Emp.	Total Hours	Nonprod. Worker Ratio	Capital-Labor Ratio
N	7697	5160	2025	8022	7888	7703	7887	5420
R^2	0.332	0.364	0.569	0.338	0.325	0.324	0.342	0.435
VI indicator	0.337*	0.053*	0.040	0.116	-0.164*	-0.169*	-0.046*	0.268*
	(0.047)	(0.021)	(0.045)	(0.079)	(0.073)	(0.078)	(0.014)	(0.073)

C. Integrated Entrants Compared to Unintegrated Incumbents

	Labor Prod.	TFPR	TFPQ	Real Revenue	Total Emp.	Total Hours	Nonprod. Worker Ratio	Capital-Labor Ratio
N	18,220	12,445	6104	18,494	18,404	18,227	18,401	12,880
R^2	0.237	0.205	0.352	0.225	0.190	0.192	0.220	0.375
VI indicator	0.358*	0.038*	0.041	-0.297*	-0.526*	-0.531*	-0.063*	0.268*
	(0.038)	(0.017)	(0.028)	(0.063)	(0.058)	(0.063)	(0.012)	(0.058)

Notes: This table reports differences in key dependent variables (listed at the head of each column) across integrated and unintegrated producers. Panel A compares growth rates across integrated and unintegrated continuers (plants that survive for two consecutive CMs). Panel B compares integrated and unintegrated entrants (plants appearing in their first CM). Panel C compares integrated entrants to unintegrated incumbents. Market-year fixed effects are included in all specifications. An asterisk denotes significance at five percent.

Table 9. Integration and Exit Probabilities, Revisited

Likelihood of Exit Across Integrated and Unintegrated Plants

	Concrete			Cement		
	[1]	[2]	[3]	[4]	[5]	[6]
N	35,094	24,217	24,072	1412	982	982
R^2	0.086	0.089	0.097	0.445	0.442	0.467
VI indicator	-0.046*	-0.053*	-0.002	-0.069*	-0.070	-0.011
	(0.013)	(0.014)	(0.014)	(0.031)	(0.038)	(0.037)
Multi-unit firm indicator			-0.085*			-0.226*
			(0.007)			(0.057)
TFPR			-0.058*			-0.029
			(0.012)			(0.049)

Notes: The dependent variable is a dummy indicating plant exit by next CM. Market-year fixed effects are included in all regressions. An asterisk denotes significance at five percent.

Table 10. Integration and Inventory Holding Behavior

	Ready-Mixed Plants, Materials Inventory Ratio	Cement Plants, Materials Inventory Ratio	Cement Plants, Work-in-Process Inventory Ratio	Cement Plants, Final Goods Inventory Ratio
N	31,976	1454	1456	1454
Mean	0.024	0.087	0.029	0.061
R^2	0.019	0.475	0.539	0.495
VI indicator	0.003*	0.013*	0.006*	0.003
	(0.001)	(0.005)	(0.003)	(0.004)

Notes: Market-year fixed effects included in all regressions. An asterisk denotes significance at five percent.

Table 11. Differences between Integrated and Unintegrated Ready-Mixed Concrete Plants, Controlling for Multi-Unit Status of the Owning Firm

	Labor Prod.	TFPR	TFPQ	Real Revenue	Nonprod. Worker Ratio	Capital-Labor Ratio
N	31091	18017	8555	31,801	31,511	18,720
R^2	0.239	0.178	0.312	0.214	0.181	0.336
VI indicator	0.188*	0.008	0.023	0.272*	-0.015*	0.035
	(0.019)	(0.009)	(0.014)	(0.034)	(0.007)	(0.031)
Multi-unit firm indicator	0.222*	0.042*	0.060*	0.077*	-0.006*	0.143*
	(0.008)	(0.005)	(0.009)	(0.015)	(0.003)	(0.012)

Notes: This table reports differences in key dependent variables (listed at the head of each column) across integrated and unintegrated producers in the ready-mixed concrete industry. The reported coefficients are those for indicator variables denoting that a plant is in a vertically integrated firm or in a multi-unit firm (vertically integrated firms are by definition a subset of multi-unit firms). Market-year fixed effects are included in all specifications. An asterisk denotes significance at five percent.